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Preserve Teacher Engineering Design Teaching Efficacy

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PRESERVICE TEACHER ENGINEERING DESIGN TEACHING EFFICACY

by

Laura Wheeler

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ABSTRACT

The Engineering Design Efficacy of Preservice Science Educators

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Since adopting the *Next Generation Science Standards*, many states have aligned their science standards to reflect the addition of engineering core concepts and practices. Science teachers must teach and integrate engineering design in their science classrooms. Many teachers lack experience in engineering design, having received little formal training as part of their science preservice coursework. Preservice educators' conceptions of engineering and lack of engineering design experience are responsible for initial reports of low engineering design teaching efficacy. Lack of teacher engineering design efficacy may lead to decreased standards appropriation and student performance. The purpose of the study was to describe preservice secondary science teachers' self-efficacy related to the teaching of engineering design and the science and engineering practices as intended by state science standards during an engineering design unit in a science teaching methods course. A mixed method case study utilized student journals, journey maps, focus groups, and clinical teaching to describe the development of preservice teacher efficacy throughout an engineering design unit. Investigators targeted students enrolled in a secondary science methods II course at a university in a mountain west state. Efficacy developed with a wavelike function on a continuum of developmental stages. It is recommended that preservice educators need scaffolded content-specific curriculum enactment experiences with mentorship to develop engineering design teaching self-efficacy. Description and support of preservice teacher engineering design teaching self-efficacy may lead to the enactment of engineering curriculum, reformed teaching practices, improved student science understanding, and increased student engineering literacy.

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PUBLIC ABSTRACT

The Engineering Design Efficacy of Preservice Science Educators

Laura Wheeler

Science educators are tasked with enacting The *Next Generation Science Standards* that include engineering core ideas and practices. Many teacher preparation programs and content courses do not include or require engineering design leading many science teachers to believe they are unprepared to teach engineering design. The lack of experience and belief of being unprepared to teach engineering design results in preservice educators' lack of engineering design teaching self-efficacy. Preparation programs inclusion of efficacy in is essential to understanding later enactment. This mixed-method case study researched the engineering design teaching self-efficacy of eleven preservice educators during an engineering design unit taught in a science methods II course at a university in the western U.S. The changes in preservice educator self-efficacy over the development and delivery of an engineering design unit was explored to describe fluctuations and elements of the engineering design unit that influenced efficacy. This researcher triangulated journals, focus groups, journey maps, video protocols, and instructor session notes to better describe the influence of the elements of an engineering design unit on preservice educator efficacy development. The analysis revealed that the engineering design unit included elements that facilitated sensemaking leading to task competency beliefs. These engineering designs teaching self-efficacy beliefs developed over time with wavelike fluctuations. Preservice educator engineering design teaching self- efficacy progresses from onset, developing, emerging, to maturing. Fluctuation in efficacy is consistent with progression if preservice educators receive mentorship to facilitate sensemaking through the process. To reach the efficacy maturing stage, teachers need the autonomy to enact engineering design curriculum and needed science education reforms. It is expected that a description of developmental engineering efficacy will assist professional learning instructors and curriculum developers to increase enactment of engineering design in secondary science classrooms. Student engagement and engineering literacy may result when teachers have increased engineering design teaching self-efficacy.

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CHAPTER I

INTRODUCTION

Since the release of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012), many states have reformed their science standards to reflect the addition of engineering design core ideas and practices. Science teachers must reform the current classroom curriculum to reflect engineering-inclusive standards. However, many teachers lack experience in engineering design, having received little formal training as part of their science preservice coursework or K-12 education (Banilower et al., 2013). Teacher conceptions of engineering and lack of engineering design experience have the potential to lead to decreased engineering design teaching self-efficacy (EDTSE). This lack of teacher efficacy may also lead to reduced standards implementation and decreased student performance.

To understand and describe the elements of an engineering design unit needed to assist science teachers developing EDTSE, this study was designed. This study describes the development of preservice secondary science teacher's EDTSE throughout an engineering design unit within the context of a science methods course. The intent of the study is to inform educational researchers seeking to increase science standards implementation leading to reformed teaching practices and improved student engineering literacy. The researchers in this study sought to describe the EDTSE of preservice teachers at time points in an engineering design unit within the science methods course. Researchers tracked the development of efficacy through time and in relation to targeted methods of instruction. The development of engineering design teaching efficacy may inform future research in efficacy development, teacher preparatory programs, engineering design appropriation, and student outcomes.

Context

The purpose of reformed teaching and learning is to advocate for methods of instruction that best support student learning. These “best practices” were described in the *Science for All Americans* (American Association for the Advancement of Science [AAAS], 1989) report describing science teaching as student-centered and inquiry based. The second phase of the report suggested that science learning should extend beyond the classroom and promote a scientifically literate populace through reformed curriculum models. Building on these ideals of scientific literacy, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012) promoted a three-dimensional teaching and learning approach that expands the ideas of inquiry-based teaching and adherence to a scientific model to include science and engineering practices, crosscutting concepts, and disciplinary core ideas. The *Framework* details the core scientific and engineering concept progressions through K-12 education to establish what students should know about science and engineering upon graduation. The science and engineering practices represent skills and broadly describe what scientists and engineers do.

The *Next Generation Science Standards* (NGSS Lead States, 2013) are based on the research-backed recommendations of the *Framework.* They expect scientific inquiry *and* engineering design practices, crosscutting concepts, and core ideas are to be used collaboratively to solve problems. Engineering design coupled with science education has its roots in the 1990s when the *Benchmarks for Science Literacy* (AAAS, 1994) and the *National Science Education Standards* (National Research Council, 1996) were released. Engineering and technology were components of scientific literacy, but practices or core ideas were absent (Purzer & Quintana-Cifuentes, 2019). Although engineering has been established in science education, “The NGSS represents a significant departure from past approaches to science education” (Bybee, 2014, p. 215). This statement typifies the significant expectation placed on science teachers in the wake of reformed standards advocating for engineering practices and core ideas.

Although changing curriculum can be difficult for teachers, the NGSS defends the inclusion of engineering design as a fundamental part of science education and establishes a definition of engineering as “any engagement in a systematic practice of design to achieve solutions to particular human problems” (NGSS, 2013, Appendix I, p. 1). To assist teachers in reforming curriculum, the NGSS suggests introducing real world problems to students and allowing them access to tools and materials that would engage learners in comparing and analyzing practical solutions that most effectively solve the problem. Students should be taught the engineering design process (EDP) to direct iterative problem-solving.

The *Framework for Quality Engineering Education* (Moore et al., 2015) defined the EDP using the following six phases: problem, background, plan, implement, test, and evaluate. In April 2013, the NGSS released an appendix suggesting the eight science and engineering practices have engineering design applications. The “designing solutions” and “defining problems” practices are unique to engineering, and the NGSS suggests the other six practices have engineering applications. The NGSS aids teachers in describing the difference between science and engineering practices with the following statement,

> The best way to ensure a practice is being used for science or engineering is to ask about the goal of the activity. Is the goal to answer a question? If so, students are doing science. Is the purpose of defining and solving a problem? If so, students are doing engineering. (NGSS, 2013, pp. 2-3)

Although this statement makes the teaching of engineering and delineation between science and engineering practices appear simple, implementing an engineering curriculum is still challenging for educators. Designing a cohesive curriculum is difficult when a common perception of engineering in classrooms describes engineering as just an applied science or engineers as people who simply fix things (Capobianco et al., 2011; Kilty & Burrows, 2019).

The NGSS rationalizes the need to define engineering because the misconception exists that engineering is just an applied science and does not differ in scope and practice (Grubbs et al., 2016; Hammack & Ivey, 2017; Hammack et al., 2020; Pleasants & Olson, 2019; Utley et al., 2019). Teachers need engineering design pedagogical content knowledge to accurately teach and identify engineering design conceptions in themselves and their students (Kambouri et al., 2011; Wandersee, 1994), but this is difficult when teachers lack experience and hold misconceptions themselves (Capobianco et al., 2011; Kilty & Burrows, 2019). Because of the hardship of reforming the curriculum while holding misconceptions of engineering design, science teacher preparation program standards were also evaluated to assist novice teachers (Morrell et al., 2020).

In 2015, The National Science Teacher Association (NSTA) and the Association for Science Teaching Education (ASTE) formed a joint task committee to develop teacher preparatory program science standards to better assist teachers in developing curricula aligned with the *Framework.* The standards, released in 2020, inform methods course instructors in designing curricula that will develop preservice teacher engineering design pedagogical skills with greater emphasis on engineering practices (Morrell et al., 2020). However, an oversimplification of engineering teaching through SEPs alone promotes engineering misconceptions (Kilty & Burrows, 2019). This research suggests preservice educators will develop more informed views of engineering by learning the EDP separately and in connection with the science and engineering practices (SEPs; Cunningham & Carlsen, 2014). Cunningham and Carlsen state that the organization of the standards and more specifically the science and engineering practices do not facilitate accurate conceptions of engineering and that "the practices of engineering are meaningless outside of the context of the entire problem-solving process" (p. 201).

The state in which this study was conducted focused their science and engineering standards on the *Framework* and did not include separate engineering DCIs. The EDP is taught through standards that emphasize engineering practices. Research would suggest then that preservice teachers in this state should receive training on the EDP in addition to SEP training (Cunningham & Carlsen, 2014). In this state, high schools implemented new science standards in 2021 following a global pandemic, during which, many schools were closed, and teaching was conducted online. Professional learning experiences on the new state standards were held to a minimum due to the limitation of professional learning and teaching during a pandemic. This suggests that teachers serving as mentors to preservice teachers may not have received training on the state standards and the inclusion of engineering. Preparing preservice science educators to teach engineering standards, possibly without mentor assistance and modeling, may be a large task, but it comes with many student benefits (Boesdorfer, 2017; Christian et al., 2021; Romero-Ariza et al., 2021).

Teaching engineering design as part of state and national standards includes the benefit of fulfilling the larger need for an engineering literate populace (National Academy of Sciences, 2020). Teaching science literacy and engineering literacy is essential for students to apply problem solving (Kaya et al., 2017). When science educators include engineering in their teaching (as in the NGSS), they experience a shift in science instruction to include more student-centered pedagogies and effective learning transfer (Boesdorfer, 2017; Christian et al., 2021; Romero-Ariza et al., 2021).

It has been almost a decade since the *Framework* and the NGSS were released. Forty-four states adopted the NGSS (20 states) or created standards based on the *Framework* (24 states). This means that at least 71% of U.S. K-12 students live in states with engineering inclusive science standards (NSTA, 2014). So, if the teaching of engineering holds the promise of increased student engineering literacy and increased student-centered pedagogy, why then do few secondary science teachers (6% middle school, 7% high school) believe they are well prepared to teach engineering (National Science Board, 2014)?

Problem Statement

Science educators find themselves in a unique position, the expectation to include engineering design principles exists in state mandated standards, but the EDTSE stemming from engineering design content knowledge and the pedagogical skill necessary to teach engineering design may not have been developed during preservice coursework (Banilower et al., 2013). Many teacher education programs do not require engineering coursework as a prerequisite for elementary or secondary science teaching and it is unlikely (14%) that current secondary science teachers have participated in engineering courses (Banilower et al., 2013). Because of the lack of preservice science teacher experience with engineering design, enacting reforms in science education should address teacher self-efficacy in preservice programs (Czerniak & Lumpe, 1996). Preservice educators build teaching self-efficacy based on their perceptions of successful teaching while using effective methods that increase student performance (Arcelay-Rojas, 2018; Bandura, 1997; Tschannen-Moran et al., 1998). Thus, science methods courses should develop in depth engineering design units in context of the SEPs to increase engineering design pedagogical content knowledge (Love & Hughes, 2022). Methods courses should intentionally target engineering design pedagogical knowledge to increase EDTSE (Aydin-Gunbatar et al., 2018; Hill-Cunningham et al., 2018; Kilty & Burrows, 2019; Kim et al., 2019). Lack of EDTSE developed during preparation coursework may suggest why many teachers are not using reformed science practices that include teaching engineering and do not believe they are prepared to teach engineering (Capobianco & Rupp, 2014; DeJarnette, 2018; Hill-Cunningham et al., 2018; Hsu et al., 2011; Sun &

Strobel, 2014).

A teacher's lack of EDTSE may come at the cost of teacher perceived ideas of student capabilities and outcomes (Hsu et al., 2011; Van Haneghan et al., 2015). Teachers lacking EDTSE hold beliefs that gender, age, and ability status can influence a student’s ability to learn engineering (Hsu et al., 2011; Van Haneghan et al., 2015). Teacher perceived constraints stemming from low EDTSE are also reported to influence engineering integration (Sun & Strobel, 2014) even though increases in EDTSE correlate with positive changes in teacher practice (C. Crawford et al., 2021; Hill-Cunningham et al., 2018). Thus, teacher motivation as a construct of self-efficacy can influence student outcomes (Ekmekci & Serrano, 2022; Kewalramani et al., 2020; Malone et al., 2018). Teachers who report increased levels of efficacy use methods of instruction focused on student learning using strategies that increase individual student performance. Consequently, teachers with lower efficacy levels are more likely to give up on students that do not achieve desired results (Bandura, 1993).

Although much research has been conducted on preservice elementary teacher EDTSE during a methods course (Antink-Meyer & Parker, 2021; Deniş Çeliker, 2020; Kaya et al., 2017; Nesmith & Cooper, 2021; Perkins Coppola, 2019), no studies have focused on preservice secondary science educators. The few studies focused on experienced secondary teachers EDTSE are often within the realm of makerspace or STEM and not the NGSS (Annetta et al., 2013; Kelley et al., 2020; Smith et al., 2021; Van Haneghan et al., 2015). Although studies have reported on the overall increase in teaching engineering design self-efficacy following a design unit as part of in-service or preservice training (Gerber et al., 2012; Hammack & Ivey, 2017; Hilton et al., 2020; Smith et al., 2021), the research was often conducted using a pre/post instrument and may not have tracked the development of efficacy through time and in relation to targeted methods of instruction. Studying preservice educators' development of EDTSE is essential during methods courses because they may be resistant to change once established in classrooms (Hoy & Spero, 2005). For these reasons described in this study, researchers described preservice secondary science teacher EDTSE development over time points of an engineering unit in a methods course.

Purpose of the Study

The purpose of this mixed method study was to describe preservice secondary science teacher's self-efficacy related to the teaching of the EDP and state Science and Engineering Education (SEEd) standards. Further, in this investigation preservice educator EDTSE at different stages (time points) during an engineering design unit were identified and described. The researchers explored possible relationships between the stages of the intervention (time points) and EDTSE as both construct and developmental process (Putney & Broughton, 2010; Vygotsky, 1978). By conducting the research in a Science Methods II course, researchers maintained normative classroom procedures and assignments carried over from the Science Methods I course. Normative classroom procedures and assignments reflect highly socialized and reflective practices shown to guide efficacy development (Putney & Broughton, 2010). Preservice educators reflected on their efficacy (individually and collectively) following targeted methods of instruction during the engineering design unit.

Preservice educators reflecting on their efficacy beliefs at time points in relation to methods of instruction revealed EDTSE as a developmental process. Research supports efficacy development as wavelike instead of linear, developing over time and with experience (Putney & Broughton, 2010). Gaining insight into the wavelike function of EDTSE may help researchers understand why teachers often return to less effective methods after experiencing failure (Cheng & Brown, 2010), avoiding reformed teaching practices (Abrami et al., 2004). Although EDTSE may decrease at points in an intervention, understanding efficacy as a process allowed the preservice educators to move through stages realizing that efficacy may increase again with continued experience and mentor scaffolded learning.

Research by Van Haneghan et al. (2015) suggests “tracking, examining, and influencing what teachers believe about outcomes related to engineering education is an important area of research” (p. 8). However, there is a lack of research in secondary science teacher engineering design self-efficacy, possibly making it difficult for professional developers to accurately understand the EDTSE needs of preservice secondary teachers. Researchers hope to provide evidence of EDTSE development and the influence of the elements of an engineering design unit. A greater understanding of EDTSE may lead to intervention replication or evidence-based changes to instruction to maximize teacher EDTSE.

Preservice and in-service professional development providers may benefit from understanding the changes in EDTSE that occur during an engineering unit and how different targeted strategies of an intervention may influence EDTSE through time. Understanding how EDTSE is influenced by constructs such as mastery experiences, vicarious experiences, social persuasion, and emotional or psychological states (Bandura, 1997) in addition to socio-cultural factors, may alter the amount of time and resources allotted to engineering design for preservice secondary science teachers. Teacher education programs may include an engineering design unit within the context of the science and engineering practices and specific state standards to increase later reformed teaching practice. Professional development program providers wanting to increase state science standard implementation may wish to include an intervention focused on increasing engineering design efficacy. Understanding the wave-like function using a developmental scale (Putney & Broughton, 2010) of EDTSE through time may influence professional learning developers to offer specific and continuous support and mentorship.

Research Questions

1. How do preservice teachers describe their EDTSE at different time points of an engineering design unit?
2. Which elements of an engineering design unit facilitate preservice teachers EDSTE development?

Study Overview

The purpose of this mixed method case study is to describe the elements of an engineering design unit in relation to the development of preservice teacher EDTSE. The engineering design unit was delivered over five time points that corresponded to methods of instruction targeting preservice educator EDTSE development (see Figure 1). At each time point, participants of the engineering design unit reflected individually through journal entries then collectively through focus groups (class debrief experiences). After completion of a lesson plan, preservice educators taught and video-recorded the lesson as part of a clinical/practicum course. The recording of preservice educators teaching their lesson plan was collected as data to compare student to instructor perceptions of EDTSE including the construct of confidence, emotional state, and mastery of experience. A preservice educator journey map was collected at time point 5 to describe EDTSE

Figure 1

Time Points

through all time points. All data sources were triangulated during analysis. Discourse analysis of qualitative sources utilized *a priori* coding to identify EDTSE constructs (motivation, confidence, expectation of success, and anxiety), elements of the engineering design unit influencing EDTSE, and EDTSE changes. Quantitative descriptives were analyzed to portray nomothetic patterns of EDTSE over time. Targeting specific time points throughout the learning process provided data to illuminate the process, stages of development, and elements that influence efficacy development during an engineering design unit.

Personal Experience and Positionality

Having worked with many science teachers and preservice teachers over the past 20 years, I have noticed that secondary science teachers have extensive backgrounds in their chosen science fields, but not in engineering. Even with an extensive science background, secondary science teachers may think they are including design elements into existing curriculum but are in fact just including a scientific inquiry activity that includes designing the parameters of the lab or activity (design and carry out an experiment SEP). I have noticed that pre-service science teachers do not have a proficient background in engineering and often display a lack of efficacy. The lack of efficacy often leads to teachers ignoring engineering design regardless of its inclusion in most state science standards. Teachers often feel pressure to move quickly through a science textbook or cover extensive science content standards, so engineering takes a “back seat” to content the teacher feels more confident in implementing. The burden often falls on the individual teachers to seek support in enacting standards reform. My personal experience as a secondary science teacher was instrumental in my desire to further investigate the development of preservice science teacher EDTSE. This aligns to the research that states preservice science teachers begin methods courses with little understanding of the EDP and engineering as an aspect of science teaching (Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Kim et al., 2019).

CHAPTER II

LITERATURE REVIEW

This chapter will review the theoretical framework and empirical research relevant to the current study. The first part of the chapter will introduce the theoretical frame that underpined the research and provided a lens to explore and describe the research. A progressive framework for professional learning is described to guide the development, delivery, and analysis of an engineering design unit taught in the methods course which served as the case under study. The second part of the chapter presents the literature on preservice teacher engineering design teaching efficacy. The third part of the literature review will describe the methods of instruction shown to increase teacher efficacy. The chapter will conclude by providing a summary of the key knowledge that guided the research questions and analysis.

Theoretical Framework

Preservice teacher beliefs should be included as a part of teacher education (Richardson, 1996) with the personal beliefs of one's ability to teach one of the most important aspects of teacher preparation (Pintrich, 1990). Research suggests strengthening efficacy beliefs is essential for preservice educators when seeking to enact science education reforms (Czerniak & Lumpe, 1996). Bandura's Social Cognitive Theory (1977, 1997) describes self-efficacy as an individual's internal motivation and drive for accomplishment. Related to an individual's well-being, self-efficacy embodies perceptions of personal accomplishment and/or the ability to master certain tasks or attainments (Bandura, 1977). Bandura suggests that there are four main sources that contribute to an increase of self-efficacy including mastery experiences, vicarious experiences, social persuasion, and emotional or psychological states with mastery experiences the most influential (Bandura, 2015). Self-efficacy can change depending on an individual's cognitive processing and/or reflection on perceived success or failure communicated from social feedback (Tschannen-Moran et al., 1998). Bandura (1993) explains that reflection and dialogue on domain specifics efficacy (such as engineering teaching) will guide the development of efficacy.

Teaching self-efficacy is related to EDTSE and belief of the individual's ability to successfully accomplish the teaching of engineering design (Hammack & Ivey, 2017). The Teaching Engineering Self-Efficacy Scale (TESS) for K-12 teachers (Yoon Yoon et al., 2014) was the first validated instrument to measure teaching engineering self-efficacy and is constructed based on the Framework of the teacher self-efficacy formation which conceptualizes teaching self-efficacy as a cognitive feedback loop (Tschannen-Moran et al., 1998). Bandura's (1986) four sources of self-efficacy are mediated by a "teachers' analysis of a teaching task and their self-assessment of teaching competence…" which "self-efficacy shapes teachers' personal goals, amount of effort, and level of persistence" (Tschannen-Moran et al., 1998, p. 465). Thus, because the validated instruments to measure teaching engineering self-efficacy are based on frameworks that include Bandura's four sources, and subsequent research has studied elementary teacher engineering self-efficacy sources, it is believed that the sources of self-efficacy are the same as the sources of EDTSE (Cinici, 2016; Polat et al., 2021).

When researching teaching efficacy, it is important to not only consider the sources (events) in the intervention, but also the ways individuals reflect and perceive their experiences (Morris et al., 2017). The events of the intervention, or teaching tasks, provide opportunities for teachers to assess teaching competence which informs their beliefs or teacher self-efficacy. Teacher self-efficacy then entwines with teacher practice and develops through reflective interpersonal negotiations of task analysis (Bandura, 1993; Putney & Broughton, 2010; Tschannen-Moran et al., 1998; Yoon Yoon et al., 2014). A teaching efficacy cycle may develop with continued introduction to teaching tasks and new sources from which the individual assesses teaching competence (Tschannen-Moran et al., 1998). Therefore, teaching efficacy is built and maintained over a period of time (Putney & Broughton, 2010, 2011; Ward et al., 2020). It is conceivable that during the efficacy cycle, teachers may face future failure or negative feedback when attempting to implement reformed teaching practices. How a teacher processes negative information may mediate the sources of self-efficacy (Morris et al., 2017). Bandura (2015) suggests that teachers who experience negative teaching performance may report decreased confidence, motivation and overall teaching self-efficacy. In contrast, individuals with higher self-efficacies are more likely to persist when presented with negative feedback and obstacles, choosing to exert control over the social environment (Bandura, 2015). Teachers who report being highly efficacious approach reformed teaching practices and perceived setbacks with sustained effort (Bandura, 1993).

The four main sources that mediate teaching self-efficacy include verbal persuasion, vicarious experience, mastery experience, and physiological states (Bandura, 2015; Wyatt, 2015). Bandura describes verbal persuasion as interpersonal dialogue that shapes and informs the belief of an individual's ability to successfully attain a goal or task completion. Vicarious experience is the observance of a mentor or peer and the resulting comparison of competence. Which evaluation of competence informs the development of efficacy. Thus, preservice educators need sources of mentor modeling of engineering design to compare competence as a source of self-efficacy. Physiological states, such as base anxious state when performing a task may inform belief of competence, although it is reported to be the least influential of the sources of self-efficacy. The greatest source mediating self-efficacy is mastery experiences. Mastery experiences can greatly mediate self-efficacy when opportunities to succeed through a demonstrated competency are scaffolded through training and guided skill (Bandura, 2015).

In addition to an individual's sources of self-efficacy is an individual's belief in a positive outcome expectancy. Outcome expectancy describes one's belief in the consequences of action. It is assumed that a teacher who believes there are no consequences for the failure to use reformed teaching practices, may choose not to even if they have the self-efficacy stemming from skill and knowledge (Ward et al., 2020). Outcome expectancy also describes a teacher's confidence to use and apply effective teaching methods that will positively impact student outcomes (Enochs & Riggs, 1990). A teacher's self-efficacy is a major component of the classroom learning environment (Bandura, 1993). A teacher with higher self-efficacy and outcome expectancy is more likely to create a classroom culture promoting student engagement, student-centered mastery experiences, and supports for low performing students (Bandura, 1993; Enochs & Riggs, 1990). Therefore, outcome expectancy will also be included in the overall discussion of EDTSE.

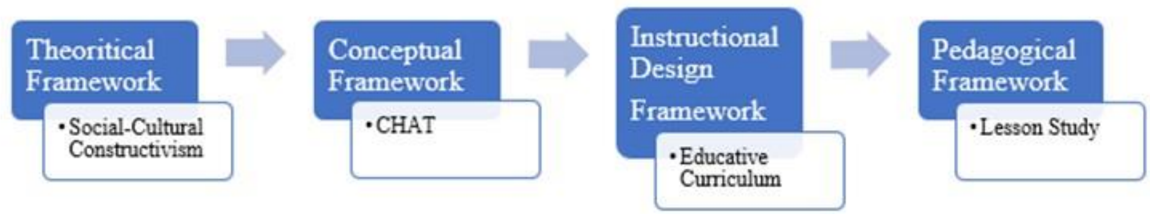
Frameworks for Professional Learning

Effective pedagogical classroom practice is influenced by a myriad of factors. These internal and external factors should be targeted during professional learning experiences to influence teacher pedagogy. The internal factors may include teacher experience (ED coursework; K. S. Davis, 2003; Keller-Schneider et al., 2020), content specific knowledge such as engineering design (Roehrig & Kruse, 2005), pedagogical content knowledge (including the NGSS; Van Driel et al., 2014), and teacher internal belief system about student learning (B. A. Crawford, 2007). Together, these internal factors can represent teachers' current knowledge and beliefs systems. External factors that influence teacher pedagogy may include school climate and/or physical environment (Deed et al., 2019), access to mentors (Visone, 2019), and access to current standards and/or curriculums (Woodbury & Gess-Newsome, 2002). This study targeted internal teacher belief systems (EDTSE) by increasing teacher content knowledge and pedagogical knowledge. However, this study was developed recognizing internal belief systems are influenced by social factors (Putney & Broughton, 2010, 2011). Teacher internal systems are shaped and developed by external systems (Vygotsky, 1978). Thus, this study could not separate school climate, standards, and mentors from the socially intertwined discussion of teacher beliefs. When researching and developing a professional learning experience for both internal and external factors, a theoretical progressive that supports ED research should be used (Magana, 2022). The following description supports the use of progressive frameworks in engineering professional learning.

Professional learning experiences should include a framework that guides and informs all involved in developing, carrying out, and researching in the field of education (Clarke & Hollingsworth, 2002; Magana, 2022). When teaching and researching engineering, a framework should be included (Kim et al., 2019; Magana, 2022). Frameworks can benefit professional learning developers with organizing best practices and understanding the learning of engineering design (Kim et al., 2019). For these reasons, professional learning experiences should seek to establish clear theory and frameworks that will benefit participants and researchers with a defined vision of curriculum and research goals. The theory descriptions that follow first begin with a broad theoretical framework that was derived from a learning theory. Second, a conceptual framework that grounds professional learning in a theory that describes how a teacher's curriculum is influenced by their activity. Third, an instructional design framework describes an empirically derived theory aimed at supporting preservice teacher learning through experience of exemplar and illustrative lessons. Last, a pedagogical framework discussion explains the development of lesson plans that scaffold teacher learning and serve as a tool to direct instructor/student social interactions. This research is driven by a progressive framework of theory (see Figure 2).

Figure 2

Frameworks for Professional Learning



Sociocultural Constructivism

Teacher conceptions of engineering design are socially constructed through meaning making of their personal and social experience (John-Steiner & Mahn, 1996). This suggests that meaning making is two-fold, both personal and social. Traditional theorists suggests that one either upholds a social cognitivist perspective where meaning making is personal such as Bandura's (1993) theory, which advocates for self-efficacy as personally constructed beliefs or a theorist such as Vygotsky that advocated for meaning making as sociocultural constructed (Vygotsky, 1978, 1986). Even Bandura (1993), commenting on Vygotsky's sociocultural theory stated, "Children's intellectual development cannot be isolated from the social relations within which it is embedded and from its interpersonal effects. It must be analyzed from a social perspective" (p. 120). Additionally, Bandura described the highly socialized nature of efficacy through domain specific social reflexive discourse.

Although this research used Bandura's self-efficacy theory (1993, 1997) constructs to describe EDTSE at time points, it employed a sociocultural lens to the planning of the intervention and analysis of EDTSE over time. This unique lens allowed for the addition of language to describe efficacy as a developmental process where meaning making is sociocultural constructed through mentor/mentee relationships, instructor/student relationships, and peer language reflective dialog (Putney & Broughton, 2010, 2011). Vygotsky (1978) suggests efficacy, traditionally thought of as an interpersonal process, can develop into an intrapersonal process. “The transformation of an interpersonal process into an intrapersonal one is the result of a long series of developmental events” (p. 57). These “developmental events” are replicated in this study as methods of instruction targeted over five time points and described in subsequent chapters.

Vygotsky (1978) explains that when learners are presented with a phenomenon, they initiate sensemaking by drawing on past experiences. When sensemaking (learning) occurs, it leads the way to future development. Sensemaking is the process by which people give meaning to their collective experiences (Weick et al., 2005). Research by Weick et al. describes sociocultural sensemaking as a mechanism that facilitates change in activity over time, which activity leads the progression of cognition. Therefore, when efficacy is considered from a sociocultural lens, sensemaking can lead to the development of self-efficacy (Putney & Broughton, 2010).

Vygotsky’s (1978) work on the zone of proximal development explains what happens if individuals are presented with a developmental event that requires sensemaking by drawing on prior experiences. If experience is lacking or is rooted in misconceptions, then it can halt the development of sensemaking because the learning task is too hard. If individuals work collaboratively with a “more knowledgeable other” and peers, then sensemaking is achievable (Vygotsky, 1978). A more knowledgeable other scaffolds collaborative learning experiences to move preservice educators into the zone of proximal development. Collaborative learning is responsible for increasing what preservice educators can do with help in comparison to individual learning or what they can do individually (Vygotsky, 1978). Therefore, the zone of proximal development is defined as the difference between what a learner can accomplish unassisted and the achievable learning level with socialized sensemaking scaffolded from a more knowledgeable other (Vygotsky, 1978).

Research supports learning from a more knowledgeable other or mentor as a sociocultural practice (Lave & Wenger, 1991). Mentor teachers with higher science self-efficacy play a pivotal role in mentee efficacy development (Simsar & Jones, 2021). Highly efficacious preservice teachers report having positive mentor relationships and teaching supports (Capa Aydin, 2005). When studying the enactment of preservice teacher engineering design curriculum, replication of school-based mentors modeling engineering design was pivotal to appropriation of engineering design (Capobianco & Radloff, 2022). Due to the low percent of secondary teachers that report feeling well prepared to teach engineering design (National Science Board, 2014), it is assumed that a small percentage of mentor teachers are modeling engineering design as an aspect of sociocultural efficacy development. Therefore, frameworks for professional learning should include the scaffolding of engineering design skill by engaging with a teacher who can serve as the mentor or more knowledgeable other (National Research Council, 2015).

Because developmental learning envelops individual and group dimensions (Souza, 1995), efficacy development may not be linear or predictable (Putney &

Broughton, 2011). EDTSE may develop wavelike with shifting highs and lows depending on the stage of the intervention (developmental event). Research supports efficacy development as wavelike instead of linear, developing over time and with experience which can be described using the “Preservice Teacher Efficacy Developmental Scale” (Putney & Broughton, 2010, p. 12). Efficacy is described as a three-stage developmental process progressing on a spectrum from onset, developing, to maturing (Putney & Broughton, 2010). Preservice educator's onset development stage is characteristic of mentor teacher observations with an emphasis on mentor teacher actions. The developmental stage is evidenced by preservice teachers expanding their view of the mentor teacher to include the classroom community. The preservice observer recognizes the mentor teacher's sociocultural classroom development while making connection between mentor teacher curriculum as a component of the class community. The shift to the maturing stage is evidenced by the preservice educators building confidence from actualizing their role as teacher into the classroom community (Putney & Broughton, 2010).

Although efficacy develops on a spectrum, there can be situational fluctuations (Goddard et al., 2004). Gaining insight into the social developmental process of EDTSE with situational fluctuations may help researchers understand why teachers often return to less effective methods after experiencing failure (Cheng & Brown, 2010) and avoiding reformed teaching practices (Abrami et al., 2004). Thus, the purpose of this study was to examine preservice educators EDTSE developmental process through a highly socialized experience that includes personal and focus group reflection as well as mentor and peer reflective dialog. The investigation is situated in two different sociocultural environments (methods course and clinical class). Putney and Broughton (2010) suggest preservice self-efficacy research should continue examining self-efficacy through a Vygotskian lens of development over time and should examine the role of sociocultural reflective dialog in the developmental process.

Cultural Historical Activity Theory

Self-efficacy as a transformative and socially constructive process is developed through productive activity (Putney & Broughton, 2011). Building on a base of development through productive activity, Cultural Historical Activity Theory (CHAT) describes how the social nature of the participant mind is inexorably linked to activity (Stetsenko & Arievitch, 2004). Activity describes how subjects (participants) interact with objects (the world). To facilitate activity, participants have needs that are met through activities that will transform the participants (Engestrom, 2000; Grossman et al., 1999). The motives of the participants are considered and correspond to the needs of the participants (external and internal factors). Another facet of activity is the operations or conditions participants must accomplish to meet the goal of a lesson plan. To meet the needs of the participants, the meaning of the objects must be explicit and clear (Engestrom, 2000; Grossman et al., 1999). Mediating tools enhance activity and are typically either conceptual or practical, so professional learning supplies, materials, software, and exemplar lesson plans act as practical tools while professional learning concepts, discussions, and reflections acting as conceptual tools (Grossman et al., 1999; Longhurst et al., 2022; Van Duzor, 2011).

Educative Curriculum

Educative curriculum materials describe a professional curriculum experience where the participants act as student learners of exemplar lesson plans. An educative curriculum is defined as immersive curriculum materials designed to best support teacher learning (Davis & Krajcik, 2005). Participants are educated or taught a reformed curriculum through the lens of a learner. Participants will reflect on modeled lessons from a student's perspective (student hat) then from a teacher's perspective (teacher hat). Educative curriculums allow teachers to adapt or adopt the modeled lesson based on the needs of their own classroom with collaborative peer discussion and scaffolded experience (Krajcik & Delen, 2017). Professional learning should include time and support to allow teachers opportunity to make decisions about enactment or appropriation of new instructional practices that meet the sociocultural needs of the participant (Davis & Krajcik, 2005; Longhurst et al., 2017, 2022; Remillard, 2005). To meet the needs of the participants, research suggests that educative curriculum materials should be theoretically driven (E. Davis et al., 2014).

Lesson Study

Lesson study is a pedagogical framework that models a three-stage approach to action research (Lewis et al., 2019). The first stage of lesson study describes colleagues planning lessons where the activity aligns to the inquiry questions (Takahashi & Yoshida, 2004). The second phase of lessons study describes the research process of observation of lessons, assessments, and interviews. The third stage of lesson study describes iterative reflection and planning on best practices for teacher appropriation (Lamb & Aldous, 2016). Professional learning developers, researchers, and participants applying reflexivity to lesson plan creation is an essential aspect of lesson study (Lamb & Aldous, 2016). Reflexivity involves a process of reflection while the individual is immersed in experiences that enables the learner to process application of new teaching practices (Collet & Keene, 2019). The model lesson, created during the professional learning experience, should align to particular curricula, however, a focus on reflexivity will give participants opportunities to collaborate on the needs of their class and how the activity or design may be enacted to their curricular needs (Lewis et al., 2019).

Review Discussion

An initial search was conducted targeting research of secondary science methods courses or secondary preservice courses that targeted engineering design self-efficacy, yielding no results. The lack of literature reveals a gap in the reported research and the need to study secondary science preservice educators EDTSE. The second step was to identify literature related to preservice secondary science teacher's self-efficacy and perceptions or knowledge of engineering design. Because of the scarcity of literature, STEM education targeting engineering design was included. The third search was to identify experienced secondary teacher engineering design or STEM self-efficacy. The fourth step widened the search to identify studies that targeted preservice and in-service elementary teacher engineering design self-efficacy and/or implementation. The fifth search identified studies that included findings and suggestions for professional learning methods found to increase teacher self-efficacy. A systemic literature review was conducted using a coding table format in Microsoft Excel. Information was collected on variables within five broad categories: secondary preservice engineering efficacy, secondary preservice engineering knowledge, secondary teacher engineering efficacy, elementary teacher engineering efficacy/beliefs, and teacher education recommendations. Designing the intervention based on recommendations from the literature is further subdivided by knowledge reflection, modeled lesson plans, microteaching with peer feedback, and authentic teaching experience with self-reflection (see Table 1).

Secondary Preservice Engineering Efficacy

Preservice secondary science teacher engineering design self-efficacy has not been reported in the literature. This displays a lack of knowledge in understanding how current preservice secondary science teachers report and are developing self-efficacy to teach current science and engineering state standards during their teacher preparation courses. Although not specific to secondary engineering design teaching but science teaching, Bandura's four sources of self-efficacy beliefs (emotional sates, social persuasion, vicarious, mastery experiences) are reported as sources of science teaching efficacy with anxiety relating to the emotional source of self-efficacy (Cinici, 2016; Polat et al., 2021).

In general, novice science teachers develop efficacy in science instruction during their methods courses (Wagler & Moseley, 2005) and may report a decrease in efficacy following authentic teaching experience (Cinici, 2016; Polat et al., 2021). Authentic teaching experience may lead to "teaching shock" displaying an inverse relationship between teaching anxiety and self-efficacy (Cinici, 2016; Polat et al., 2021). Authentic

Table 1

Literature Review Searches and Refined Results

Participants	Search	No. of articles	Reference
Preservice secondary science teachers	Engineering design self-efficacy	0	
	Self-efficacy	3	Cinici, 2016; Polat et al., 2021; Wagler & Moseley, 2005
	Engineering/pedagogical knowledge	4	Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Kim et al., 2019; Love & Hughes, 2022
Secondary teachers	Engineering design or STEM self-efficacy	6	Annetta et al., 2013; Blonder & Mamlok-Naaman, 2016; C. Crawford et al., 2021; Daugherty & Custer, 2012; Kelley et al., 2020; Romero-Ariza et al., 2021; Smith et al., 2021; Van Haneghan et al., 2015
Elementary teachers	Preservice engineering design or STEM self-efficacy	5	Antink-Meyer & Parker, 2021; Kaya et al., 2017; Nesmith & Cooper, 2021; Perkins Coppola, 2019; Yesilyurt et al., 2021
	Preservice engineering design or STEM	2	Pilten et al., 2017; Radloff & Guzey, 2016
	Engineering implementation	2	Capobianco et al., 2021; Hill-Cunningham et al., 2018
All teachers	In-service and preservice methods of instruction	6	Carpenter et al., 2019; Christian et al., 2021; Ferguson & Sutphin, 2019; Karlström & Hamza, 2019; Larkin, 2012; Santoyo & Zhang, 2016; YiĞiToğlu Aptoula, 2021

teaching is needed to develop a belief in the ability to engage students (Wagler & Moseley, 2005). Following student teaching, overall efficacy can decrease returning to pre-methods course levels (Wagler & Moseley, 2005). These studies represent the little that is known about secondary science educator’s self-efficacy in relation to their engineering self-efficacy and relates more to general teaching self-efficacy.

Secondary Preservice Engineering Knowledge

Research does include preservice secondary science teacher pedagogical and/or content knowledge of engineering design. Preservice science teachers begin methods courses with little understanding of the EDP and engineering as an aspect of science teaching (Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Kim et al., 2019). Preservice science teachers display varying degrees of confidence to teach engineering based on prior experiences with engineering (Kim et al., 2019). This suggests that some preservice educators may have confidence to teach engineering design even though they have very little knowledge of the EDP or engineering in the standards. Teacher preparation programs in-depth teaching of the EDP and engineering practices will increase novice teacher engineering pedagogical and/or content knowledge (Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Love & Hughes, 2022) and increase preservice educator confidence to teach engineering design (Kim et al., 2019).

Overconfidence and oversimplification of engineering design may result in the misconception that engineering is simply building something or solving a problem (Kilty & Burrows, 2019). Therefore, it may be necessary to allow teachers opportunities to explore engineering design in depth and in context of the NGSS. Teacher preparation programs inclusion of engineering design in context of the NGSS significantly corelate with later classroom teaching of engineering (Love & Hughes, 2022). Research suggests that novice science teachers are entering their methods courses with little understanding of engineering design and how to effectively teach it as a part of their state standards (Banilower et al., 2013; Kim et al., 2019; Love & Hughes, 2022). In conclusion, when engineering design is included in teacher preparatory programs pedagogical and/or content knowledge of engineering design increases and does affect later appropriation of engineering teaching.

Secondary Teacher Engineering Efficacy

When reporting on secondary teacher efficacy following a professional learning experience, it is not within the recommendations of state science standards but is often reported in the larger context of STEM or design-based instruction (Annetta et al., 2013; Kelley et al., 2020; Smith et al., 2021; Van Haneghan et al., 2015). Although in-service teachers report an initial lack of familiarity with engineering design (Smith et al., 2021) after professional learning, teachers also report significant gains in engineering self-efficacy (Smith et al., 2021) and engineering teaching self-efficacy (C. Crawford et al., 2021; Kelley et al., 2020). Because many studies are not specific to science standards, teachers report increased understanding of how engineering design *could* be applied to their unique content and context (Smith et al., 2021).

Science teachers that undergo professional learning that includes a lesson aligned to a science and engineering practice in the NGSS showed greater gains in engineering efficacy than nonscience teachers (Kelley et al., 2020). Additionally, teachers are more likely to transfer what has been learned during professional learning when the STEAM content applies to their unique classroom and the provided resources support teacher implementation (Romero-Ariza et al., 2021). This suggests that if engineering teaching is done outside the context of the NGSS, it is less likely to transfer to science teaching practice. Teachers that create their own curriculum materials and use a lesson plan template are more likely to experience sustainable change (Blonder & Mamlok-Naaman, 2016). If learning transfer does occur following a professional learning experience, teachers' student-centered teaching practices increases (Romero-Ariza et al., 2021). This supports the aims of the *Framework* that include engineering design in science education as supportive of reformed teaching practice. When seeking to increase reformed science teaching practices, professional learning should focus on teaching self-efficacy (Blonder et al., 2014). No studies report on teaching engineering design as part of state science standards specifically. This exposes a gap in literature that expands on science teachers who are teaching engineering design practices as included in the NGSS aligned state standards and the intervention targeted strategies that best support EDTSE development.

Elementary Teacher Efficacy/Beliefs

Although this study targets preservice secondary science teachers engineering efficacy, the following review of elementary teacher engineering design self-efficacy is of value because both groups of teachers report lack of engineering experience and content knowledge (Hill-Cunningham et al., 2018). There are also many gaps in the secondary science teacher efficacy literature, therefore understanding elementary teacher engineering self-efficacy may lead to greater insights into the state of secondary science teacher engineering self-efficacy.

Following the adoption of the NGSS and the requirement for science teachers to include engineering practices, many researchers studied elementary teacher beliefs about teaching and learning engineering in elementary education (Capobianco et al., 2021; DeJarnette, 2018; Hsu et al., 2011; Sun & Strobel, 2014; Utley et al., 2019). Teacher engineering design efficacy is often reported as both self-efficacy and their beliefs of a student's ability to learn engineering. "Lack of science efficacy leads to teacher avoidance of inquiry-based science. As prevalent as this problem is with elementary teachers, the lack of teachers' engineering efficacy is even greater" (Hill-Cunningham et al., 2018, p. 58). This statement suggests elementary teachers lack science efficacy, but engineering efficacy is severely lacking which contributes to reports of teachers' feelings of low efficacy prior to beginning engineering professional learning experiences (Capobianco et al., 2021; DeJarnette, 2018; Utley et al., 2019).

Even if elementary teachers initially report confidence to teach engineering design, their confidence may not translate to classroom practice. Teachers may report neutral in confidence to teach engineering design in the classroom regardless of reporting that engineering design was rarely taught (Hsu et al., 2011). This suggests that teachers lack the efficacy, experience, and content knowledge in engineering design that will lead to classroom implementation even if they report confidence in their ability to teach. Although teacher efficacy is shown to increase following a professional development experience, an increase in engineering integration does not always increase (Sun & Strobel, 2014) suggesting a teacher's engineering design knowledge and teaching engineering design efficacy must both be addressed when promoting engineering design lesson enactment. Research by Sun and Strobel explored teachers perceived constraints of teaching engineering design in the elementary classroom. Teachers reported beliefs that their lack of knowledge and experience in teaching and learning engineering design would be problematic for integration (Sun & Strobel, 2014). This suggests that elementary teacher's lack of EDTSE is associated with a lack of engineering design teaching.

Stemming from their own lack of engineering self-efficacy, teachers may also report beliefs about their student's ability to learn engineering design. Teachers with little experience reported bias against girls being able and motivated to learn engineering design (Hsu, 2011). Research by Van Haneghan et al. (2015) reported over half the teachers did not believe that most of their students were capable of analyzing and interpreting data, identifying, formulating, and solving problems, and becoming self-directed learners. Research by Sun and Strobel (2014) explored teachers perceived constraints of teaching engineering design in the elementary classroom. Teachers reported beliefs that their lack of knowledge and experience in teaching and learning engineering design would be problematic for integration (Sun & Strobel, 2014). This suggests that elementary teacher's lack of EDTSE is associated with a lack of ED teaching. These studies suggest that a teacher's experience with engineering design can impact their view of students' ability and access to learn engineering design.

Professional Learning

Many studies report on recommendations for those responsible for professional development with intent to increase appropriation of reformed teaching practices (Longhurst et al., 2022; Marra et al., 2011). Professional development was responsible for teacher pedagogical practices immediately following the workshop and sustained change months later regardless of the science content area specialization (Christian et al., 2021) suggesting that professional development does affect teacher pedagogy, such as student-centered reformed practices, resulting in greater student achievement. "Gains in teacher learning, teacher practice, and student learning can be linked, demonstrating how teacher learning and practice might translate to the student learning context" (Longhurst et al., 2016, p. 440). Research suggests that professional learning experiences should include an emphasis on influential factors such as collaboration, sustained practice, and opportunities for adaptation and modification (Longhurst et al. 2022). Before teachers can reform teaching practices and increase appropriation with subsequent student gains, teachers must have the self-efficacy to believe they can reform their science teaching practices (Czerniak & Lumpe, 1996; Levitt, 2002). Based on literature, a discussion on the recommendations for teacher education will follow.

Teacher Education Recommendations

Teachers report initial deficiency in the NGSS engineering practices and STEM content knowledge supporting the need for teacher professional learning in methods courses (Christian et al., 2021; Kim et al., 2019). Professional learning was responsible for teacher pedagogical practices immediately following workshop and sustained change months later regardless of the science content area specialization (Christian et al., 2021) suggesting that engineering professional learning can affect teacher pedagogy. More effective engineering instruction is needed in preservice teacher education programs modeled after the professional learning research of in-service teachers in order to increase teacher appropriation and subsequent student learning (Kim et al., 2019). Preservice education should address autonomy in pedagogical development to increase teacher self-efficacy (Soini et al., 2015). Teachers should have autonomy to construct, adapt, and modify pedagogy during and following professional development (Longhurst et al., 2017). Thus, preservice education should address autonomy in pedagogical development to increase teacher self-efficacy.

Research also reports on recommendations for preservice science teacher education programs specifically and suggests including designed activities and experiments to increase efficacy to overcome psychological barriers (Polat et al., 2021). Acknowledging that engineering design teaching psychological barriers exist, STEM visualization combined with instruction are important in STEM teacher development (Radloff & Guzey, 2016). Preservice education programs should address student self-efficacy (Czerniak & Lumpe, 1996) and research reports that feedback is an important aspect of increasing self-efficacy (YiĞiToğlu Aptoula, 2021). Preservice science teacher's trainer feedback led to immediate corrections and was considered the most important variable in teacher development, and they expect to receive peer feedback about task processing but would also like feedback from teacher trainers about self-regulation (YiĞiToğlu Aptoula, 2021). To decrease anxiety that can result from clinical teaching and mentor teacher feedback, focus groups held in methods courses can help to alleviate preservice educators' anxiety (Arcelay-Rojas, 2018). In summary of the above cited literature, teacher education programs should address efficacy, autonomy, authentic experience, and social feedback to increase teacher enactment of engineering design. Following is a review of the literature reporting on specific targeted instructional strategies associated with teacher self-efficacy, beliefs, and enactment of reformed curriculum.

Direct and Emergent Knowledge Reflection

Professional learning should begin with an opportunity for participants to collaboratively reflect on current conceptions of teacher practice in comparison to expected teacher practice or student outcomes (Goodnough, 2018). Assessing and reflecting on current teacher content and pedagogical knowledge, beliefs about teaching and learning, and teaching experiences may provide the first step in conceptual change and the need for emergent thinking. During this phase, participants should assess current conceptions, collaborate with peers, engage in new content, and practice language necessary to accommodate new knowledge and skills. Teachers that were forced to confront contradictions were motivated to make changes in their STEM teaching practices. Confronting contradictions can occur through social collaboration and feedback (Goodnough, 2018). Teachers should also be aware of the goals of the professional learning experience and reflect on their own unique and personal goals.

Modeled Lesson Plans

Engineering design experiences should include the opportunity for preservice educators to engage in engineering design as a student. Research by Antink-Meyer and Parker (2021) suggests engineering in a single methods course is not enough to enact pedagogical change needed by elementary preservice teachers and they need opportunities to engage in learning engineering separate from learning to teach engineering. This suggests that preservice teachers need opportunities to learn engineering design through a student lens. Providing teachers with engineering design experience first as a student and then as a teacher during clinicals increased preservice science teacher engineering design self-efficacy (Perkins Coppola, 2019). Providing teachers opportunities to learn in the role of a student is an important aspect of educative curriculum, defined as immersive curriculum materials designed to best support teacher learning (E. A. Davis & Krajcik, 2005). Research by Williams et al. (2019) recommend educative curricula be used when integrating NGSS and engineering pedagogical changes as part of a professional development program. “Professional development that supports teachers in implementing a strongly written engineering educative curriculum can allow the transfer of design-based pedagogy into teacher-developed curriculum” (Williams et al., 2019, p. 677). In conclusion, based on research preservice educators should have the opportunity to engage in engineering as a learner (Antink-Meyer & Parker, 2021; Krajcik & Delen, 2017; Schneider & Krajcik, 2002; Williams et al., 2019) with intent to increase content knowledge (Love & Hughes, 2022) and self-efficacy (Perkins Coppola, 2019).

Micro-Teaching with Peer Feedback

Engineering design pedagogical experiences should include the opportunity for preservice educators to engage in microteaching engineering design self-created lesson plans with peer and teacher feedback. Campbell et al. (2019) revealed teachers reported value in discussing and sharing ideas for NGSS lesson implementation because teachers do not always have access to social collaboration. Research by Cinici (2016) suggests microteaching promotes cognitive and affective support to enhance teacher efficacy. Microteaching should be considered as a preservice science teacher method due to its ability to increase teacher efficacy. Research by Dyehouse et al. (2019) recommends professional development should include time to collaboratively develop lesson plans with opportunity for peer feedback. Teachers should engage in microteaching with peer feedback to address needed changes in a positive environment. Teachers that were forced to confront contradictions were motivated to make changes in their STEM teaching practices. Confronting contradictions can occur through social collaboration and feedback (Goodnough, 2018). To support an increase in teacher self-efficacy and teacher developed curriculum, the engineering design unit should include preservice teacher opportunities to engage in microteaching with peer feedback. In summary, interventions should include opportunities for students to present and micro-teach their lessons to peers. Peer feedback can lead to development of the lesson (Campbell et al., 2019; Dyehouse et al., 2019). Micro-teaching with peers and the opportunity to make changes from feedback can lead to an increase in student self-efficacy (Cinici, 2016).

Access to Mediating Tools

After attending a professional learning experience at NASA where teachers were provided opportunity to learn from engineers, teachers were tasked with developing lessons that included 3-D printing. When asked if they would implement the lessons plans in their class, several teachers replied that they could not because they did not have 3-D printers in their schools (Dyehouse et al., 2019). This is an obvious practical tool that was needed to enact professional learning. Thus, teachers should have access to tools that mediate their ability to transfer learning from professional learning to classroom practice (Campbell et al., 2014; Chao et al., 2017; Longhurst et al., 2017). Professional learning should include practice using tools for later use in classroom practice or for continued adaptation of curriculum materials (Longhurst et al., 2022).

Video recording of teacher practice and the 6E learn byDesign are two mediating tools that facilitate learning and transfer (Alexander et al., 2012; Bishop et al., 2015; Nesmith & Cooper, 2021). Professional learning practice with lesson plan templates increases enactment and sustained change (Blonder & Mamlok-Naaman, 2016; Nesmith & Cooper, 2021). Using tools to initiate reflection, such as video self-monitoring, improves instruction through instructor validation of fidelity (Alexander et al., 2012; Bishop et al., 2015). Preservice educators that use technology tools for self-monitoring can lead to increased teaching self-efficacy (Newman-Thomas et al., 2012). Technology enhanced tools can initiate and facilitate changes in practice (Campbell et al., 2014).

Clinical Teaching with Reflection

Engineering design pedagogical experiences should include the opportunity for preservice educators to engage in authentic classroom teaching experiences with self-reflection. Research by Brand (2020) reported teachers increased motivation to implement engineering design when professional development includes “time for practical application, reflection, and revision” (p. 8). Research by Can (2015) reports preservice teacher undergraduate experiences are vital in building experiences that support self-efficacy beliefs. Teacher education programs should consider authentic teacher experiences to reduce the effect of reality shock and increase efficacy (Cinici, 2016) since many teachers’ efficacy dropped after the realities of teaching a “real” class were realized. Ferguson and Sutphin (2019) suggest that following a preservice teacher’s opportunity to design and teach a lesson in an authentic setting a preservice teacher’s understanding of the role of a teacher matures from extrinsic observation to a more intrinsic understanding. Authentic teaching experiences should be followed by self-reflection to promote a teacher's pedagogical efficacy or intrinsic understanding. Research by Lekhu and Matoti (2020) recommend teacher education programs to include reflective journals to increase self-efficacy and professional identity and the practice of being a reflective practitioner. To support a decrease in teaching reality shock and an increase in teacher self-efficacy and engineering design classroom integration, the engineering design unit should include preservice teacher opportunities to engage in authentic teaching experiences followed by self-reflection.

Chapter Conclusion

In conclusion, the theoretical frame that underpins this research is Bandura's Self-Efficacy Theory (1977, 1997) that describes four sources of efficacy as mastery experience, vicarious experience, verbal persuasion, and emotion/psychological states (Bandura, 1997). The four sources of self-efficacy are assumed to be the same sources of EDTSE (Cinici, 2016; Polat et al., 2021; van Rooij et al., 2019; Yoon Yoon et al., 2014). In addition to the sources of efficacy, outcome expectancy is the teacher belief that effective methods of instruction can be used to bring about increased student understanding (Enochs & Riggs, 1990; Ward et al., 2020). The researcher acknowledges exploring and describing self-efficacy as a description of teacher beliefs, is best accomplished by intertwining internal and external influences (Putney & Broughton, 2010). Therefore, a Vygotskian lens was used to describe efficacy as a development process (Putney & Broughton, 2010, 2011).

The review of the literature identifies a lack of research reporting on preservice educators EDTSE. Thus, the review focused on preservice and in-service teacher engineering design efficacy and knowledge. Teachers begin engineering interventions with limited engineering experiences and knowledge (Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Kim et al., 2019). Preservice educators can build engineering knowledge and efficacy in methods courses (Kim et al., 2019; Wagler & Moseley, 2005) and during professional learning (Christian et al., 2021) which may increase enactment (Christian et al., 2021; Whitworth & Chiu, 2015). Professional learning of engineering design often lacks engineering design content knowledge and instead focuses on engineering activity with an emphasis on process rather than content (Daugherty & Custer, 2012). To increase enactment, research suggests engineering design be taught with connections to science content, (Moore et al., 2015; Pleasants & Olson, 2019) so it becomes a regular part of classroom curriculum (DiFrancesca et al., 2014). Methods of instruction used in professional learning can support efficacy development including authentic teaching (Cinici, 2016; Ferguson & Sutphin, 2019; Margolis et al., 2017), micro-teaching peers (Campbell et al., 2014; Dyehouse et al., 2019; Goodnough, 2018), knowledge reflection (Daugherty & Custer, 2012; Goodnough, 2018), and self-monitoring videos (Alexander et al., 2012; Bishop et al., 2015).

CHAPTER III

METHODS

This mixed method case study described the EDTSE of eleven preservice educators over the development and delivery of an engineering design unit in a Science Teaching Methods II course. A concurrent nested mixed method utilizing a QUAL + quant design was used. Research by Hess-Biber (2015) supports mixed-method research when an interpretivist analysis is needed. Mixed-method research is essential when addressing research questions where quantitative research is insufficient to extend or elaborate on an initial database (Creswell, 2008). Due to the interpretive nature of the research questions, a big QUAL + quant strategy was employed (Leech & Onwuegbuzie, 2009). The qualitative data represents the majority of the data collected, analyzed, and from which conclusions were drawn. The quantitative data were nested within the qualitative data to assist in pattern recognition of EDTSE over an engineering design unit. The data were concurrently collected over six time points. Qualitative and quantitative data were analyzed separately and then triangulated to describe engineering design self-efficacy development. Data triangulation is necessary when interpreting a phenomenon (Creswell, 2013). The phenomenon or unit of the case was the engineering design unit. The descriptive case study reports the development of EDTSE and the elements of the unit that facilitate participant sensemaking of engineering design teaching.

At each time point, preservice educators reflected individually through journal entries and then collectively through focus groups (class debrief experiences). Each time point also corresponds to instructor field notes. After completing a lesson plan, preservice educators taught and recorded the lesson as part of the clinical course (SCED 4300). The recording was collected as data to compare student self-perceptions of EDTSE to instructor perceptions of their EDTSE, including participant confidence, emotional state, and mastery of experience. A student journey map and teaching video were collected at time point five.

Qualitative data were analyzed using discourse analysis with cycles of inductive and deductive coding. The *a priori* codes in the initial analysis included efficacy constructs, elements of sensemaking, and EDTSE changes. Data were organized using the time point grading protocol and video observation protocol. Targeting multiple time points provided data to illuminate the process of efficacy development and fluctuations through time. The following is a description of the engineering design unit taught in a methods course, including the methods of instruction that targeted preservice educators EDTSE.

Engineering Design Unit

As part of a science teaching methods course, an engineering design unit was the case under study, intending to increase preservice educator EDTSE. The development and delivery of the engineering design unit was aligned with the literature for methods of instruction that best support preservice teacher EDTSE. The unit further aligned to the theoretical framework, including Bandura's self-efficacy and the frameworks for professional learning described in chapter three. Bandura's four sources of efficacy and outcome expectancy were considered from a Vygotskian sociocultural lens of development. Figure 3 shows the engineering design unit's intentional self-efficacy and outcome expectancy development aligned to elements of the engineering design unit. Aligning the engineering design unit to theory ensured that the sources mediating efficacy development were addressed.

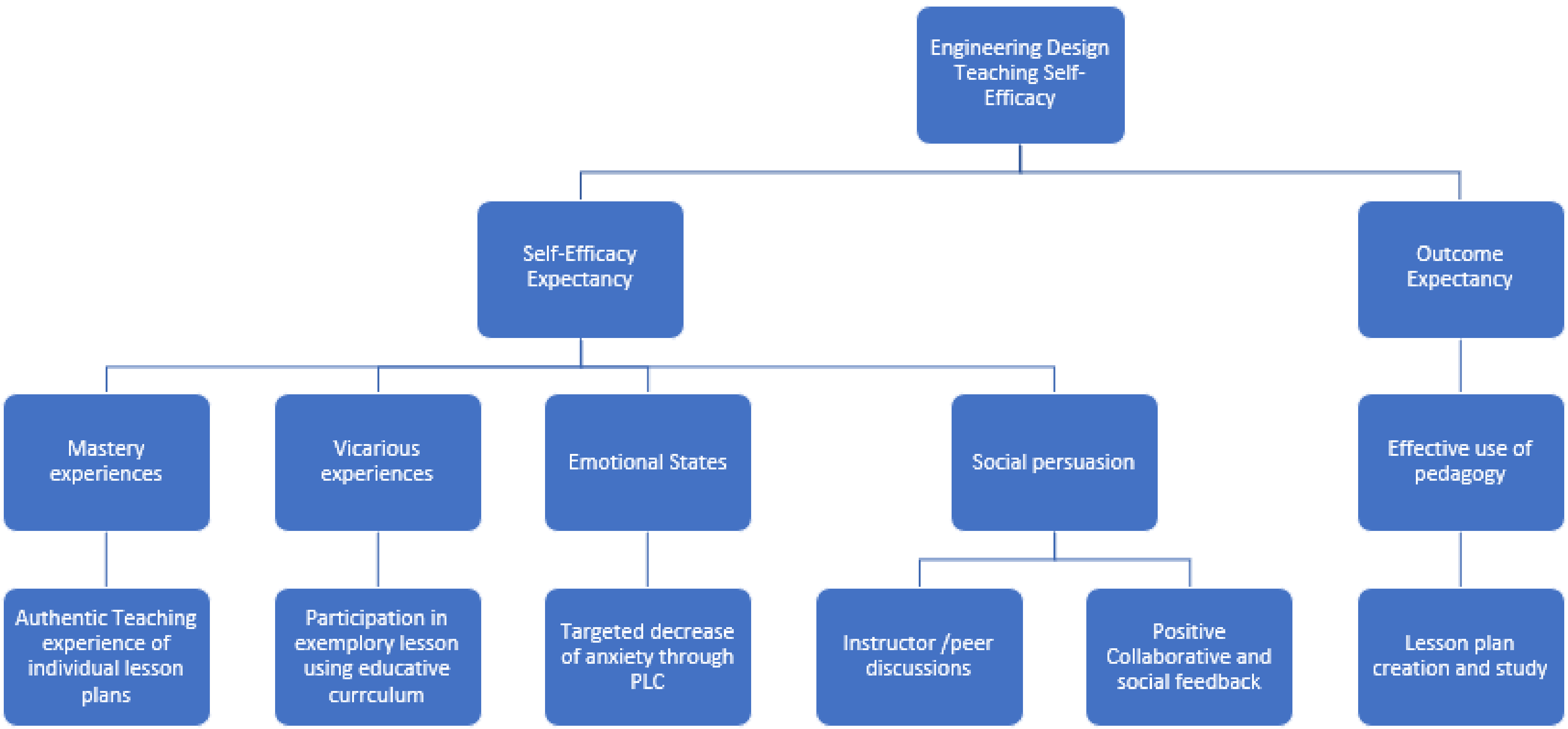
Time Point One

Time point one represents the beginning of the ED unit. Participants were assigned homework to read their standards that include the language of "design a solution" or "compare design solutions." Participants then read the *Framework's* description of the "defining problems" and "designing solutions" practices. When participants came to class, they were familiar with the language of their content standards and the engineering design specific practices. The class session began with a focus group discussion of EDTSE after having read through the SEEd standards to identify, by content area, standards that emphasize engineering practices.

Research suggests preservice science teachers begin methods courses with little understanding of the EDP and engineering as an aspect of science teaching (Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Kim et al., 2019). Thus, the first class session began with the opportunity for preservice educators to assess their current understanding of engineering design using a preassessment probe. Because research by Antink-Meyer and Parker (2021) suggests that preservice teachers need opportunities to learn engineering design separate from learning to teach engineering, participants were taught the stages of the EDP followed by a comparison of engineering design to scientific inquiry types and methods.

Figure 3

Efficacy and Unit Alignment



Participants then compared the science and engineering practices from an inquiry mindset and an engineering design mindset. The course instructor taught the EDP separately from teaching the science and engineering practices because research by Cunningham and Carlsen (2014) suggests doing so will develop more informed views in engineering design.

Shifting participant thinking from inquiry to engineering design was targeted during the intervention due to the literature that describes the prevalence of misconceptions about engineering design (Kilty & Burrows, 2019) and the lack of engineering design experience in preservice science teachers (Banilower et al., 2013). The unit included in-depth teaching of the EDP and engineering practices because research suggests doing so in methods courses will increase novice teacher engineering pedagogical and/or content knowledge (Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Love & Hughes, 2022) and increase preservice educator confidence to teach engineering design (Kim et al., 2019).

Preservice educators participated in exemplary standard-aligned engineering lessons emphasizing engineering design language and the stages of the EDP. Experiential learning was used to teach an example of the “design a solution” standard in the physics and Earth and space content standards. The physics standard states that students will design a device to transfer energy based on a real-world problem. The Earth and space science standard asks students to design a solution to mining conventional non-renewable energy resources. Participants used the stages of the EDP to design a windmill that could produce enough voltage to charge a cell phone. Experiential learning of an exemplar standard aligned lesson was a targeted method of instruction because preservice science teachers represent individuals lacking in engineering design knowledge (Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Kim et al., 2019), and experiential learning has been shown to be an effective method of increasing engineering design efficacy for individuals with little experience (Perkins Coppola, 2019).

Time Point Two

Time point two targeted experiential learning of biology and a chemistry standards that asked students to "evaluate a design solution." During the exemplar biology lesson, participants evaluated the effectiveness of bioengineered bacteria with enzymatic "digestive" processes. Participants designed an investigation and collected data on the breakdown of oil-based cat foods by comparing the patent holding brand of engineered bacteria to two other brands and a water control sample. The chemistry standard asks students to compare design solutions where chemistry is used to solve a state mining problem. Participants compare open pit limestone mining, common in the state, to a method of carbon dioxide extraction from the atmosphere mixed with sea water to create a lime precipitate that could be used in cement production. After using their knowledge of chemistry to produce lime precipitate in sea water, students evaluated carbon sequestration as a possible local solution to open pit mining. In both exemplar lessons, participants argued from evidence the best solution based on constraints. The standard's language (evaluate solutions) and intent differ from the "design a solution" language of time point one; thus, experiential learning was done by content area and standard language emphasis. Research by Williams et al. (2019) recommends educative curricula be used as a part of professional development to support engineering design pedagogical changes and curriculum development. Research suggests learning engineering design through a student lens first can increase EDTSE (Perkins Coppola, 2019).

Preservice educators were assigned the creation of an engineering design standard-aligned lesson plan. To accomplish this assignment, participants were taught and given the ITEEA 6E Learning byDesign model developed by Burke (2014) to guide the development of their engineering design lesson. The lesson plan template was a tool that assisted participants in developing or modifying a lesson plan to include engineering design. Research has shown that teachers that create their curriculum materials and use a lesson plan template are more likely to experience sustainable change (Blonder & Mamlok-Naaman, 2016). Participants were given time to explore online curriculum resources and to adapt lessons to classroom needs. In the absence of online engineering design lesson resources, participants were provided with opportunities to modify a science/inquiry lesson to an engineering design lesson. Research suggests participants that are given the autonomy to construct, adapt, and modify pedagogy during and following professional development will lead to increased appropriation (Longhurst et al., 2017).

Time Point Three

Preservice educators presented their lesson to the class first, then taught the lesson plan (micro-teach) in content area groups. Collaborative lesson plan creation and microteaching have been shown to be instrumental in EDTSE increases (Cinici, 2016).

Preservice educators refined their engineering lessons based on instructor and peer feedback, which was later taught in an authentic classroom setting. Research by Dyehouse et al. (2019) supports time be given to collaboratively develop and refine curriculum. Microteaching and collaborative reflection were included in the engineering design unit because research states that they are essential aspects of lesson study enabling learners to apply new teaching practices (Collet & Keene, 2019; Lamb & Aldous, 2016; Takahashi & Yoshida, 2004).

Time Point Four

Time point four included the authentic teaching of engineering design during the clinical class. Participants refined their micro taught engineering design lesson from time point three and taught the lesson in authentic classrooms where they could observe and receive feedback from students and their assigned mentor teacher. Participants coordinated with mentor teachers to teach an engineering design lesson (one full class period) that aligned to their current curriculum sequence. As an example, participants majoring in biology may have been assigned to a seventh-grade classroom that was teaching Earth science standards during the 3-week window participants were assigned to teach a lesson during clinical class time. Authentic teaching was included in the engineering design unit because it has been described as a mastery experience that is the most influential in EDTSE development (Bandura, 1993). Authentic teaching is needed to develop a belief in the ability to engage students (Wagler & Moseley, 2005) and increase efficacy (Cinici, 2016). Preservice educators build teaching self-efficacy based on their perceptions of successful teaching while using effective methods that improve student performance (Arcelay-Rojas, 2018; Bandura, 1997; Tschannen-Moran et al., 1998). Therefore, the engineering design unit allowed for an authentic teaching experience where participants could receive student feedback, including engagement and application of science content.

Time Point Five

Participants recorded themselves teaching an engineering design lesson in the classroom, later watching the video to assess their successful teaching of engineering design. Video self-monitoring was included in the unit due to research that suggests it is an effective tool that assists in preservice teacher reflexivity and efficacy development (Newman-Thomas et al., 2012). Preservice educators received feedback from the students, mentor, and course instructor leading to self-reflection and evaluation of their EDTSE and their ability to use effective methods of instruction that affect student outcomes (outcome expectancy). Journey maps were included at time point five as a social reflexivity tool that allowed participants to consider their EDTSE retrospectively. Social reflexivity was included at each stage of development based on research that suggests it can facilitate decreasing participant anxiety (Arcelay-Rojas, 2018) and support efficacy development (YiĞiToğlu Aptoula, 2021). To address possible negative feedback during social reflexivity, persistence and resilience through failure was emphasized, and connections were made to failure as part of iteration in the EDP. To strengthen motivation and outcome expectancy, the engineering design unit emphasized the benefit of reformed teaching practices as effective methods of instruction (Boesdorfer, 2017; Christian et al., 2021; Romero-Ariza et al., 2021).

Scaffolded Tasks

Each intervention stage was aligned to a task given as homework or in-class assignment. The course instructor mentored participants through the series of tasks. The engineering design unit included content and pedagogical content knowledge to facilitate participant belief in successful task completion. The following is a description of the scaffolded tasks and the mentorship that was provided to assist in task completion and developing competency beliefs.

Task one was to identify engineering design problems that could be solved using science disciplinary core concepts by content area. For example, chemistry students would identify engineering design problems that chemistry knowledge could solve. The course instructor provided examples of problems and solutions by content area by teaching specialized engineering fields. As an example, participants were mentored by the course instructor when introduced to the field of biological engineering and how knowledge of biological systems could be used to identify and design solutions to living systems.

The second task was to coordinate with the participants' assigned mentor teacher to identify a standard taught in the clinical classroom during a 3-week period from which an engineering design lesson could be developed. Participants brainstormed possible engineering design lesson ideas that met the intent and language of the clinical class standard. During this task, the course instructor mentored participants by assisting in brainstorming lesson ideas, providing websites and access to engineering design lessons, and helping to modify science inquiry lessons to include an engineering design emphasis.

The course instructor also “coached” participants on collaborating with their mentor teacher to coordinate a day to teach in the clinical class.

After creating the lesson plan, the third task was to micro-teach the lesson to their methods course peers and to make adjustments to a finalized version of the lesson. The course instructor and class peers acted as mentors to provide critical feedback that could assist the participant in making recommended changes to the lesson plan. As an example, the instructor or peers may have given feedback to limit time on a particular section of the lesson or to expand an idea further. Participants were reminded to use explicit engineering design language in the lesson plan.

The fourth task was to teach and video record the lesson during the clinical class. Mentor teachers provided participants with feedback after teaching the lesson, which could be used to make changes to the lesson when it was taught the next class period. Participants also received feedback from students during that teaching that assisted in modifications to the lesson.

The fifth task was to watch the lesson’s video and reflect on their belief in the successful teaching of engineering design. The course instructor asked participants to gage their successful teaching of engineering design from the perspective of a student in the class or class observer. The course instructor served as a mentor during this task by reminding participants to focus on engineering design and by watching the uploaded video and providing the participant with a mentor’s perspective.

Scaffolded tasks with mentor assistance were included in the unit due to research that describes Bandura’s (1986) four sources of self-efficacy mediation. For example, Bandura suggests that verbal persuasion is a mediator of self-efficacy. Therefore, the course instructor and peers provided positive and constructive verbal feedback to assist in task completion. Vicarious experiences were addressed when the course instructor acted as mentor to model sample engineering design lessons using experiential learning. Modeling of lessons provided by the instructor mentored participants on creating an engineering design lesson aligned to clinical class standards. A mentor scaffolding tasks was included at each stage of the engineering design unit because research has shown that teacher self-efficacy entwines with teacher practice and develops through reflective interpersonal negotiations of task analysis (Bandura, 1993; Putney & Broughton, 2010; Tschannen-Moran et al., 1998; Yoon Yoon et al., 2014).

Teacher belief of successful task completion was also described by Vygotsky's (1978) theory of optimized learning of scaffolded "events" in the zone of proximal development. The course instructor intentionally scaffolded the learning of engineering design separately and then as a part of the science and engineering practices in state standards. The instructor provided tasks that progressively built in required complexity of pedagogical understanding to complete. Based on Vygotsky's theory, participants will attempt to make sense of tasks by relying on previous experience, however, if there are no previous examples of engineering design teaching, or engineering design knowledge is rooted in misconceptions, then learning may not occur. If the tasks are too difficult to accomplish alone, then learning may also be considered too difficult. The unit was designed to maximize participant belief in task accomplishment by providing mentorship from a more knowledgeable other (course instructor) to increase what participants can accomplish with collaborative assistance. Because assigned mentor teachers had little experience with engineering design, but much experience with science teaching, participants could receive mentorship on general teaching and lesson development, but engineering design teaching was mentored from the course instructor through video self-monitoring, micro teaching, and lesson plan creation. Mentorship was an important inclusion in the engineering design unit due to research that suggests mentoring participants through completed tasks can influence teachers' goals, effort, and persistence (Tschannen-Moran et al., 1998).

The data sources and normative class procedures also serve the function of increasing participant efficacy. For example, research by Lekhu and Matoti (2020) recommends that teacher education programs include reflective journals to increase self-efficacy, professional identity, and the practice of being a reflective practitioner. Therefore, the unit consists of journaling, journey maps, and focus groups that emphasize being a reflective practitioner at each time point. Focus groups are held during the beginning of class because research suggests focus groups can decrease feelings of practicum anxiety (Arcelay-Rojas, 2018) and according to Banduras (1993) physiological states is a mediator of self-efficacy. In summary, the data sources, scaffolded tasks, mentorship, and methods used are aligned to research recommendations for increasing self-efficacy. The engineering design unit was taught in the methods course to increase preservice teacher EDTSE leading to engineering design integration, greater student engagement, and increased student engineering literacy.

Setting/Participants

Eleven secondary science preservice educators enrolled in the Spring semester 2023 Science Teaching Methods II course were targeted for this investigation (SCED 4400). The science teaching methods course was the second in a two-part series of science methods courses. Preservice educators concurrently enrolled in a clinical experience course (SCED 4300) that included 30 hours of authentic classroom experience. All participants were majoring in secondary science education, although their content areas varied. Purposive sampling is valued when targeting a specific group that represents a possible lack of engineering experience (Marshall & Rossman, 2016); therefore, for this methodology description and subsequent chapters, all participating preservice educators enrolled in the Methods II course will be called participants. By using the term “participant,” it is understood that consent has been given and they are students in the methods course. Demographic information, including name, gender, engineering experience, and major, were collected from participants. The course instructor served as an investigator and was aware of participants during the investigation, and all were expected to engage in normative classroom experiences. Although all enrolled in the course consented to participate, all were informed that participants would have no additional assignments or expectations than those who did not consent.

Participants had completed the first semester of science methods courses. During both semesters, participants concurrently enroll in a clinical teaching experience where they are assigned a mentor teacher at a local school. The two participating school districts assigned were semi-rural, and neither district employed a science curriculum specialist. Science and Engineering Education (SEEd) standards were implemented in state high schools (grades 9-12) during the 2021/2022 school year and middle schools (grades 6 – 8) during the 2016/2017 school year. Participants were assigned mentor teachers in grades 7-12. This means that some participants were in middle schools where the SEEd standards had been in effect for longer than those participants who were assigned mentor teachers in high schools that had only recently enacted the SEEd standards without the aid of a curriculum specialist. Participants began the science methods course having already established classroom norms and procedures from the previous semester. The classroom environment was designed to foster discourse and positive feedback with a growth mindset. The setting for the case study includes the university classroom and the secondary science classroom assigned for 30 clinical hours.

Participants reported their experience with engineering design (see Table 2) as part of the first weekly online journal submission and the online consent form's survey participant information. The participant's first initial follows each participant's pseudonym. The initial will identify the participant in all chapter five tables. Participants were asked their name, major, and number of engineering courses completed (N = 11), with five males (45.5%) and six females (54.5%). Three of the eleven participants (27.3%) had taken an engineering course during their university coursework, all seeking certification in physical science/physics. After further analysis, the required course was "Physics for Scientists and Engineers," which required concurrent enrollment in a physics and engineering lab. The participants reported that the course did not teach engineering design or how engineers use physics, only physics content knowledge needed by engineers. Thus, because the course title included “engineering,” three physics major participants reported that course and associated lab as completed engineering courses.

Table 2

Participant Descriptions

Name	Initial	Gender	Major	Engineering courses
Jana	J	Female	Physical Science	2
Mike	M	Male	Physical Science	2
Eric	E	Male	Physics	2
Malia	Ma	Female	Chemistry	0
Nora	N	Female	Chemistry	0
Alex	A	Female	Biology	0
Emily	E	Female	Biology	0
Isabelle	I	Female	Biology	0
Tim	T	Male	Biology	0
Chris	C	Male	Earth Science	0
Scott	S	Male	Earth Science	0

Materials

The following is a description of the materials used during the investigation. Informed consent forms were administered to all students via a Qualtrics link sent to student email accounts through Canvas announcements by the course instructor. The principal researcher (Dr. Max Longhurst) invited students to participate in the research. The principal investigator came to the class to introduce the study and answer questions while the course instructor left the room. The IRB-approved Qualtrics form provided participants with full disclosure of the study’s nature and information on identifiable data gathered during the investigation. Data was identifiable to match participant data over time. Participants were also informed that participation in the study was voluntary. They were also informed that they could withdraw at any time without penalty or course grade influence, and those who chose not to participate in the study were still required to participate fully in the unit as a normal part of the course.

Canvas was used to collect student journal entries, journey map video descriptions, and teaching videos, which were then transferred to Word for analysis. Focus groups were recorded and transcribed using Temi and transferred to Box before deletion from Temi. All data was stored in Box. Box and Canvas are password protected, access was limited to researchers, and no identifying participant information was stored using the software following de-identification and pseudonym assignment. Students used personal computing devices compatible with Canvas to upload journal responses, journey maps, and lesson video recordings.

Research Design

When conducting research in the field of engineering, the method used should be determined by the nature of the research questions (Borrego et al., 2009). The questions in this research are derived to describe the EDTSE processes of development during an engineering design unit and thus require an emphasis on a qualitative methodology (Marshall & Rossman, 2016). Previous EDTSE research employed quantitative survey instruments with supporting qualitative data that described overall changes in EDTSE following an intervention suggesting that teachers generally increase in EDTSE over time

(C. Crawford et al., 2021; Kelley et al., 2020; Smith et al., 2021), however, this study was designed to describe EDTSE at different stages of development and not merely measure the pre/post effect of an intervention or to explore the sources of EDTSE. As a result, the selection of qualitative data collection & analysis with nested quantitative data allowed for a comprehensive and rich description preservice teacher EDTSE over the delivery of an engineering design unit.

A concurrent nested mixed method case study design allowed for an in-depth analysis of an engineering design unit in a science methods course and the development of EDTSE. Case studies are desired methods when studying the lived experiences of targeted groups and require immersion in the setting to convey both researcher and participant views (Marshall & Rossman, 2016). It was necessary to collect data at multiple time points (repeated measures) to describe participant EDTSE at various stages of development. Collecting data repeatedly throughout the investigation allowed for in-depth analysis of EDTSE over time points corresponding to methods of instruction during the engineering design unit. The descriptions that follow will detail the data collection plan and data sources. Each data source, including focus groups, was intended to represent personal reflections that may range in description and are meant to provoke complex narratives that are meaningful and personal (Arcelay-Rojas, 2018).

Data Collection Plan

After receiving IRB approval, the principal investigator introduced the study to preservice educators enrolled in the SCED 4400/4300 course while the instructor left the classroom. The consent forms were administered to student emails via Canvas announcements by the course instructor and collected using Qualtrics. The course was held once a week for 2.5 hours, during which the instructor served as the investigator. The established norms of the class included assigned weekly journal entries on Canvas that were graded based on completion. Following the assigned journal entries, students participated in a group discursive reflection (focus group) during the first 10-15 minutes of class. These group reflections were not graded. Participants were then required to develop a lesson plan that was micro-taught during class to peers and later taught as part of the clinical teaching experience. During class, students created a visual journey map and audio video recording describing their EDTSE journey through the engineering design unit.

Qualitative and quantitative data were collected at six targeted time points during the intervention, including: (0) prior to intervention, (1) following engineering design instruction, (2) exemplar lesson participation, and lesson plan creation, (3) microteaching lesson with peer feedback, (4) clinical teaching of participant-created lesson plans with reflection and instructor feedback, and (5) viewing of teaching video with social reflexivity. Student journals were collected from Canvas course assignments and graded based on completion at each time point. Time points corresponded to instructor field notes and focus group transcriptions. Recordings of focus groups were deleted after transcriptions were completed. After completing the participant-created lesson plan, the lesson was taught during the clinical course (SCED 4300). Participant-assigned mentor teachers sent home an email to their science students that a mentee teacher would be recording themselves. After the participants recorded themselves teaching their lesson plan in their clinical class, they immediately reported their EDTSE. Then, after waiting several days, participants watched their video recordings and reported their EDTSE in journal entry five. The course instructor viewed the video as part of research to compare student self-perceptions of EDTSE (reported in journal entry 5) to instructor perceptions of participant confidence, emotional state, and mastery of experience using the instructor video protocol (see appendix B). The student journey map and instructor video protocol were collected at time point five. The class recordings were deleted after the instructor viewed and analyzed the video using the instructor video protocol.

Data Collection

The following data was collected during the investigation: Journal entries (6), Focus Group transcriptions (4), Instructor field notes (4), Journey map, and Instructor video protocol.

Journal Entries

Participants were assigned weekly journal entries through Canvas, graded based on completion only as a regular part of the course. Participants submitted six electronic journal entries to Canvas during the investigation. The journal entries responded to prompts regarding their engineering design self-efficacy. Participant journal entries allowed for detailed analysis of personal experience within educational institutions, which enabled participants to share their experiences while simultaneously reflecting on growth utilizing a reflexive analysis of institutional practice (Reed-Danahay, 2017). The first prompt asked the students the following.

1. Discuss your confidence, motivation, the expectation of success, and anxiety to teach engineering design as part of the standards and rate each variable on a scale of 0 to 5, with 0 representing none and 5 representing a lot.

2. What factors are influencing your EDTSE?

3. What engineering design experiences have you had prior to this course?

4. What experiences have you had with engineering teaching prior to this course?

After the initial journal response (time point 0), question three was adjusted to read:

3. What engineering design experiences have you had during this course that might have influenced your above responses?

Journal entries were analyzed using discourse analysis. The discourse analysis included *a priori* coding of (1) nomothetic and ideographic EDTSE at each time point, (2) statements of the elements of the unit that contributed to participant sensemaking, and (3) statements that describe changes in EDTSE. A priori coding is proper when analyzing predetermined categories based on theoretical descriptions (Borrego et al., 2009; D. C. Davis et al., 2002). Data from the discourse analysis were organized into the time point grading protocol (see Appendix A). A constant comparative method with an external researcher (doctoral peer) was conducted until a consensus was met.

Focus Group Transcriptions

Focus groups are explicit discussions targeting a specific phenomenon with individuals who share social commonalities (Krueger & Casey, 2014). Focus groups allow for greater sharing of personal sensitive individual experiences than one-on-one interviews (Guest et al., 2017) and can result in increased teacher efficacy through decreased feelings of practicum anxiety (Arcelay-Rojas, 2018). Allowing participants opportunities to share personal experiences in engineering education research can present researchers with unique participant views that may “confirm, contradict, complicate, or complement” other data sources (Leydens et al., 2004, p. 67). The study included eleven participants, which fell within the recommended range (4-12) of focus group participants. (Krueger & Casey, 2014). Therefore, this study used a focus group within the context of the methods course to engage participants in social discourse through the sharing of their EDTSE and practicum experiences.

Participants were led in a class discussion (focus group) by the instructor during the first 15 minutes of class time. A focus group was held at each time point, allowing the researcher to explore participant perceptions of engineering design at each stage of development. The group discourse was initiated from the same questions asked during the journal entry but allowed for emerging or clarifying questions about student confidence, motivation, the expectation of success, and anxiety about teaching engineering. Group discourse allowed the instructor to ask additional probing questions about the elements of the engineering design unit that facilitated their sensemaking and task competency. During the focus group at time point 5, participants were asked to discuss their EDTSE in general after receiving feedback from the instructor, mentor teacher, and clinical class students. Allowing students to discuss the impacts of social discourse (feedback) on their EDTSE at all time points were targeted because social persuasion is a mediator of self-efficacy (Bandura, 1993). Arcelay-Rojas (2018) suggests that discussing preservice teacher experiences during class may lead to decreased feelings of practicum anxiety.

The participants were notified that the class discussion was recorded and later transcribed. Recordings of focus groups were deleted after transcriptions were completed. Research suggests that transcription is a powerful tool that can aid the researcher in conceptualizing how the data should be coded in qualitative research (Oliver et al., 2005). The focus group transcripts were analyzed using discourse analysis. The time point grading protocol (see appendix A) used for organizing discourse analysis data from the journal entries was also used to organize individual student responses during the focus groups. Using one time point grading protocol for two data sources allowed additional statements made during the focus group to be used as supporting ideographic evidence at each time point. The discourse analysis included *a priori* coding of (1) ideographic EDTSE at each time point by construct, (2) statements of the elements of the unit that facilitated sensemaking and task competency, and (3) statements that describe changes in EDTSE.

Instructor Field Notes Data

During the intervention, the instructor/researcher gathered field notes, including student responses and observations, at all five time points. The field notes were reflective. Participant reactions and responses, in addition to general class observations, were referenced. Instructor field notes were also used to compare participants' beliefs with instructor-perceived EDTSE and class EDTSE trends. Field notes were not analyzed separately but were used as an aid and clarifier in analyzing the other data sources. During organization and analysis using the grading protocols, the field notes were used to justify and provide evidence of general efficacy for student responses.

Journey Map

Following teaching the participant-created lesson plan during practicum (clinical) or time point five, participants created a visual journey map that detailed engineering design teaching efficacy throughout the unit. Participants drew a map that showed them beginning the engineering design unit through all five time points and projections of where their journey took them. They projected their efficacy journey at two additional points, their first year of teaching and after 5 years. Participants then created an audio-video recording showing their journey map while explaining each stage of the unit (engineering design and standards content, exemplar lesson, writing a lesson plan, micro-teaching with feedback, authentic teaching with analysis, and two future projections) and their corresponding EDTSE. Participants uploaded the journey map image and the audio-video recording to Canvas. Journey maps have been used in undergraduate engineering research and have allowed researchers to target participants' emotional and thematic responses (Meyer & Marx, 2014). Marshall and Rossman (2016) suggest that arts-informed data such as Journey maps can effectively target a lived experience and change over time such as participant changes in EDTSE development, thus journey maps were included as a data source in the study.

The journey map explanations allowed participants to describe their visual art in their own words. The audio-video recording transcriptions were analyzed using discourse analysis. The images were analyzed based on emergent visual themes of efficacy development. The participant's time point grading protocol (see appendix A) was used to organize statements describing EDTSE at time points compared to the journal entry and focus group idiographic descriptions. The journey map provided a retrospective description compared to the "at the moment" journal entry descriptions. The time point grading protocol organized the discourse analysis's *a priori* coding of (1) ideographic EDTSE at each time point, (2) statements of the elements that contributed to the EDTSE estimated above, and (3) statements that describe changes in EDTSE.

Instructor Video Protocol

All participants were required to teach lessons and reflect on their experiences as part of the SCED 4300 clinical teaching course. Participants were instructed to record their instruction only limiting student visuals. The recording was collected as part of research to compare participant self-perceptions of EDTSE to instructor perceptions of participant confidence, emotional state, and mastery of experience. Participants were asked to rank and justify their confidence, emotional state, and successful teaching of their engineering design lesson immediately after teaching. After waiting a few days, participants were directed to watch their recordings ranking and justifying the constructs again. Individuals compared their descriptions of EDTSE immediately after teaching to the delayed description after viewing their videos. Participants were directed to discuss and analyze any differences between the immediate and delayed EDTSE responses in journal entry five.

After the participants uploaded the recording and journal entry five (see Appendix C) to Canvas, the course instructor/researcher viewed the video as part of research to compare student self-perceptions of EDTSE (reported in journal entry 5) to instructor perceptions of participant confidence, emotional state, successful teaching of engineering design, and general EDTSE using the instructor video protocol (see Appendix B). Following analysis, the video was deleted. The video protocol informed researchers in a comparative analysis of participant vs. instructor perceptions of a mastery experience influence on EDTSE. Participants were able to describe their confidence and expertise in engineering as high or low when the video recording may have depicted conflicting evidence. Conflicting evidence statements assisted researchers in analyzing the elements of the engineering design unit's influence on participant sensemaking and the successful teaching of engineering design. Because research suggests teacher reports of efficacy can differ from teacher practice (Kane et al., 2002), researchers needed to observe the teaching of engineering design in the classroom through a video recording to assist in the analysis of EDTSE developmental stages over the engineering design unit.

Video-self monitoring with instructor engineering design feedback was additionally used to mediate social persuasion (a source of self-efficacy). Allowing participants to discuss the impacts of social discourse (feedback) on their EDTSE at time point five was included because mentor teachers may not have been able to provide feedback specific to the teaching of engineering design, or the feedback may have been negative if the mentor teachers were unfamiliar with engineering design in the standards. The comparison of perceptions of self to perceptions of the instructor using the instructor video protocol was shared with the participants as a source of positive social feedback.

Estimated Timeline

The duration of the unit was over a five-session period (see Table 2). Each class session was 2.5 hours long. During the Spring semester, there were three holidays held on Mondays, which increased the actual duration of the intervention to seven weeks. This allowed time for participants to teach their lesson plans during the clinical course.

Procedures

As shown in Table 3, the engineering design unit in the methods course was delivered over a period of five sessions and data was collected over six total time points. Each session is described as a time point where data was collected. Participants were introduced to the study, and consent was received at time point zero, followed by baseline data collected in journal entry zero. Participants were given the assignment to create a journal entry before each class. Each class session began with participant discourse during an audio-recorded focus group. At the conclusion of each class session, the instructor recorded observations and student responses to the intervention as instructor notes. This class pattern continued throughout the investigation. After the last class session focus group, participants created and uploaded a journey map with an audio-video description. Also, during session five, participants responded to the instructor on the video protocol. The video protocol was collected at time point four after participants uploaded audio video recordings of self-teaching in the clinical class. All data were collected and analyzed separately and then triangulated to enhance validity and to use different data lenses to explore the research questions. All data sources were used to create an in-depth description of the EDTSE of preservice educators at specific time points and to generalize EDTSE development over time. Additionally, the data displayed elements of the engineering design unit's influence on participant sensemaking of EDTSE. Following data analysis, the participants were assigned pseudonyms, and all identifying information was deleted.

Table 3

Session Descriptions

Session	Procedure	Data source
0	Introduction to study and consent	Journal Entry 0
1	Assess engineering preconceptions. Teach engineering design process Teach engineering design in the NGSS and the science and engineering practices.	Journal Entry 1 Focus group 1 Instructor notes 1
2	Participate in exemplar engineering lesson Collaboratively develop lesson plan	Journal Entry 2 Focus group 2 Instructor notes 2
3	Micro teach engineering lesson Receive feedback from instructor and peers	Journal Entry 3 Focus group 3 Instructor notes 3
4	Teach lesson plan in authentic classroom setting and receive instructor feedback teaching video	Journal Entry 4 Video Protocol
5	Class debrief on clinical teaching Create Journey Map	Journey Map Focus group 4 Journal Entry 5 Instructor notes 4

Data Analysis Plan

Each data source (journal entries, journey map, focus group transcriptions, teaching video recording) was collected and analyzed separately and converged for interpretation utilizing triangulation (Creswell & Plano Clark, 2018). Constant comparative method was used until a consensus was reached. A doctoral peer served as the external rater. Self-efficacy theory (Bandura, 1997) informed the researcher during the analysis phase when assessing the four *a priori* codes of confidence, motivation, expectation of success, and anxiety. The nomothetic and ideographic descriptions of confidence, the expectation of success, motivation, and anxiety are related to the sources of efficacy and have been used in research instruments to describe EDTSE (Carberry et al., 2010; Yoon Yoon et al., 2014). These four codes allowed for a deeper description of participant EDTSE at each time point. Figure 4 shows a progression of analysis to depict the data reduction strategies used to describe the engineering design unit elements' influence on EDTSE progression. The following is a description of the data analysis including discourse analysis, data organization, description of EDTSE by developmental stage, and *in-vivo* coding of the elements of the unit that facilitated sensemaking.

Figure 4

Qualitative Analysis Procedures

Discourse Analysis

Journal entries, focus group transcripts, and the journey map explanation transcripts were analyzed using discourse analysis (Marshall & Rossman, 2016).

Research by Marshall and Rossman suggests using existing theory and research to generate initial codes to analyze the language and communication of participants when theory has previously been established. Researchers recorded participants' confidence, anxiety, motivation, and expectation of success (Bandura, 1993) to teach engineering design at each time point. The second line of *a priori* codes was to identifying statements regarding elements of the unit that facilitated sensemaking. Last, statements from the data source and any statements that indicate changes in EDTSE were analyzed. Sensemaking elements and developmental changes identified during the discourse analysis were based on Vygotsky's (1978) developmental learning in the zone of proximal development descriptions. Using discourse analysis techniques described by Miles et al. (2014) two researchers used initial theory derived codes to independently code passages. Researchers then met to debrief and compare coding coming to an agreement on coding before moving to a second cycle of coding based on emergent themes and categories described under the interpretation of the research questions. The following is a list of the *a priori* codes used in the discourse analysis which were derived from previous research instruments assessing EDTSE (Carberry et al., 2010; Yoon Yoon et al., 2014).

- Confidence
- Motivation
- Expectation of success
- Anxiety
- Sensemaking elements of the unit
- Changes in EDTSE

Data Organization

Participant idiographic statements identified during the discourse analysis were organized using the time point grading protocol (see appendix A), with supporting evidence from the instructor's field notes. Holistic grading rubrics such as the time point grading protocol with *a priori* coding have been used in previous research (D. C. Davis et al., 2002; Plumb & Scott, 2002) and are useful when organizing predetermined codes (Borrego et al., 2009; D. C. Davis et al., 2002). Organizing participant statements by time point allowed for analysis and greater description of EDTSE by time points and provided a holistic approach to detecting changes in EDTSE over the engineering design unit. The nomothetic descriptions of EDTSE were first organized in the time point grading protocol, then a Word document chart was created to organize and display each participant's nomothetic confidence, motivation, expectation of success, and anxiety across six time points.

The video observation protocol (see Appendix B) organized instructor vs. student perceptions of EDTSE at time point five. The video observation protocol was designed to assist researchers in comparing and organizing instructor perception of EDTSE as demonstrated during the video recording with student descriptions in journal entry five. Identifying discrepancies in instructor perception vs. student reports of EDTSE following clinical teaching provided insight into possible teaching shock following authentic teaching experience and evidence of the stage of efficacy development. Returning the video observation protocol to the participant served two purposes: (1) member checking and (2) the instructor was enabled to act as a more knowledgeable other influencing participant learning in the zone of proximal development (Vygotsky, 1978).

Analyzing Research Questions

After researchers organized the discourse analysis into the time point grading protocols (see Appendix A) and video observation protocol (see Appendix B), the research questions were analyzed to guide the interpretation of the organized data.

1. How do preservice teachers describe their EDTSE at different time points of an engineering design unit?
2. Which elements of an engineering design unit facilitate preservice teachers EDSTE development?

Research question one (RQ1) focused on participant descriptions of EDTSE at time points and possible changes in descriptions that may have occurred over the engineering design unit. The data was interpreted using the “Preservice Teacher Efficacy Developmental Scale” (Putney & Broughton, 2010, p. 12). Efficacy was described as a three-stage developmental process progressing on a spectrum from onset, developing, to maturing (Putney & Broughton, 2010). Discourse analysis data organized into the time point grading protocols revealed rich descriptions in the participants’ own words of their onset, development, and maturing EDTSE development. The two projected time points (years 1 and 5) of the journey maps were used as a representation of maturity. Researchers used statements from the protocols to support identified stages in participant EDTSE. The Journey map’s visual data were analyzed to show individual changes over time (including future projections).

Nested within the qualitative ideographic data were nomothetic descriptions of the efficacy constructs over each time point. Researchers compared participant shifts at time points by reporting class means of participant confidence, motivation, the expectation of success, and anxiety. Class EDTSE means were evaluated and displayed in a Word document table to detect collective experience shifts at each time point. Nomothetic descriptions were analyzed both individually and as a class to facilitate pattern recognition of change in EDTSE over time (Marshall & Rossman, 2016). The individual confidence construct was isolated and displayed using a line graph. The line graph was instrumental in interpreting and describing the pattern of developmental progression in comparison to ideographic descriptions. Although efficacy was analyzed on a developmental continuum, it was necessary to allow for situational fluctuations (Goddard et al., 2004). Situational fluctuations were recognized as shifts or changes that can lead to progression on the efficacy progression spectrum with continued scaffolding and support.

Research question two (RQ2) focused on the elements of the engineering design unit that influenced participant sensemaking leading to the development of EDTSE. After the “Preservice Teacher Efficacy Developmental Scale” (Putney & Broughton, 2010, p. 12) was used to analyze participant stage of development, researchers used a hybrid approach to coding. A deviation from theory was needed when the developmental scale did not accurately describe the unique challenges of developing EDTSE. Therefore, *in-vivo* coding was used to identify elements of the revised theory for preservice educator EDTSE development and sensemaking elements of the unit (Marshall & Rossman, 2016). Using a hybrid approach (inductive and deductive) that allows researchers to use existing theory and emergent codes based on participant experience is beneficial to accurately portray overarching themes of the phenomenon (Fereday & Muir-Cochrane, 2006). Following this second cycle of coding, researchers met again to debrief and compare coding coming to agreement.

The tasks introduced at each time point were described by participants and the elements that contributed to their ability to accomplish and make sense of the tasks. Because the tasks themselves and the knowledge to accomplish them were given during the engineering design unit, both task requirement and knowledge are considered in the stages of development and as elements of the engineering design unit. Participant descriptions of social discourse leading to changes in EDTSE were analyzed as elements of the intervention because social reflexivity was an intentional element of the engineering design unit. Participant sensemaking of the engineering design unit was determined by the progression of participants on the “Preservice Teacher Efficacy Developmental Scale” (Putney & Broughton, 2010, p. 210). It was assumed that if a participant could progress on the spectrum, from onset to developing to maturing, the engineering design unit included elements facilitating participant sensemaking.

Using a Vygotkian lens during analysis assisted researchers in interpreting and describing EDTSE as a developmental process (change over time), interpreting the influence of social-cultural elements, and describing the sociocultural elements of an engineering design unit’s influence on participant sensemaking. The triangulation of ideographic descriptions of EDTSE from multiple sources at multiple time points during the engineering design unit were necessary to interpret efficacy development during an engineering design unit. The nomothetic descriptions provided a lens to interpret the fluctuations and wavelike features of EDTSE development.

Validity

Creswell (2013) views the closeness of the researcher to participants as a strength of qualitative research and enhances validity when a relationship of trustworthiness is established. In this qualitative research study, researchers sought to establish trustworthiness through credibility, transferability, confirmability, and dependability (Marshall & Rossman, 2016). The following is a description of the methods and procedures that were established. To establish trustworthiness, researchers employed the following strategies: describing participants, code-recode, member checking, and peer examination (Marshall & Rossman, 2016). Participant information was gathered and reported to assist in generating a general description of participant background and experience that support their views of EDTSE. It is assumed that participants with increased experiences with ED will initially report higher EDTSE (Carberry et al., 2010). Member checking occurs when the participants can view transcriptions and offer feedback or changes (Marshall & Rossman, 2016). Participants were emailed the video observation protocol and urged to comment on any changes they would like to make or additional insights they would like to add. Participants were also given their time point protocols, including evidence statements from journal entries, focus groups, and journey map transcripts. As part of a post-unit journal submission, participants were encouraged to make changes and provided feedback on the analysis of participant EDTSE analyzed on the two protocols.

The code-recode process occurred when the researcher identified themes in an initial analysis and then, after waiting a period of time, reanalyzed the data and determined if the initial coding still correctly represented the researchers' intents (Leydens et al., 2004). After completing the time point protocols, the researcher reanalyzed the data to see if important findings were not understood as confidence, motivation, anxiety, or expectation of success. This later holistic approach to interpretation allowed the researcher to include all noteworthy statements (Marshall & Rossman, 2016). Peer examination allowed for collaboration and consistency in coding and interpretation (Creswell, 2013). A doctoral peer simultaneously read through the transcripts and journal entries, and consensus occurred for both protocols.

Another important strategy is for the researcher to clarify and state any possible bias to establish confirmability. As stated in the personal connections section (see Chapter I), this researcher had little to no formal engineering experience in undergraduate work. All my engineering design experience occurred during a master's level course or from common sense and life skills. My bias was upheld when all eleven participants reported no formal training in engineering design. However, my bias was problematic when assuming engineering design connections could easily be made to common sense and life skills. Many participants who had been science-only trained had difficulty shifting their inquiry-based lens to include a problem-solving lens. The scenarios presented to the teachers for problem framing represented "everyday" experiences. It was assumed this was the area teachers would be most familiar with when not all were. To overcome any possible bias, a strict accounting of the steps and processes in the analysis was included in Chapter IV.

The credibility of this mixed-method research was increased through the triangulation of multiple data sources. The journal entries, focus groups, and field notes provided detailed insight at each time point. Journey map descriptions retrospectively covered all time points and estimated future projections of EDTSE, providing a holistic view. The video protocol provided another source to evaluate EDTSE from the instructor's view. All these data sources provided unique lenses on EDTSE development over time, and triangulation of the sources provides credibility.

To increase transferability, the researcher provided thick descriptions of the teachers' experience and attempted to convey feelings and impressions regarding that experience. One way this was accomplished was through the focus group's inclusion of dialogue and descriptions that revealed the thought processes and reasoning of the participants over time. Participant anxiety, motivation, confidence, and expectation of success were provided in the participants' own words.

Chapter Summary

A concurrent nested mixed method utilizing a QUAL + quant design was used to describe the development of EDTSE over the delivery of an engineering design unit. The development, delivery, and methods used to teach engineering design during the unit were aligned to the literature that supports professional learning and efficacy development of preservice educators. The multiple data sources collected at six time points during the study were also aligned to efficacy development and normative classroom procedures. Researchers triangulated data for an in-depth interpretation and description of participant EDTSE development. The interpretation and analysis included the stages of efficacy development and the elements of the unit that facilitated sensemaking of engineering design teaching tasks. Efficacy development and sensemaking analysis was guided by theory. The synthesis of the analysis presented in Chapter IV will present (1) a detailed description of the participants and their previous experience with engineering design; (2) a description of each time point of the engineering unit; (3) participant description of EDTSE over the engineering design unit; (4) the EDTSE developmental stages in relation to participant descriptions, and (5) the elements of the engineering design unit that influenced participant sensemaking.

CHAPTER IV

FINDINGS/ANALYSIS

The following is an introduction to the findings and analysis of the mixed method case study of an engineering design unit's influence on preservice educators' EDTSE during a Methods II course at a university in the western U.S. The engineering design unit provided opportunities for preservice educators to learn as a student (vicarious experience), micro-teach engineering design lessons while receiving receive peer feedback (social persuasion), and finally teach the lesson in their classroom (mastery experience) with the intent to increase participant confidence, motivation, and expectation of success through alignment to Bandura's (1993) four sources of self-efficacy (Bandura, 1997).

Because developmental learning envelops individual and group dimensions (Souza, 1995), efficacy development may not be linear or predictable (Putney & Broughton, 2011). EDTSE may develop wavelike with shifting highs and lows depending on the intervention stage (developmental event). Research supports efficacy development as wavelike instead of linear, developing over time and with experience, which can be described using the "Preservice Teacher Efficacy Developmental Scale" (Putney & Broughton, 2010, p. 12). Efficacy is described as a three-stage developmental process progressing on a spectrum from onset, developing, to maturing (Putney & Broughton, 2010). Preservice educators onset stage is characteristic of mentor teacher observations emphasizing mentor teacher actions. The developmental stage is evidenced by preservice teachers expanding their view of the mentor teacher to include the classroom community.

The preservice observer recognizes the mentor teachers' sociocultural classroom development while making a connection between the mentor teacher curriculum as a component of the class community. The shift to the maturing stage is evidenced by the preservice educators building confidence from actualizing their role as teachers in the classroom community (Putney & Broughton, 2010).

Although efficacy develops on a spectrum, situational fluctuations can occur (Goddard et al., 2004). Gaining insight into the social developmental process of EDTSE with situational fluctuations may help researchers understand why teachers often return to less effective methods after experiencing failure (Cheng & Brown, 2010) and avoid reformed teaching practices (Abrami et al., 2004). Thus, this study aimed to examine preservice educators' EDTSE developmental process through a highly socialized experience that includes personal and focus group reflection as well as mentor and peer reflective dialog. The investigation was situated in two sociocultural environments (methods course and clinical class). Putney and Broughton (2010) suggest preservice self-efficacy research should continue examining self-efficacy through a Vygotskian lens of development over time and should examine the role of sociocultural reflective dialog in the developmental process.

All eleven preservice educators in the science methods course participated in an engineering design unit and described their EDTSE at developmental stages. The engineering design unit was taught over several weeks and scaffolded the learning of engineering design separately and connected with state Science and Engineering Education (SEEd) standards. EDTSE was assessed prior to beginning the unit, and five additional time points corresponding to targeted methods of instruction were shown to increase teacher self-efficacy. A mixed method case study allowed for in-depth analysis and a rich description of EDTSE development over time and in relation to scaffolded engineering design experiences. Participants relayed self-reported nomothetic and ideographic descriptions of their confidence, anxiety, expectation of success, and motivation to teach engineering design, and each category aligns with Bandura's sources of efficacy and/or instruments used in previous EDTSE research. Researchers allowed participants to reflect, describe, and quantify current beliefs at specific points in time. The nomothetic descriptions were intended to display trends in participant and collective EDTSE and were not intended to assess the statistical significance of changing beliefs or to provide correlations between methods of instruction and EDTSE.

Using a Vygotskian lens allowed researchers to consider the social and cultural influences on self-efficacy and a more detailed account of EDTSE as a developmental process over time. Participants concurrently enrolled in a clinical science teaching course and taught self-created lesson plans that included engineering practices in authentic classrooms. These clinical classrooms have unique social-cultural environments created by mentor teachers, students, and school personnel. Participants interacted using social dialogue with mentor teachers and clinical classroom students, and each classroom's cultural parameters had differing ideas of an expectation of success. Although the researcher/instructor attempted to create a cultural environment within the methods course that fostered positivity and open discourse, it must be acknowledged that participants were navigating between social-cultural spaces. The purpose of the mixed method case study was to include detailed accounts of the development of EDTSE over an engineering unit and to establish elements (including sociocultural) that influence participant sensemaking leading to changes in EDTSE. Describing EDTSE is an important step in furthering research to help teachers feel well-prepared to teach engineering, leading to reformed science teaching practices, increased student engagement, and engineering literacy.

The case report will present: (1) A detailed description of the participants and their previous experience with engineering design; (2) A description of each time point of the engineering unit; (3) The EDTSE developmental stages in relation to participant descriptions; (4) Participant description of EDTSE over the engineering design unit; and (5) The elements of the engineering design unit that influenced participant sensemaking.

Analysis

The following is a description of the intervention by time point, the stage of development, and the elements of the engineering design unit that facilitated the sensemaking of engineering design during a methods course in light of the lack of mentorship during clinical coursework. Participants reported their EDTSE as measures of confidence, motivation, the expectation of success, and anxiety to teach engineering design on a Likert-like scale of 0 (none) to 5 (very high). Participants were free to respond numerically, and several used (.5) to indicate marginal differences. The numerical representation was useful for detecting trends that indicate shifts in EDTSE across time. Participants were also invited to add an idiographic description of their general EDTSE. This established a base for understanding how preservice educators with a little introduction to engineering but much instruction on three-dimensional methods of instruction and the state standards perceived their EDTSE. This is unique to preservice educators and distinct from current science teachers who may have little exposure or knowledge of three-dimensional methods and SEEd standards but express high teaching self-efficacy. However, both groups may represent individuals with little engineering design knowledge and experience.

The following is a description of participant responses first as a written description, then a numeric ranking. The presentation of the analysis of the case at each time point will provide purposefully selected statements exemplifying participant “at the moment” descriptions of EDTSE and the stage of efficacy development based on participant descriptions and existing theory. The participant-provided numeric rankings are given as a side-by-side comparison to show the variance in individual responses. Thus, all participant’s nomothetic rankings will be provided at each time point. Purposefully selected participants serving as exemplars of participants who attained differing stages of EDTSE development over the unit will be provided in addition to their confidence line graphs, journey maps, and confidence statements in conjunction with an analysis of EDTSE over time.

Time Point Zero

Below is a description of the participants and their engineering design (ED) experience at time point zero (see Table 4). Displaying individual statements shows the variance in what the participants constituted engineering design prior to beginning the ED

Table 4

Engineering Experience by Participant

Name	Engineering design experience
Jana	I have had some engineering design experiences in some of my physics labs prior to this course. The experience I do have, though, is very limited, and I am not 100% sure that it is a complete engineering design experience.
Mike	I have had some really excellent teachers in middle and high school that used engineering design a lot in their classes. My Middle school science teacher especially used engineering design principles from everything to building the best planter box to rockets to transmitting radio over lasers.
Eric	I have had a few prior experiences, including past employment, that have helped me look at the world through an engineering lens. I have worked in a few different machine shops, which allows you to think through a problem like an engineer.
Malia	I have four uncles that are engineers, and I took an engineering class in high school (~6 years ago), and I remember not liking it.
Nora	I have had no engineering design experience, and if I did, then I do not know what it was. I have been a part of many labs in college, but it was always like following a recipe guide. There was nothing that had to do with me as a student designing a lab to make solutions to a problem.
Alex	Prior to this course, I have only had a few, I believe. These were in the form of modeling, and they were in my health class. We had to model what would happen to the body based on a stimulant we received, and we had to decide on one medical treatment after evaluating multiple for another assignment. I have made models in some other science classes as well.
Emily	I have had pretty much no engineering design experience which makes me lack motivation and confidence in teaching it. I had an engineering-based class in 6th grade that was really fun and we built bridges and rockets, but the why behind the designs I didn't do. It was because they were aesthetically pleasing and not scientifically accurate.
Isabelle	I think that I have very little experience with this. I don't even fully remember the last time I was taught this way either.
Tim	I have had very little engineering experience prior to this course. The closest thing I can think of is in 7th or 8th grade, I had a CTE course where we had to make a bridge on a dinky little software program that could withstand a certain amount of force.
Chris	While I remember some solution designing in middle school science, I think the bulk of it would be doing theatre for six years. There was a lot of set, lighting, prop, and costume design that required constructing solutions to meet the desired end result.
Scott	I was in my school's robotics club for a couple of years, 8-9th grade, I think. I've also had plenty of experience fixing things at various jobs and around the house. Not a big focus on design there, but plenty of trial and error.

unit. The open-ended question asked participants to discuss any ED experiences they had experienced prior to the methods course and did not mention “in school.” Notably, two participants could not recall any formal or informal ED experiences. Although they may have applied ED to formal learning contexts only, it still speaks to the need to instill learners with engineering literacy to increase awareness of ED in formal and informal problem-solving contexts.

Experiences with ED varied from K-12 classroom experience, modeling, and drama set design, to fixing things. It is interesting that five participants listed experiences in middle school. After further probing, it was determined that the rocket and bridge building mentioned by several participants occurred in a required middle-school career and technical experience (CTE) course, as stated by Tim.

Participants were asked to report and comment on engineering design experiences during their clinical semesters. At the time of questioning, they had completed Clinical Course I and were several weeks into Clinical Course II. In the clinical course, participants were encouraged to have discussions with their mentor teachers about the standards taught and the scope and sequence of the curriculum so they could coordinate the teaching of an engineering design lesson not accounted for in the regular curriculum. Participants also made observations of mentor teacher methods of instruction and curriculum ties. Discussions with the participants during focus groups revealed that six of the eleven participants were in classrooms where the curriculum was based on SEEd standards. As perceived by the participants, five teachers serving as mentor teachers were not teaching curricula based on state standards. With further probing, only three participants reported explicit use of three-dimensional science instruction by the mentor teacher. Jana mentioned that her current mentor drastically differed from the clinical class she was assigned in the first semester. “This teacher has posters of the science and engineering practices (SEPs) and crosscutting concepts (CCCs) around the classroom and refers to them with her students. It is probably because she is a middle-school teacher. She is awesome!” Another participant added that although his mentor does use CCCs for sensemaking, he isn’t explicit with them or the SEPs. This suggests that participants were in varied social-cultural environments that had the potential to influence participant EDTSE.

When discussing engineering design with mentor teachers, once again, only Jana’s mentor had ever taught a lesson addressing standards that use engineering design practices during either semester’s clinical courses. Only 9.1% of mentors were potentially modeling engineering design for preservice educators. This statistic is not intended to generalize secondary science at large. Still, it does provide a glimpse into the realities of preparatory programs fostering new generations of teachers to use three-dimensional science and engineering instruction, specifically engineering design, without mentorship and modeling during clinicals. Emily explained, “It is something I didn’t experience as a student and haven’t seen implemented in science classrooms that I have observed.” Tim added, “I didn’t have any engineering courses in high school and don’t have any now in college. I also haven’t seen these lessons taught in a high school classroom, so I don’t know how students will respond to them.” These statements typify the lack of engineering design experience during K-12 and clinical class observations.

In summary, it is likely that preservice educators will not see engineering design lessons modeled during their clinical course and may not have previous experience during formal K-12 schooling and undergraduate university coursework. Without the engineering design unit in the methods course, only one preservice educator out of the eleven enrolled would have participated in a modeled engineering design unit during the clinical course. Preservice educators will likely not participate in modeling engineering design standards during their clinical experiences. Because modeling (vicarious experience) mediates EDTSE, preservice educators do not appear to be developing EDTSE through clinical class observations. As described by Putney and Broughton (2010), the onset stage of efficacy development suggests that preservice educators' efficacy initiates by observing the mentor teacher's methods and actions. In the case of EDTSE, preservice educators are most likely not observing the teaching of engineering design, and thus, the onset stage of development may be delayed or lack initiation unless intentionally added to methods courses.

At time point zero, participants had been introduced to the science and engineering practices and had read the *Framework* and state standards documents. Although they were familiar with engineering practices as a component of the *Framework* and the SEEd standards, they were unfamiliar with how engineering design related to their content state standards.

Before the engineering design unit, preservice educators represented individuals with low EDTSE. Participants reported low EDTSE as a lack of experience in engineering design (K-12 and university coursework) and a lack of modeling by mentor teachers during their clinical class. The lack of experience, modeling of engineering design, and a general lack of awareness of engineering design in the standards are characteristic of preservice educators in the onset stage of the EDTSE continuum.

Prior to beginning the unit and assignment to a stage of EDTSE development, participants shared the beliefs of their confidence, motivation, expectation of successful teaching, and anxiety to teach engineering design, providing greater insight into the rationale for their low EDTSE and onset stage of development. Jana and Isabelle reported a two for confidence and explained that before having knowledge or experience, they could not justify much confidence. Jana stated, “I ranked myself low for confidence because, at the moment, I feel like I don’t have enough knowledge and experience to teach engineering design very well. Isabelle added, “My confidence is really low because I don’t have very much experience with this principle, so I lack the confidence needed to be able to feel like I can do it.” These statements by Jana and Isabelle are evidence of how a lack of experience and knowledge of engineering design is related to low confidence in teaching engineering design.

Isabelle expressed initial indifference in motivation until her expectation of success could increase. “I want to do this, but I don’t know how well I can do it yet, so I feel indifferent about it.” Isabelle’s indifference toward engineering design was characteristic of her lack of experience. She had no gage to determine how successful she could be because teaching engineering design had never been modeled for her.

Emily is representative of preservice teachers who are unaware of engineering design as an aspect of science teaching. This is especially true of non-physics content areas. Emily explained, "I didn't even know incorporating engineering practices into biology courses was a thing before the methods course… I definitely have to research more examples of engineering designs in biology classrooms." Emily's statement not only suggests a lack of awareness of engineering design as an aspect of science teaching but also adds interesting insight into the lack of awareness of how engineering design relates to science content (biology). The lack of awareness of engineering design can create anxiety when preservice teachers believe reforming teaching practices without experience is a burden. Chris typified this when he stated,

> I've gotten anxious about every aspect that goes into education. It feels overwhelming to meet the standards of ambitious science teaching, creating equitable classrooms, IEPs, etc., and every time I learn of something new to include such as engineering practices, it's kind of like running up a hill with someone putting more and more rocks into your backpack.

Chris's statement suggests that when preservice educators learn that engineering design is included in the standards, anxiety may result from their belief, leading to decreased EDTSE. Learning of the expectation without experience may result in believing that engineering design is just another reform. The expectation to include engineering design as an unexpected addition left participants feeling additional anxiety in addition to general teaching anxiety. When explaining her high anxiety ranking, Malia noted that she was associating teaching engineering design with her high school engineering class. "I link engineering with my past experiences with engineering classes, and I didn't like them very much." Prior experiences with high school engineering informed Malia's low efficacy. Malia's statement also supports Sociocultural Learning Theory's description of past experiences informing current belief systems.

In summary, preservice educators seem to report low efficacy prior to beginning an engineering design unit based on their lack of experience and engineering design knowledge. Low efficacy was described as low confidence, motivation, expectation of success, and higher anxiety. Due to the general unawareness of engineering design as an aspect of science teaching, preservice science educators begin methods courses in the onset stage of the EDTSE continuum. A lack of knowledge, experience, awareness, indifference, and anxiety characterizes this onset stage of development. This deviates from the "Preservice Teacher Efficacy Developmental Scale" (Putney & Broughton, 2010, p. 12). Efficacy is described as a three-stage developmental process progressing on a spectrum from onset, developing, to maturing (Putney & Broughton, 2010). Preservice educators onset stage is characteristic of mentor teacher observations emphasizing mentor teacher actions. Because participants could not observe mentor teachers teaching engineering design, the onset stage of development is modified to describe a lack of observation, awareness, and experience. It also led to a revision of the entire model to better describe the unique challenges of science teachers developing a belief system of engineering design outside the traditional clinical/practicum observation model.

When journaling at time point zero (preassessment), participants used quantitative ratings (0 = none to 5 = a lot) to support their confidence, motivation, the expectation of successful teaching, and anxiety to teach engineering design, providing greater insight into the rationale for EDTSE at this time point (see Table 5). The participant-provided numeric rankings are given as a side-by-side comparison to show the variance in individual responses. The group means are calculated for later analysis of collective

Table 5

Self-Reported EDTSE at Time Point 0

Name	J	M	E	Ma	N	A	E	I	T	S	C	Mean
Confidence	2	3	3	3	1	3	3	2	2	3	2.5	2.5
Motivation	5	4	5	3	5	5	2	3	4	4	4	4
Expectation of success	4	3	4	4	4	3	4	3	3	4	3.5	3.6
Anxiety	5	1	3	4	5	2	4	5	3	4	5	3.7

experience and group shifts in EDTSE. The nomothetic descriptions of EDTSE before beginning the unit revealed a pattern supporting the ideographic statements. Confidence is the lowest mean of the efficacy constructs, and anxiety is the highest. This is an expected result because confidence and anxiety are often inversely related. The unexpected result is that motivation is listed high (4) when the ideographic statements suggest that participants were not as motivated to teach engineering design until they had more experience with engineering design. The high motivation may suggest that teachers believe that engineering design benefits students. Jana noted that engineering design in science could potentially impact student engineering literacy.

> I believe there is a very good reason that the NGSS and the Utah Core have been included in the engineering practices as part of the curriculum. I think that teaching these engineering practices will give students good skills to have in their future academic careers.

It is an important finding that even though preservice teachers may lack experience and understanding of engineering design, they still recognize the importance of engineering literacy for students.

Engineering Design Unit

As part of a science teaching methods course, an engineering design unit served as the case under study intending to increase preservice educator EDTSE. The development and delivery of the engineering design unit was aligned with the literature for methods of instruction that best support preservice teacher EDTSE. The unit further aligned to the theoretical framework, including self-efficacy and the frameworks for professional learning. Bandura's four sources of efficacy and outcome expectancy were considered from a Vygotskian sociocultural lens of development. The engineering design unit introduced scaffolded tasks at each time point that required sensemaking. Participant sensemaking of each task facilitated perceptions of competence that informed EDTSE at each time point.

Time Point one

Time point one represents the beginning of the ED unit. The class session began with a focus group discussion of EDTSE after having read through the SEEd standards to identify, by content area, standards that highlight engineering practices. Participants were directed to specifically look for standards that include the language of "design a solution" or "compare design solutions." Participants then read the *Framework's* description of the "defining problems" and "designing solutions" SEP. When participants came to class, they were familiar with the language of their content standards and the ED specific SEPs. The in-class engineering unit began with the opportunity for preservice educators to assess their current understanding of engineering design and the teaching of the EDP in contrast to scientific inquiry. Experiential learning was used to teach an example of designing a windmill aligned to the "design a solution" standard in the physics and Earth and space content standards.

Initial introduction to engineering design and the resulting change of beliefs is described as the developing stage of EDTSE development. The developing stage EDTSE was influenced by awareness of misconceptions, observation of engineering design, increased engineering design knowledge, and a projection of mentor and student reaction to engineering design curriculum. Participants were given the task to identify engineering design problems by content area. Participant beliefs of their ability to complete the task influenced their EDTSE. Task competancy was influenced by pedagogical knowledge developed during experiential learning. Participants described their EDTSE as increased confidence and motivation, and a decrease in anxiety.

Confidence

Participants commented on their confidence after the introduction to the EDP. Participant comments suggest prior misconceptions of engineering design affected their confidence. Eric explained how he had overthought the expectation of being a teacher of engineering, but knowledge about ED had helped to understand the intent of ED in the standards.

> After our discussion in class, I feel like I might have been overthinking what it means to teach engineering design. Especially with physics, I feel like it is a natural extension of the subject. Once a student learns how something works, they will be able to use that knowledge as they think with an engineering mindset. After I had an experience with learning engineering design, I now feel much more confident teaching that to my future students.

Tim discussed how his confidence was affected by his misconception and misunderstanding of the intent of the standards.

> I feel more confident having seen a demonstration of what an engineering lesson looks like. We can provide very clear criteria for what we want our students to do. For example, as I was brainstorming about how to teach BIO.1.5, I felt overwhelmed because I interpreted the standard as wanting students to each pick their own problem to design a solution to. While that is possible, and maybe a good way to approach the topic, it doesn't have to be that way. I could pick a problem for the students to design a solution to, and lead everything in a very focused direction while still allowing for student flexibility in solving the given problem.

The above statements highlight the need to address participant perceived misconceptions of engineering design separately and in connection with the expectation and language of the standards in their content area.

During session one, the only content-specific standards modeled for students were physics coupled with Earth and space science. Several participants commented that their confidence was directly tied to having lessons plans modeled on their specific content area. They mentioned the need to distinguish lessons emphasizing the SEP to "design a solution" compared to "evaluate design solutions." Nora stated. "It will probably go up (confidence) when I can comprehend engineering practices specifically for chemistry." Alex supported this statement by adding, "I think that this number will go up after next class when there is a biology example of engineering. I still do not have experience with it specifically in my area which is why I am a 3 still."

Emily suggested her confidence was hinging on experience with engineering standards that ask students to "evaluate design solution." This SEP details students considering existing design solutions and arguing for which design is best under constraints. Students use evidence collected during lessons that support their argument. Students are not necessarily designing anything but may create models or research existing solutions to gather evidence to support their argument. Emily commented on this by stating, “My confidence has stayed the same score because I still don’t have that experience, especially for the biology standards which is more analysis based. I think I will gain more confidence when I have more experience.” Chris, like many participants recognized that although knowledge about the EDP does increase confidence, it is experience over time that is strongly tied to confidence. Chris expounded, “I think that seeing it in action has lifted my confidence a bit. However, it still feels intimidating thinking of doing it myself.” Jana presented an interesting position when she described how her confidence was tied to her inability to switch from thinking like a scientist and using inquiry for much of her life to include a new way of seeing and thinking about the world, such as problem framing using ED.

> I still don’t feel fully confident. I know what an engineering design looks like and I think I could create one. My confidence lacks in the fact that my brain really does not think like an engineer, so it is really hard for me to make that switch and then teach a lesson like that.

In summary, confidence at time point one was described by participants in journal entry one as being tied to their conceptions of ED, experiential learning within content, prolonged experience, and a needed change in perspective. Understanding that preservice teachers confidence is tied to content area is a new and important finding for curriculum developers. Engineering design professional development is often tied to physics (electrical, structural, movement). This exposes a gap for non-physics majors ability to progress on the efficacy continuum with modeling within content area due to the siloing of contents in secondary science (9-12). Unlike elementary educators, secondary science educators often have extensive backgrounds in science. Therefore, preservice teachers may need more practice viewing the design world through a non-inquiry lens to build confidence in problem framing as an aspect of teaching engineering design. Problem framing by content area was the task assigned at time point one. Participants perceptions of their ability to complete the task shifted their confidence and motivation resulting in a developmental stage change.

Motivation

Participants described their motivation at time point one and described how learning about the EDP and their ability to problem frame were valuable to them personally. Participants recognized that including SEPs from an engineering lens also benefited students. Participants motivation at time point one was tied to the benefits to students (engagement, increased application of science content, increase student skill), sharing with faculty, and conceptual understanding through social discourse. Tim suggested,

> Having seen how engaging designing a solution to a problem is, I really want to lead an engineering lesson. I think it will engage students in ways that non-engineering lessons simply can't. I think it is a good way to reach students who may otherwise not be interested in biology.

Malia thought it was important for students to be able to differentiate between scientists and engineers.

> My motivation is a 5 because I think that it's very important for our students to be able to distinguish the differences between engineers and scientist. I think it's a great way for our students to learn different science content areas through engineering.

Although Jana recognized engineering as a beneficial skill for her students, it was interesting that her confidence was also tied to her ability to affect change with other teachers.

> I think that teaching the engineering design really opens up and new realm of skills that our students can learn and apply to their lives. I also want to learn how to create good lessons so that I can share that with other teachers one day when I start teaching.

Emily suggested that her confidence was tied to the focus group's discussion and her need for social discourse leading to conceptual deconstruction of engineering design in the standards.

> I am way more motivated to teach SEPs now that we have all talked about our fears with it and I feel like I needed to deconstruct what engineering looked like in my mind to be able to be more motivated to teach these SEPs.

In summary of participant motivation at time point one, participants motivation was tied to the benefits to students (engagement, increased application of science content, increase student skill), sharing with faculty, and conceptual understanding through social discourse. It is important to note that science educators express increased motivation to teach engineering design if student benefits include increased student engagement and application of science disciplinary core ideas (DCIs). Therefore, if engineering design increases science understanding, then science educators are more motivated. To increase participant motivation, based on the evidence, professional developers may need to consider an in-depth consideration of the DCIs needed to identify problems, consider constraints, design solutions, and evaluate or argue for design solutions. Additionally, to increase EDTSE participants experiential learning of EDTSE allowed them to apply science content, experience increased engagement, and predict student engineering design skill.

A shift in confidence and motivation resulting from a belief in participant ability to problem frame within content area resulted in a shift from the onset to the development stage of EDTSE. The developmental stage is characteristic of preservice teachers expanding their view from mentor to mentor/student interactions and an emphasis and the sociocultural environment. It was expected that an increase in confidence and a decrease in anxiety would result from increased engineering design understanding and experiential learning with a focus on student engagement and application of science content knowledge.

Group Change

Group changes from time point zero to time point one were analyzed by comparison of group means. The nomothetic descriptions align and support the ideographic statements. It is important to note that although there were individual differences, the evaluation of group mean differences allows for a macro view of EDTSE at time point one. The participant reports of EDTSE (see Table 6) were highly individualized, however an evaluation of group means (see Table 7) supported the changes described by participants and a shift to the developing EDTSE stage. Confidence and motivation increased while anxiety decreased supporting the need for preservice educator knowledge and experience with engineering design by content area. The expectation of success remained the same suggesting that mastery of experience or actual teaching experience is needed for participants to gage their ability to successfully teach engineering design.

Table 6

Self-Reported EDTSE Time at Point 1

Name	J	M	E	Ma	N	A	E	I	T	S	C	Mean
Confidence	4	3	4	4	1	3	3	2	4	4	3	3.2
Motivation	5	4	5	5	5	5	4.5	4	5	4	5	4.7
Expectation of success	4	3	4	4	4	3	5	2	3	4	4	3.6
Anxiety	4	1	2	3	4	4	3	5	3	4	5	3.4

Table 7

Changes in EDTSE at Time 1

EDTSE	Mean time 1	Mean Time 0	Difference	Group change trends
Confidence	3.2	2.5	+.7	increased
Motivation	4.7	4.0	+.7	increased
Expectation of success	3.6	3.6	0	no change
Anxiety	3.4	3.7	-.3	decrease

Time Point Two

At time point two participants began the weekly session with a focus group. They discussed the elements that were influencing their EDTSE after reflecting and thinking about the previous week's lesson and assignment. Participants were assigned homework to pick one standard that would be taught during their clinical class that could integrate ED. Most participants picked a “design solution” or “evaluate solution” inclusive standard. A few participants described how the current scope and sequence in the middle school classrooms did not have an ED specific standard during their time in clinicals and so they would then focus on engineering design aspects of the “modeling” SEP. Participants were encouraged to “brainstorm” possible ideas for lessons and search for existing online lessons that could be modified to include engineering design and content

DCIs. When participants shared ideas during the focus group, they came from an understanding that they needed to develop a lesson that would be taught during clinicals. Participants were taught and given the ITEEA 6E Learning byDesign model developed by Burke (2014), to guide the development of their ED lesson. During the class session, participants engaged in experiential learning of engineering design lessons aligned to "evaluate design solutions" standards in chemistry and biology content areas.

Time point two is described as the developing stage of EDTSE. The stage of development did not change from time point two. This was evidenced by the nomothetic and ideographic descriptions at time point two remaining fairly constant with the examples at time point one. Although EDTSE was highly individualized by the beliefs of the individual to create a lesson plan, motivation to teach engineering design remained high. Participant beliefs of their ability to successfully accomplish writing an engineering design lesson influenced their EDTSE, but a continued participant emphasis on teacher/student sociocultural classroom without actual teaching experience suggests a continuance in the developmental stage.

Confidence

Confidence at time point two varied by participant. Nora described how her confidence increased after seeing an "evaluate design solutions" would look in her content area. "After seeing how an engineering lesson is done in chemistry, I am more confident, but it does still seem a harder task than making regular lesson plans." Alex described a decrease in confidence after her content was modeled. She felt that her lesson plan did not measure up to the model. Alex shared, "I feel a little less confident because I feel that my ideas were not aligning with how a biology lesson could actually be done." Alex suggests that vicarious experience and social comparison negatively influenced her confidence. Tim offered a third perspective and suggested his confidence wavered due to the added hurdle of teaching outside his content area. Tim is a biology major teaching 7th grade science that includes Earth science content standards. This predicament exists in science education when content specific trained teachers are employed to teach integrated middle level science.

> My confidence wavers back and forth when thinking about teaching an engineering lesson. I felt pretty confident after our class on Monday, but not so much now. My clinical is in 7th grade science, and I will have to teach an engineering lesson about Earth science, which isn't my forte. My mentor teacher really wants me to incorporate engineering into an existing lab that they have, but I don't feel it can be done smoothly, so that has my confidence down a bit.

Tim's experience contrasts with Jana who is majoring in physics and teaching physics in her clinical. Jana suggested that creating and teaching ED as part of physics content was easy. "The physics standards are pretty easy to find engineering problems for the lesson plans. I feel pretty good about coming up with ideas." Confidence at time point three was highly individualized with examples of increases and decreases. The task to create a lesson plan was responsible for participant confidence and could be content specific with physics representing more ease of application and lesson planning.

Motivation

By time point two, participants comments on their motivation to teach ED were focused on student benefits and had not changed much from the previous week. Once participants learned about ED and participated in experiential learning, their motivation remained high. Motivation remained high even though they described changes in other areas of their EDTSE. Alex described why her motivation remained the same, “I still think the engineering design is a great component of the standards and is extremely beneficial to students which makes me motivated to teach these lessons.” Sam reiterated,

> My motivation is still a 5 because I think that it’s very important for our students to be able to distinguish the differences between engineers and scientist. I think it’s a great way for our students to learn different science content areas through engineering.

Expectation of Success

Participants described their ES using optimistic terms. Mike described the use of the state core guides in building lesson plans as an element that influences EDTSE. Core guides are state documents that assist educators in developing curriculum based on state standards. They act as bridging tools between standards and class curriculum. Teachers in the methods course had previous experience with using and interpreting the core guides as a tool. Mike explained, **“**I think that my expectation of success is high, …I think the examples and tools, we have, especially the core guide makes me feel it will be successful.” Emily described her optimisms after she practiced her lesson with her family. Her family provided a safe space to practice her lesson and to receive feedback. Emily’s social communications influenced her co-constructed EDTSE. Emily explained the influence her family had.

> I taught this to my family, and it went well. I have a lot to reflect on and improve upon, but this also helps me understand that even though it doesn’t go perfectly it will be okay and the point will get across. I can always make improvements.

Participants used positive terms to describe their expectation of success like “work out” and “be okay” to describe their EDTSE over time.

Anxiety

Once again anxiety was highly individualized with some participants experiencing decreases in anxiety and other’s experiencing increases. Participant anxiety shifted to focus on the task of lesson planning. Nora described her decreasing anxiety related to lesson planning, “I am not as anxious now that I understand the concept of engineering lessons better.” While in contrast, Alex shared why her anxiety had increased due to lesson planning,

> Trying to create my lesson plan that I will be teaching took me hours to even find a lesson, let alone making a lesson plan around it. I want to make sure that all of my lessons have meaning, are beneficial and that the students are enjoying the learning process... maybe I am overthinking them which is causing the anxiety.

The same stage of the intervention could impact participants anxiety differently. Lesson planning is one such task that can have individualized effects but was necessary to scaffold pedagogical skill.

In summary, participants described their EDTSE at time point two by their ability to accomplish the task or lesson plan. All participants remained in the developing stage marked by their continued emphasis on modeling and lesson plan creation beliefs. Confidence and anxiety were individualized with examples of increases and decreases. Confidence can be content specific with physics representing more ease of application and lesson planning. At this stage, participants had no gage to consider their ability to successfully teach engineering design outside of having a prepared lesson plan. Without teaching experience, participants remain in the developmental stage. Participants used positive terms to describe their expectation of success as an iterative process over time. Once participants learned about ED and participated in experiential learning, their motivation remained high and focused on student benefits.

Group Changes

Participant reports of EDTSE (see Table 8) remained highly individualized, which supports the findings of the statements. Slight shifts occurred in group trends (see Table 9) in reported confidence, motivation, and ES. No group shifts occurred for anxiety. The reported shifts all resulted in decreases; however, supporting nomothetic ranking suggest that the stage of EDTSE remained developmental due to the incremental group mean

Table 8

Self-Reported EDTSE at Time Point 2

Name	J	M	E	Ma	N	A	E	I	T	S	C	Mean
Confidence	4	4	4	3	2	2	2	3	2	4	4	3.1
Motivation	5	5	5	5	5	5	4	3	4	4	5	4.5
Expectation of success	3	4	4	4	3	3	5	3	2	4	4	3.5
Anxiety	3	0	2	4	3	5	3	5	2	3	5	3.4

Table 9

Changes in EDTSE at Time 2

EDTSE	Mean time 2	Mean Time 1	Difference	Group change trend
Confidence	3.1	3.2	-.1	decrease
Motivation	4.5	4.7	-.2	decreased
Expectation of success	3.5	3.6	-.1	decrease
Anxiety	3.4	3.4	0	no change

differences. For example, the overall group mean difference for confidence was only a marginal difference of .1 suggesting very little overall change.

Time Point Three

Time point three began with a focus group where participants discussed the effects of finalizing their lessons that they would later micro-teach to their peers during class and receive feedback. Participants presented their lesson plan to the class, then broke into content areas to teach and receive feedback from the instructor and peers. The class environment had previously been established to be a safe place of giving and receiving feedback with the end goal of improving participant instruction.

Time point three is characteristic of the emerging stage of EDTSE progression. The characteristics of the emerging stage are described by beliefs in their ability to teach developed curriculum that meets the expectation of the standards. The task introduced at time point three was to teach and receive feedback from peers. The emerging stage is a change to the existing model of preservice efficacy development, which was previously called maturing. The emerging stage of development placed an increased emphasis on developing teacher practice. Microteaching presented opportunities to both teach and participate in content lessons from their peers. The mix of mastery experience (teach), vicarious experiences (participation), and social persuasion (peer feedback) was a beneficial transition to the emerging stage of development.

As in previous time points, the task preceded a shift in participant beliefs. Participants gaged their confidence, motivation, expectation of success, and anxiety by their belief in their ability to teach their lesson plan to peers. The task was scaffolded, building upon the creation of a lesson plan. Participant reports of teaching ability were often based on social comparisons to modeled lessons and lesson plan writing abilities. The following descriptions are a selection of participant beliefs and the shifts that occurred from microteaching.

Confidence

Participants described their confidence after micro-teaching their lesson to peers while giving and receiving feedback in their content area. The social activity affected participants by either increasing or decreasing their confidence. Only one participant reported a decrease in confidence with all others staying the same or increasing. Alex described her increase in confidence and her future projection on her confidence after teaching her lesson in her clinical class in the following way.

> I think last class helped a lot. I am teaching this Thursday and I think that will either increase or decrease this number.… I am better at understanding how to teach this more and more after each class.

Tim shared that his confidence had improved from the prior week now that he had practiced teaching his lesson. “I’m feeling better than last week about how to approach my specific engineering lesson for my clinical, which has me feeling more confident overall about engineering teaching in general.” In contrast, Jana suggested that her confidence had decreased after sharing her lesson and feeling that her peers were better than her own. She described the need to change her lesson to comply with the wording and intent of the middle school physics standards.

> I think my confidence actually went down because hearing all my peers’ lessons plans, they all seemed much more put together and better than my lesson plan... I’m having a hard time with making the lesson out of context of the entire

standard and planned way too much in my one lesson.

In summary, the micro-teaching lesson provided participants with a controlled teaching opportunity (mastery experience). The social experience influenced participant confidence. Although most participants reported an increase in confidence resulting from teaching experience, for some the social comparison to peers can decrease confidence.

Motivation

The motivation to teach ED remained high at time point three. Participants reiterated their continued motivation to successfully implement ED leading to increases in student engagement and engineering literacy. One participant reported a decrease in motivation while two others reported an increase and eight remained the same. Jana shared, “I’m still really motivated to create a successful lesson plan and to feel confident about it.” And Isabelle explained how receiving positive peer feedback increased her confidence ultimately increasing her confidence. Her comment reflects the integrated nature of confidence, motivation, expectation of success, and anxiety on EDTSE. When commenting on why her EDTSE had increased, Isabelle shared, “collaboration with others in the class and learning more about how to write this lesson plan! My motivation has grown since I feel more confident.” Although Eric’s confidence remained high (5), he stated that micro-teaching helped him shape his motivation by understanding the student effects. “Practicing helped me see how informative a good engineering lesson could be for students.”

Expectation of Success

Micro-teaching to peers was the first opportunity for participants to receive feedback on their ability to successfully teach engineering design. All participants either reported an increase in their expectation of success, or it remained the same as the previous session. There were no reported decreases in expectation of success. Emily explained why her expectation of success, remained high (5), “I can already see my improvement in mimicking” and “I know I can teach this.” Chris shared why his expectation of success, had increased (.5),” I think that looking more at the storylines online as well as looking at some of the instructors Earth science lesson plans will give me a better floor to work off of so I’m still hopeful of succeeding.” These statements are evidence of the need to provide opportunities within methods courses (such as micro-teaching) to provide opportunities for preservice educators to feel successful leading to increases in EDTSE.

Anxiety

Reflecting on their microteaching experience, two participants reported increased anxiety and four participants reported decreased anxiety. Five participants reported no change in anxiety. Alex explained why her anxiety had decreased at this stage of the ED unit.

> I think I need more experience not just teaching engineering but creating lessons because I have a very hard time figuring out what to do for the engineering standards and how to make the lessons maximize their full potential for the students.

Alex described her need for continued experience in lesson planning, specifically engineering for biology standards. Eric, as a physics teacher, stated his anxiety decreased because, “physics is so closely related to engineering, and last week I was able to see how any lesson could be connected to engineering pretty easily.” Jana, also a physics teacher, noted many lesson plans ideas, but suggested her “anxiety is still high because I am still having confidence issues.” Tim, a biology major teaching Earth science, stated why his anxiety had increased, “My anxiety is actually a little higher right now about my engineering lesson than for normal science lessons. I think it’s because I have the least experience with teaching engineering so far.” All the above statements display the relationship between experience and anxiety. Those participants that had the most anxiety also felt they had the least experience with engineering design lesson planning.

In summary of time point three descriptions, participants described the emerging stage of EDTSE progression as an increased emphasis on teaching experience. The scaffolded teaching experience allowed participants to assess their expectation of success and transition from vicarious experience to mastery experiences. The task to microteach a lesson plan preceded a change in beliefs. Although changes were highly individualized with some participants reporting increases and others decreases, all participants transitioned to an emerging stage of EDTSE after microteaching a developed lesson plan. Understanding the transition from developing to the emerging stage is an important finding for professional developers. It speaks to the need to provide scaffolded pedagogical tasks that lead to mastery experiences. If preservice teachers are only provided with experiential learning of modeled lessons, they will only progress to the developing stage.

Group Change

Group changes from time point two to time point three were analyzed by comparison of individual nomothetic descriptions (see Table 10) and group means (see Table 11). The following is a discussion of the collective trends that occurred over time. It is important to note that although there were individual differences, the evaluation of group mean differences allowed for a macro view of EDTSE at time point three. Session three group means support an increase in confidence and expectation of success, and a corresponding decrease in anxiety following peer micro-teaching with feedback. The motivation remained high with no change. These results support a shift to an emerging stage of EDTSE progression. This was an expected result after the analysis of the journal entries provided evidence of only Jana's decreased confidence and no participant reports of decreased expectation of success. Four participants decreased anxiety in contrast with two reported increases was responsible for a net decreased anxiety trend. It was expected that increased levels of confidence would correspond with decreased anxiety levels. Student motivation responses remained high with Nora reporting a decrease and Tim and Isabelle reporting increased motivation.

Table 10

Self-Reported EDTSE at Time Point 3

Name	J	M	E	Ma	N	A	E	I	T	S	C	Mean
Confidence	2	4	4	4	2	3	4	4	3.5	4	3.5	3.5
Motivation	5	5	4	5	4	5	4	4	5	4	5	4.5
Expectation of success	4	4	4	4	4	3	5	3	3	4	4	3.8
Anxiety	4	0	1	3	5	4	3	3	3	3	5	3.1

Table 11

Changes in EDTSE at Time 3

EDTSE	Mean time 3	Mean Time 2	Difference	Group change trend
Confidence	3.5	3.1	+.4	Increase
Motivation	4.5	4.5	0	No change
Expectation of success	3.8	3.5	+.3	Increase
Anxiety	3.1	3.4	-.3	Decrease

Time Point Four

After micro-teaching and receiving feedback from peers and the course instructor on self-created lesson plans, participants were instructed to teach their lesson as part of the clinical course. Participants recorded their lesson and were directed to journal following the authentic teaching experience.

Time point four is described as an emerging stage of EDTSE progression. Participants description of point four suggest authentic teaching is a mastery experience needed for participants to develop their outcome expectancy. Participants used student and mentor teacher feedback to gage their successful completion of an engineering design lesson. Previous research suggests that mastery experience is the greatest mediator of efficacy. This study upholds that theory due to the large increase in student confidence resulting from authentic teaching. However, when participants reported their EDTSE, they had difficulty separating general and engineering design teaching efficacy. Participants reported changes in efficacy due to the introduction of a new task at time point four. The task to authentically teach was instrumental in progression on the continuum regardless of participant reports of increased or decreased efficacy. This was evidenced by participant suggestion that although they may have experienced a negative shift, they recognized the need to have continued experience. Many participants recognized negative shifts had occurred due to the circumstances of teaching in a different sociocultural environment that may not value engineering design. Another mediator was teaching an engineering design lesson out of context of an entire storyline. Participants reported not feeling successful if students could not fully understand or develop their engineering design understanding from just one lesson. All the limiting mediators of efficacy are evidence of participant progressive understanding of the engineering design pedagogy in a science classroom. The following is a detailed description of participant EDTSE at time point four.

Confidence

Confidence at time point four represents all participants' first authentic ED teaching experience. The results indicate five participants reporting confidence increases. Emily suggested the source of her confidence increase was her ability to iterate the lesson based on student response. "The students really enjoyed the lesson. The students throughout the day participated very willingly…Understanding how to alter a lesson throughout the day with students helped boost my confidence in teaching engineering concepts." Malia also mentioned her ability to improve with each class period but reported her confidence had not changed from her previous journal. "My confidence level is a 4 because now I have more experience. I taught this lesson three different times and felt like I got better at teaching it every time." Scott shared that his confidence had decreased but did share he "knew the material well" and "liked the experience, both helping with the hands-on portion of the lab and teaching afterward." These comments suggest that confidence to teach ED was developed through student reaction, continued improvement, and knowing the material covered in the lesson.

Motivation

Analysis of participant motivation at time point four showed two participants increasing and decreasing in motivation. Emily explained that her motivation after teaching her lesson influenced her future intent to integrate additional ED lessons.

> When the school day ended, I was on a kick of incorporating engineering-centered lessons way more frequently than I was planning. I realized I do have a lot of freedom in what I want to focus on with hands-on activities and I think engineering lessons are an amazing way to incorporate problem-solving in curriculum.

Tim provided an explanation for why he reported a decrease in his motivation following authentic teaching. Tim expressed he “was very motivated”, but “didn’t have full freedom to act on my motivation.” Tim expressed much frustration with a mentor teacher who limited the ED lesson by insisting he use her “worksheet” that had science questions. In his words:

> My goal for this lesson/lab was to have students evaluate a design solution. The prototype they were evaluating was a density column meant to model the layers of the earth. I introduced the lesson from an engineering perspective, encouraging the students to think like engineers, but the lab sheets my mentor teacher wanted to use focused much more on scientific thinking than on engineering thinking. (I’ll add, too, that it was not great at encouraging scientific thinking either.) I added two questions to the lab question handout that I think were also helpful in focusing on the engineering portion of the lab. I had them answer the questions “Does this model help you, as an engineer, to visualize earth’s layers? I had this question to start them evaluating how well the design of the model helped them visualize earth’s layers, as geologic engineers have to. I had a follow-up question to keep them thinking about how to evaluate and analyze the solution: “What is one thing you could change about the model to make it a better representation of earth’s layers?” I went around and asked some students how they answered these questions. One student said “Well, we know that there are rocks and stuff in the

> earth's crust and layers. Maybe we could add something to our model to represent the stuff we'd find in each layer." Another student suggested trying to build a model with layers in proportion to what is seen in earth's layers. I think that not all students were able to get to these questions, however, and to really hit home the idea of the importance of evaluating design solutions I had wanted to have a 5- or 10-minutes discussion after the activity about how they had answered these questions. I ran out of time though. If it were my own classroom, I'd simply have that conversation the next period. However, I don't know if my mentor teacher will have such a conversation with them.

Tim's detailed account of his motivation reveals an in-depth knowledge of ED, understanding of the expectation of the standards, and his ability to lesson plan, however his confidence was affected by the social-cultural influences of a different environment. By using the worksheet with science questions, Tim interpreted the mentor teacher's actions as not valuing ED. In contrast, Malia shared why her motivation remained high through the teaching experience.

> My motivation is a 5 to teach engineering design. I think it's a very important skill…to make sure that students know what an engineer does and how. Lessons like these are very difficult to develop but are great resources for the students. I want to be able to effectively teach engineering design and I think that just takes practice and time. It can be scary at first which can definitely affect the rating for motivation, but I think if I develop enough lessons and find them to be productive and good lessons, then my motivation will increase. For example, today I was very nervous to teach my lesson because I felt it might not have involved enough engineering methods. After encouragement from my teacher and good feedback from the students, I want to try harder in engineering lesson development and it motivated me to continue with engineering lessons.

Malia statement revealed the classrooms social-cultural climate was motivating her to continue creating lessons for future implementation. This was in addition to the belief that ED builds student skill. Mike suggested the engagement of the students and application of DCI's was affecting his motivation.

> After teaching the lesson and seeing how engaged the students were, my motivation to teach engineering increased. I also felt like having engineering

> discussions and a way to apply the concepts to solve a real problem helped many of the students really solidify their understanding of the DCI.

Chris reported an increase in confidence that was also based on student engagement.

> I feel that I have remained consistent in wanting badly to be good at teaching engineering lessons but after seeing one of the students who struggles greatly with staying on task be so engaged in my lesson, I feel even more motivated to do it for students like him who may get more out of lessons like this than any other.

In summary participant confidence was affected by the social-cultural environment of the clinical classroom. The behaviors, values, and attitudes during authentic teaching influenced participants in positive or negative ways. Participants who witnessed increased student engagement and student understanding of science and engineering ideas reported increases in motivation to teach engineering design.

Expectation of Success

Analysis of participant expectation of success at time point four showed two participants increasing and seven decreasing in motivation. Malia reported a decrease in her expectation of success and discussed her rationale by stating:

> I would rate myself at a 3 because I still feel I'm struggling with developing engineering lessons that hit the standard on the head. For example, the standard that I chose was CHEM 3.5 which states, "Develop solutions related to the management, conservation, and utilization of mineral resources (matter)." My lesson is about gold mining and how we use sodium cyanide to extract gold from the ore. I had students do research on cost, efficiency, and environmental impacts of the use of sodium cyanide which I believe to be an engineering practice, but it wasn't hands-on and that is why I have a hard time giving myself a higher rating. I have a hard time developing hands-on activities for chemical engineering lessons, but I hope with time, I will be able to develop more involved lessons for my class.

Malia's ES was determined by her use of hands-on learning methods. Isabelle also felt that her expectation of success was dependent on the lesson plan. She stated she had a successful lesson plan, but only rated herself a 3. “I believe that I have a successful lesson that I can use in my classroom in the future.” In summary, participant expectation of success was tied to the method of instruction and lesson planning.

Anxiety

Analysis of participant anxiety at time point 4 showed two participants increasing and seven decreasing in anxiety. Emily shared why her anxiety had decreased.

> Implementing my lesson plan in a classroom full of kids was a bit nerve-racking, but after I started teaching the first lesson, I felt fine. The students were engaged in the lesson and enjoyed a change of pace. Teaching the engineering lesson in my clinical classroom took a lot of the unknowns I was worried about and eased my anxiety about teaching engineering lessons.

Nora shared that her initial anxiety was high, but after gaging the reactions of the students, her anxiety decreased.

> Surprisingly my anxiety while I was teaching was low. I knew that I knew the material and was comfortable explaining to others. My anxiety right before I taught was quite high (5) but during it I felt much more calm. Once I saw students comprehending what I was saying, I was more at ease.

Mike also used student reaction to moderate his anxiety by sharing, “I was a little nervous to get started, but then the entire class was verbally excited about the lesson. As participants started sharing insights and questions in class, my nervousness went away, and it was only fun.” Isabelle reported an increase in anxiety due to the anticipated negative response of her mentor teacher.

> It was my first time teaching an engineering lesson. I was anxious that I would not be able to convey the difference between engineers and scientists to my students. Another reason why my anxiety was so high was because of my mentor teacher. Prior to me teaching this day, she was really set in her ways, and was not very happy about me having to teach. I was anxious she would not like my lesson and would only give me negative feedback at the end of the day.

Participants anxiety was influenced by their interpretation of student and mentor teacher reactions to the ED lesson.

In summary of the descriptions of EDTSE at time point four, participants described an emerging stage of EDTSE. The emerging stage is characterized by authentic teaching or mastery experience and social persuasion from mentor teachers. The task was to teach an engineering design lesson which resulting in shifting beliefs in competency. The negative or positive shifts in efficacy were still indicative of EDTSE progression due to increased pedagogical understanding of engineering design. Student feedback including engagement and science understanding were an important facet of preservice teacher emerging EDTSE.

Group Change

The following is a description of participant responses as a numeric ranking (see Table 12) given as a side-by-side comparison to show the variance in individual responses. Group changes from time point three to time point four were analyzed by comparison of group means (see Table 13). It is important to note that although there were individual differences, the evaluation of group mean differences allows for a macro view of EDTSE at time point four. Analysis of group means suggests a collective increase in confidence with a corresponding decrease in anxiety. It is expected that an increase in confidence would result in a decrease in anxiety. As in previous time points, there was no shift in motivation. A decrease in expectation of success was reported. Interestingly, confidence was shown to increase, yet participants would report they had not believed they were successful in teaching engineering design. Instead, seven participants reported decreased belief that they had successfully taught an engineering design lesson.

Table 12

Self-Reported EDTSE at Time Point 4

Name	J	M	E	Ma	N	A	E	I	T	S	C	Mean
Confidence	4	3	4	4	4	4	4.5	3	3	3	4	3.7
Motivation	5	5	4	5	5	5	5	4	4	3	5	4.5
Expectation of success	2	3	4	3	3	3.5	3.5	3	2	4	3.5	3.1
Anxiety	2	1	1	2	2	3	2	5	2	4	4	2.4

Table 13

Changes in EDTSE at Time 4

EDTSE	Mean time 4	Mean Time 3	Difference	Group change trend
Confidence	3.7	4.5	+1.2	Increase
Motivation	4.5	4.5	0	No change
Expectation of success	3.1	3.8	-.7	Decrease
Anxiety	2.4	3.1	-1.0	Decrease

Interestingly, participant confidence increased to the highest point during the study, yet participant belief of successful decreased. This trend supports the ideographic details of limiting mediators of teaching in a different sociocultural environment. It also supports that preservice teachers can experience decreases in efficacy but still show evidence of progression in pedagogical understanding and resulting confidence. Previous literature has reported that a decrease in EDTSE can occur after authentic teaching by preservice educators. In this study, participant confidence increased and anxiety decreased with no apparent "teaching shock."

Time Point Five

At time point five, all participants had taught their engineering design lesson in the clinical class. A 3-week period had lapsed since the previous time point to allow time for teachers to coordinate their lesson on mentor teacher schedules and to allow for the university spring break. Class also fell on a national holiday. The instructor had viewed participant video recordings of the clinical teaching and had provided the video observation protocol to participants, allowing for participant responses and feedback.

Time point five is described as an emerging or a maturing stage of EDTSE progression depending on instructor evaluation of successful teaching of engineering design in the video observation protocol. Successful teaching of engineering design was determined to be the boundary between emerging and maturing due to participant mastery of experience and having observed student engagement and application of science content during an engineering design lesson. Participants description at time point five suggest the task of video self-monitoring and the practice of being a reflective practitioner shifted participant beliefs. Shifting beliefs indicated progress on the EDTSE continuum regardless of whether the shifting was negative or positive. After describing EDTSE constructs at time point five, four purposeful exemplar participants will be provided to illustrate the boundary between an emerging and maturing stage of EDTSE progression.

Confidence

After watching the video, Emily suggested that her initial high confidence after teaching had decreased because she was critical of the methods she used during teaching.

She was struggling to separate ED confidence from general teaching confidence.

> I was feeling way confident right after the last lesson because I was proud of myself for making it through. I rated this confidence lower because I saw some improvement that I need to with explaining the connections between everything and also with revoicing answers that students say to tie their answers into the lesson. I also want to get better at asking more pressing questions and more “why do you think that?” I also think I needed to ask for evidence to back up their hypothesis. Overall, I think it went well watching it back, but I also think it showed a lot of improvement to be done.

Chris’s confidence had previously been affected by his belief that the students did not understand him. After watching the video, Chris noticed the students understood the concepts, “I was definitely a bit easier to understand than I thought I might’ve been, and I do genuinely believe I was understood.” Watching the video affected participants ED teaching confidence depending on their ability to separate ED from general teaching confidence.

Motivation

After watching the video, motivation was dependent on student reaction. Participants were able to notice student comments and engagement. Emily shared,

> I am still just as motivated to teach engineering lessons to my students as before watching the video again. I think this time I heard some whisperings and comments made by the students that I didn’t hear while teaching and it made me happy to hear the excitement in their voices and it made me more motivated to do things like this in my classroom.

Isabelle recognized her enthusiasm while teaching reflected student engagement.

> For motivation I would keep my rating of 4. You can tell by my smiley, happy attitude that I was really excited to teach my lesson. Watching the video back, I was able to see how I bounce off the student’s energy. That makes me want to keep doing lessons like this in my future.

Expectation of Success

An evaluation of the expectation of success determined that three participants increased and two reported decreases. Alex shared that she believed she had successfully taught engineering design but recognized there were improvements to be made. The following description details her recommended changes and her changing beliefs.

> I think that I could have explained enzyme better and how engineers have created eczematic detergents. I do think I went through the process well though with the students, helping them specifically understand constraints. I think that I was too hard on myself when I initially ranked myself. I was focusing too much on the few little things that didn't go to plan rather than on the lesson as a whole. I had much more go right than wrong. I was able to adapt to the class, which is crucial for successful teaching. I had stated that I didn't explain enzymes enough initially, however, I do think that I did a sufficient job after re-watching. The lesson wasn't a unit on enzymes, rather we were evaluating solutions that had them in them and my explanation went into enough depth that they needed for the experiment. I need to remember that I am still learning and cannot expect to be perfect.

Jana reported a decrease in ES. She also noted opportunities for improvements.

> I noticed watching the video I need to be more explicit about engineering design. There were many opportunities that I could have taken to speak directly to the process, but I did not do that. That is something that I really need to work on.

In summary, participants made suggestion for lesson plan implementation improvements. Many of the things they mentioned were out of their control and were dependent on the variables associated with teaching in a different social-cultural climate. However, watching the video allowed participants to view their explicit engineering design language.

Anxiety

Anxiety level decreases were supported by participant watching of the video and the social-cultural environment of the clinical class. Nora shared why her anxiety decreased. "My anxiety level went down a number. I believe seeing the video and analyzing it helped with this decrease. I gained experience, which was also very important." Nora shared that the clinical class was a supportive judgement free environment.

> Watching back the video I seem confident in what I am saying which would put me more at ease as a student. Also, when they were talking with my mentor teacher about how the radium girls could have been spared, they felt comfortable having a group class discussion and at times being wrong. Her class feels very judgment free and thus eliminated a lot of anxiety.

In summary of time point five description of EDTSE, participants described difficulty in separating general teaching efficacy from engineering design teaching efficacy. Overall, the video observation revealed that some teachers were much harsher on their estimation of EDTSE after watching themselves teach. In many cases the sociocultural environment and frustrations of teaching a single lesson led to participant decreases after viewing the video. Participants described how watching the video informed their views of student engagement and science understanding. Video-self monitoring and reflecting on successful teaching of engineering design resulted in shifts in efficacy suggesting the task was proceeding a change in efficacy beliefs.

Emerging vs. Maturing

All preservice educators began the engineering design unit in the methods course as efficacy onset stage of development. By the end of the unit, Chris, Nora, Eric, and Scott had reached the emerging efficacy stage. Jana, Emily, Tim, Malia, Isabelle, and Mike had all reached the efficacy maturing stage. The achieved stage of development was analyzed based on participant outcome expectancy resulting from the successful teaching of engineering design. Thus, the description of emerging and maturing stages describes belief systems and pedagogical skill.

Four purposeful exemplar participants will be provided to illustrate the boundary between an emerging and maturing stage of EDTSE progression. The stage of development was determined by video monitoring and participant statements supporting successful completion of teaching an engineering design lesson and reflecting on needed changes. Chris and Scott represent two participants that ended the engineering design unit in the emerging stage due to their unsuccessful teaching of an engineering design lesson. The lessons taught were not explicit with engineering language and design applications. Without an emphasis on engineering design, participants were not able to observe and assess student engagement or application of science content during the EDP. Their lack of pedagogical development is evidence of remaining in the emerging stage.

> Chris: One of the biggest things that seems so obvious now that wasn't going in was that I didn't teach it like an engineering lesson. Students did not review the engineering process or connect that while creating their motors, they were continuously swapping batteries, adjusting the placement of their paper clips and magnet, straightening out the wire, etc. and making the important revisions they needed to design their solutions. I had all the tools to build an engineering lesson but assembled them into a science lesson anyway.

> Scott: I know I'm still struggling with lesson planning, and I ended up just using my placement teacher's lesson, but it was still a fun and interesting experience. I'm excited to try applying the things we talked about for the engineering lessons.

In contrast to the above examples, Alex and Mike exhibited the maturing stage. After successful creation and teaching of an engineering design lesson in the clinical class, both received student and mentor teacher feedback that supported an increased outcome expectancy. All participants that achieved the maturing stage provided evidence of pedagogical understanding resulting from a mastery experience. Alex stated, I understand the design process well and believe that I could explain it to anyone and show them the importance of it."

> Mike: I am so ready to be in a classroom of my own. I am ready to start learning by doing. I know I have so much to learn still, and I love this class, but teaching my lesson in a class of high schoolers was so valuable in actually understanding and trying to apply what I am learning. I just want to be in my own classroom and really figuring out who I am as a teacher.

Mikes statement is evidence of the requirements for further progression within the maturing stage. Although time point five marked the end of the engineering design unit, preservice educators may continue to progress in EDTSE if they have the autonomy to develop and teach engineering design during their student teaching experience. Mike recognized that in order to continue progressing he will need opportunities in his own class to further develop his lesson into a full storyline. Other participants provided evidence of this interpretation of the maturing stage. Nora shared, "I think I could have done a better job if I had more control over the lesson and if it were my own classroom." Karla supported the idea of autonomy leading to further development. "I now have the knowledge to be able to design more engineering lessons for my future classroom. I believe that once I have my own classroom, I will be able to be more effective in teaching the engineering design process."

In summary, although not all participants reached the maturing stage of EDTSE, they were all able to progress. Further development for those participants who reached the emerging stage can happen during student teaching if they apply the needed changes recommended during time point five. Those participants that reached the maturing stage can also continue to progress during student teaching if they have the autonomy to develop and teach their lesson as a full storyline .

Group Changes

The following is a description of participant responses as a numeric ranking (see Table 14) given as a side-by-side comparison to show the variance in individual responses. Collective changes from time point four to time point five were analyzed by comparison of group means (see Table 15). It is important to note that although there were individual differences, evaluating group mean differences allows for a macro view of EDTSE at time point five.

Table 14

Self-Reported EDTSE at Time Point 5

Name	J	M	E	Ma	N	A	E	I	T	S	C	Mean
Confidence	3	4	4	4	3	5	3	4	4	4	3.5	3.7
Motivation	5	4.5	4	3	4	5	5	4	3	4	5	4.2
Expectation of success	1	4.5	4	3	3	4	3	3	2	4	4	3.2
Anxiety	2	1	1	3	2	2	1	1	2	3	3.5	2.0

Table 15

Changes in EDTSE at Time 5

EDTSE	Mean time 5	Mean Time 4	Difference	Group change trend
Confidence	3.7	3.7	0	No change
Motivation	4.2	4.5	-.3	Decrease
Expectation of success	3.2	3.1	-.1	Decrease
Anxiety	2.0	2.4	-.4	Decrease

Analysis of group means suggests that confidence remained stable after watching the video and reflecting on practice. Once removed from the anxiety of teaching, the reported anxiety at time point five decreased. There was very little change with the expectation of success. Motivation decreased for the first time during the study. Further examination revealed that four participants felt the students would not be very motivated by the ED lesson they taught because they had been too research-based, not hands-on enough, or did not have enough time to elaborate. Instead of focusing on their motivation, they considered their ability to motivate classroom students using their lesson.

Efficacy Development Over Time

This analysis allows for a retrospective interpretation of personal experience compared to a time point analysis. The time point analysis was an "in the moment" view while the retrospective analysis presented an alternate view of EDTSE progression. The analysis presentation of efficacy development over time will include four purposefully selected participant examples demonstrating EDTSE. The analysis includes tables of ideographic and nomothetic descriptions of efficacy over the ED unit followed by two exemplar paired line graphs and four journey maps. The line graphs were intentionally paired to enhance the variability in individual progression through time. Confidence was the only construct of EDTSE displayed in the line graphs because it is inversely related to anxiety. Motivation remained constant and high after time point one. The expectation of success was tied to teaching experience, which the instructor only offered at time points three and four. Therefore, the line graphs use the confidence construct.

Exemplary ideographic confidence statements by time point (see Table 16) suggest that participants increased in EDTSE over the engineering design unit. All began the unit by describing low confidence compared to the end of the unit where they described the confidence to successfully create and teach engineering design curriculum aligned to their content standards. The confidence statements did not portray linear growth because each participant described at least one decrease or no progression occurrence. For example, Jana stated, "After watching the video my confidence actually went down."

The journey maps support the nonlinear growth of the efficacy statements by time point. Individuals depicted their journey in three main styles: a continuous climb, a winding path, and an accent with periods of up and downs (see Figure 5). Individuals did not depict stopping and returning or going the opposite direction, suggesting that changing beliefs were seen retrospectively as progress.

Participants who visually depicted efficacy as a continuous climb used verbal descriptions to suggest the accent was bumpy. The confidence line graphs also support the nonlinear wavelike progression of EDTSE over time; however, the line graphs contrast participant ideographic statements that suggest continued progression. For example, Emily began and ended the unit by describing her confidence as a 3 (see Table 17).

This might suggest that over the unit, her confidence did not increase. Triangulation with her time point analysis and journey maps suggest that her EDTSE increased significantly. For example, Emily's end of unit (3) reflected her belief in ED teaching competency after viewing her video and not a progress-oriented belief from

Table 16

Ideographic Efficacy By Time Point

Time Point	Participant	Efficacy statement
0	Emily	I am not super confident
1		My confidence has stayed the same
2		I really want to incorporate engineering design into my lesson
3		I feel a lot more confident
4		Teaching the lesson throughout the day with students helped boost my confidence.
5		I feel much more confident teaching my ED lesson now
0	Chris	I still don't feel overly confident in most of my teaching abilities.
1		I think that seeing it in action has lifted my confidence a bit.
2		What currently shakes my confidence is combining engineering and my content.
3		I feel my answers have started to solidify.
4		I think that as long as I am confident in my lesson I will do okay. I just don't quite feel good in a lot of lessons yet.
5		I am worried this will get shakier as stray off on my own. My confidence took a slight ding watching myself.
0	Jana	I'm low for confidence because at the moment I feel like I don't have enough knowledge and experience
1		My confidence lacks in the fact that my brain really does not think like an engineer.
2		I feel pretty good about coming up with ideas. I'm still not completely confident in doing the entire story line for an engineering standard.
3		My confidence actually went down because hearing all my peers.
4		I felt pretty confident about teaching this lesson. I felt confident because I had prepared well for the lesson.
5		After watching the video my confidence actually went down a little. I believe now that I can really become successful at teaching the EDP and having my students understand and enjoy the process.
0	Isabelle	My confidence is really low
1		I lack the confidence needed to feel like I can do it.
2		I think that writing the lesson plan has helped me feel a little bit more confident
3		Now that I have been able to share my lesson with others I feel better about teaching in the actual classroom.
4		I believe that I have a successful lesson that I can use in my classroom in the future.
5		I now have the knowledge to be able to design more engineering lessons for my future classroom

Figure 5

Journey Map Progression Types

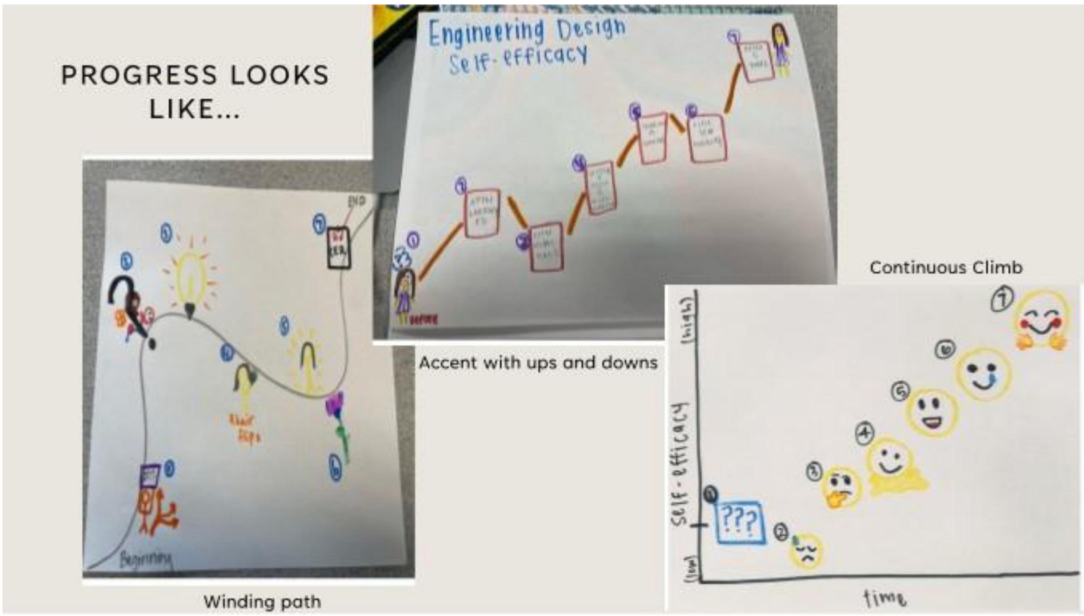


Table 17

Nomothetic Efficacy By Time Point

Participant	Construct	Time point 0	1	2	3	4	5
Emily	C	3	3	2	4	4.5	3
	M	2	4.5	4	4	5	5
	ES	4	5	5	5	3.5	3
	A	4	3	3	3	2	1
Chris	C	2.5	3	4	3	4	3.5
	M	4	5	5	4	5	5
	ES	3.5	4	3.5	3	3.5	4
	A	5	5	5	5	4	3.5
Jana	C	2	4	4	2	4	3
	M	5	5	5	5	5	5
	ES	4	4	3	4	2	1
	A	5	4	3	4	2	2
Isabelle	C	2	2	3	4	3	4
	M	3	4	3	4	4	4
	ES	3	2	3	3	3	3
	A	5	5	5	3	5	1

onset (time point 0). This interpretation is evidenced when Emily stated, “I’m excited to incorporate engineering inside my own classroom where at one point I was really kind of against it.” Emily’s statement suggests much change over time.

Every participant line was different, but the commonality between individuals is that the progression of efficacy was not linear (see Figures 6 and 7). For example, Isabelle and Jana began the unit with a (2). By the end of the unit, Jana had increased to a (3) and Isabelle a (4). The point of interest is time point three. At time point three a large variance in EDTSE is displayed. The same task resulted in large opposing changing beliefs. This finding supports research that suggests efficacy develops on a spectrum and there can be situational fluctuations (Goddard et al., 2004).

Figure 6

Wave Progression of Participant EDTSE for Emily and Chris

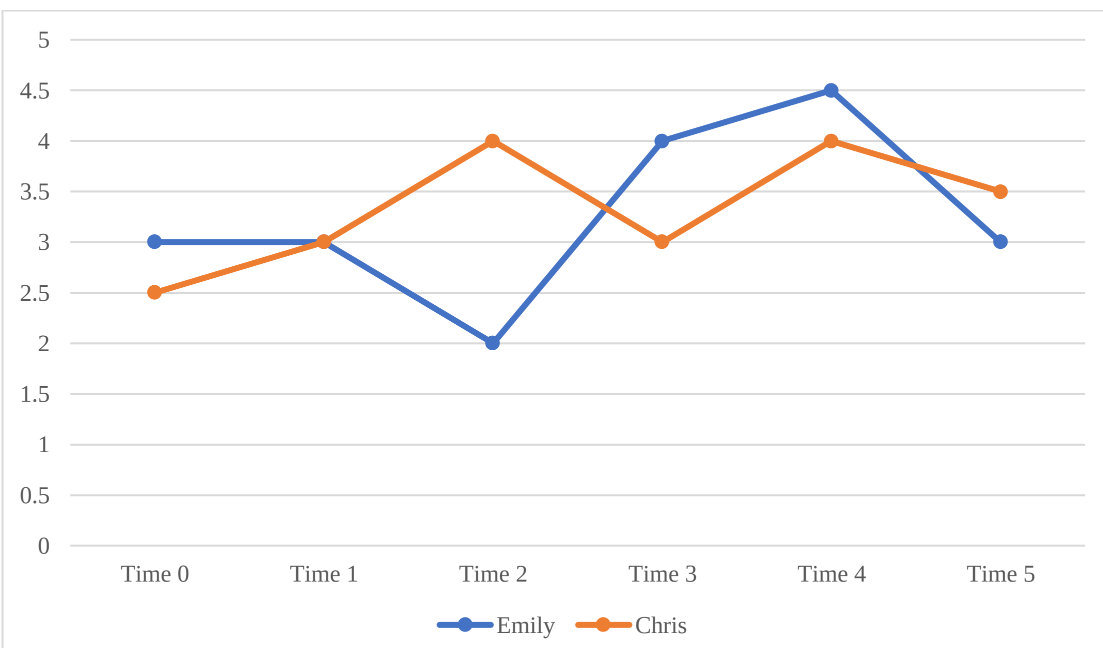
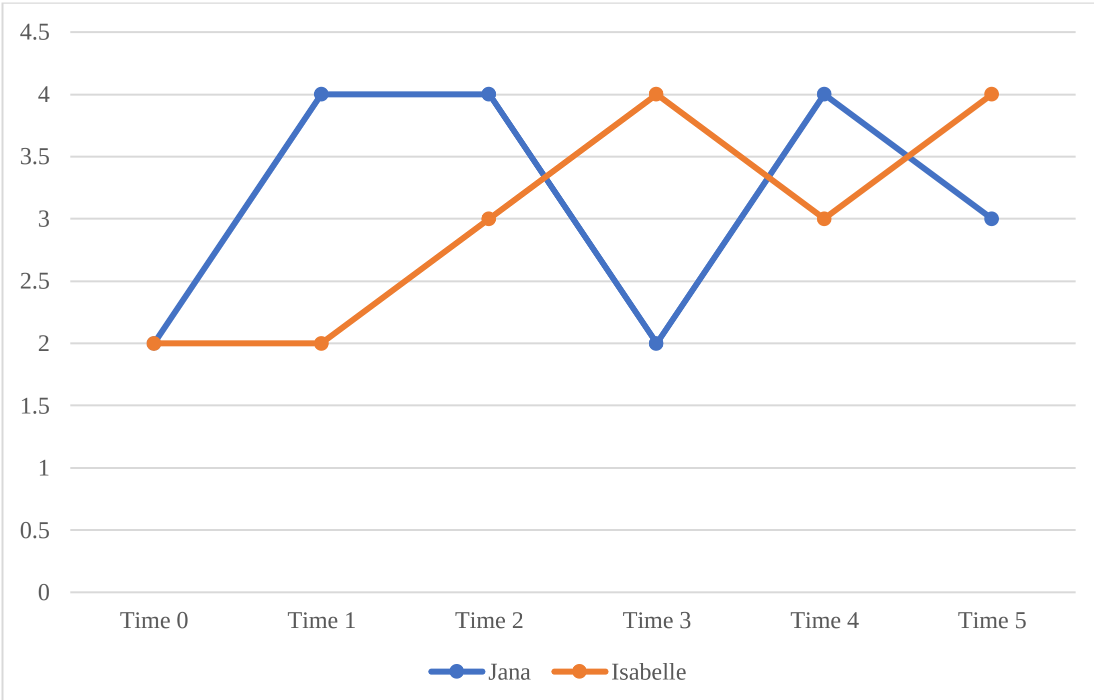


Figure 7

Wave Progression of Participant EDTSE for Jana and Isabelle



Jana's negative shift was still evidence of progression when she later reported increased pedagogical understanding. Jana later stated, "I felt pretty confident about teaching this lesson. I felt confident because I had prepared well for the lesson." Part of her preparation was the previous scaffolded task that resulted in a negative shift. Individual belief of task competence can result in negative or positive shifts yet the data suggest these shifts were seen as progress retrospectively. This suggests that tasks introduced at each time point proceeded individual shifts in efficacy. This finding supports research that suggests teacher self-efficacy entwines with teacher practice and develops through reflective interpersonal negotiations of task analysis (Bandura, 1993;

Putney & Broughton, 2010; Tschannen-Moran et al., 1998; Yoon Yoon et al., 2014). Therefore, the nomothetic descriptions "in the moment" reflected participant beliefs of time point task competency and not overall EDTSE growth since time point zero. This is why Emily's beginning and ending (3) were in the moment task analysis descriptions and not evidence of overall growth.

Another example of time points reflecting task analysis is time point zero, or the baseline data before beginning the unit. Jana and Isabelle reported a (2) for confidence at time point zero. Yet, Jana stated, "I'm low for confidence because at the moment I feel like I don't have enough knowledge and experience." Jana recognized that her lack of knowledge and experience left her ignorant about engineering design. Later in the engineering design unit at time point three, she also reported a (2). This time she stated, "my confidence actually went down because hearing all my peers" and "I still felt I could do what I needed to." Jana recognized her confidence resulting from experience and the knowledge to create and teach an engineering design lesson. Yet, her task competency analysis at time point three resulted in a (2) which was very different from her initial ranking before a task was introduced. Thus, because her baseline data was not associated with a task analysis, ranking a (2) was seen to be somewhat arbitrary. This study adds to the research that situational fluctuations are evidence of progression because self-efficacy and teacher practice entwine and EDTSE develops through interpersonal negotiation of task analysis.

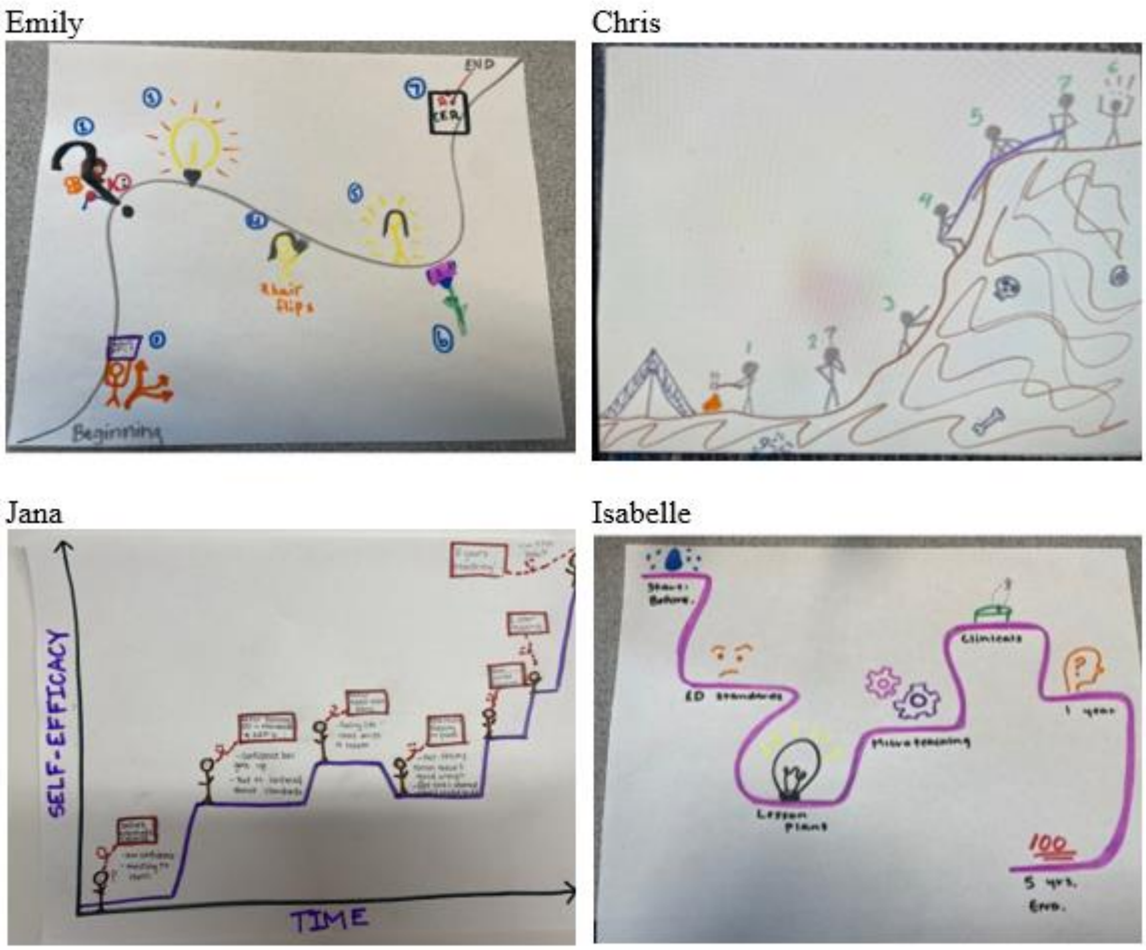
Comparing time point with change over time data suggests that participant reported nomothetic EDTSE was not a predictor of skill. For example, Emily's final (3) was less than Chris's (3.5); however, evaluation of attained stage of EDTSE from the time point analysis suggests that Emily achieved a maturing stage and Chris achieved the emerging stage of development. Thus, the reported belief value is not evidence of stage attainment.

Assessing developmental stage vs. nomothetic value better describes the needed mentor supports of participants and describes EDTSE entwined with skill level. Chris's journey map depicts himself climbing a mountain with assistance (see Figure 8). As interpreted from video evidence, this is an insightful depiction of Chris's need for continued mentorship to successfully teach an engineering design lesson using explicit ED language and the EDP before he attains the maturing stage. Emily successfully taught an engineering design lesson using the EDP and explicit engineering language receiving feedback from students that support increased engagement and application of science content. Thus, evaluation of EDTSE by developmental stage may better assist professional developers in evaluating and providing mentor supports because it entwines pedagogical skill with belief. Emily's reported confidence decrease after video self-monitoring and reflection supports the finding that (1) task competency beliefs at each time point is evidenced by efficacy shifts and (2) shifting efficacy precedes efficacy progression.

The journey map data suggests mentor facilitated sensemaking as an element of the unit that proceeds wavelike EDTSE progression. For example, when Emily drew her journey map, she depicted many arrows and possible paths to take (see Figure 8). She stated. "There's a bunch of different roads to go on" and "I didn't know how to approach

Figure 8

Exemplar Journey Maps



it and I didn't know what to do." These statements suggest that when seen retrospectively, participants recognize they did not have the sensemaking to initiate their EDTSE journey prior to the unit. Chris stated, "I had no real understanding as to how I was going to get there." This statement suggests an initial lack of sensemaking. Later Chris suggested, "That's where I have a way up," because he recognized he had received sensemaking "tools from our methods course." Jana mentioned sensemaking of task competency for the reason her efficacy had developed. She used terms like, "after I was able to learn engineering design and SEPs," "modeled in class," and "I could write a lesson" to describe her progressive journey. Isabelle depicted sensemaking as a light bulb. She described sensemaking using a light bult because, "the light bulb represents me… getting it and understanding how to implement it into my own classroom." Based on interpretation of the evidence, a retrospective analysis of EDTSE over the unit supports that progress was attributed by participants to sensemaking elements of the unit.

Elements of the Engineering Unit

Initial coding included elements of the unit that influenced EDTSE. During the interpretation and analysis of the engineering unit elements, themes emerged from the data that suggest the elements all facilitated sensemaking. Because all participants increased from an onset stage to an emerging or maturing stage and used statements justifying their increase due to unit elements, it was assumed the engineering design unit facilitated the sensemaking of engineering design teaching. Analysis of the sensemaking themes during the unit will be provided below. Sensemaking is the process of giving meaning to their collective experiences (Weick et al., 2005). The collective experience was the engineering design unit. Thus, sensemaking was the process by which participants gave meaning to an ED unit. Research by Weick et al. describes sociocultural sensemaking as a mechanism that facilitates change in activity over time, which activity leads the progression of cognition. Therefore, sensemaking is recognized as the mechanism that enabled task competency leading to EDTSE progression during the unit. Using a Vygotskian lens to develop the ED unit and interpret EDTSE data was essential because sensemaking is sociocultural and based on collective experiences. The following analysis will describe the unit's elements that facilitated sensemaking, leading to individual stage attainment.

Elements of the unit that facilitated sensemaking are ED knowledge, scaffolded pedagogical tasks, modeled ED teaching, positive discourse, mediating tools, and sociocultural environment reflection. However, it was interpreted that all the elements were provided as a result of a mentor's planning and carrying out of the ED unit. Therefore, the primary emergent code was mentorship, with all other codes a byproduct of mentorship. Mentorship during the unit was the sociocultural interpersonal relationship where the mentor acted as a more knowledgeable other. The mentor moved learning into the Zone of Proximal Development or the achievable learning level with scaffolded socialized sensemaking (Vygotsky, 1978). To designate between participant-assigned mentor teachers and the course instructor/researcher, the word "teacher" will be applied to the assigned mentor, and "instructor" will apply to the clinical class instructor as a mentor. It is understood that both relationships were mentor relationships. The term "mentor" will serve as a verb and describe the actions of the teacher and instructor to increase EDTSE through collaborative learning of engineering design.

Mentorship

The instructor mentored participants by facilitating the sensemaking that precedes EDTSE development. The instructor facilitated sensemaking through engineering design knowledge, scaffolded pedagogical tasks, modeled engineering design teaching, and positive discourse, mediating tools, and sociocultural environment reflection. The teacher facilitated sensemaking through positive discourse.

Engineering design knowledge. The instructor introduced engineering design knowledge during point one of the interventions, which facilitated the sensemaking of all future tasks. Task one was to frame problems by content area that science content knowledge could be used to design solutions for. This task required participants to have ED knowledge of content specific problems. It was necessary for the participants to recognize their deficiency in engineering design knowledge. The instructor mentored participants through metacognition. By learning about engineering design, Nora and Emily recognized that they lacked knowledge. Recognizing a lack of knowledge was an important aspect of sensemaking. Nora explained,

> A big factor that influences my teaching self-efficacy is my lack of knowledge for what chemistry has helped solve problems. I am going to have to learn a lot more about real life chemistry application to better pick phenomena/ problems for lessons.

Emily stated, “As a biology teacher there’s the total lack of knowledge of engineering” and “I definitely have to research more examples of engineering designs in biology.” Emily also acknowledged that her lack of engineering design knowledge resulted in misconceptions. Emily suggested, “When I generally think of engineering, I have no motivation and I think that’s because there’s also a lot of misconceptions about engineering and … my vision of what engineering looks like.” Tim also commented on the difficulty of sensemaking as a result of misconceptions.

> I think that some of the factors affecting my EDTSE are my mental blocks about engineering. In middle and high school, engineering was described to me as building infrastructure, designing technology, or building spaceships. Having thought of engineering like this for a decade or more now, it is hard for me to see how engineering applies in biology. However, learning about how engineering is focused on defining problems and designing solutions has helped.

The course instructor mentored participants by providing engineering design knowledge to facilitate metacognition of a lack of design knowledge and misconceptions. When provided engineering design knowledge as a tool for sensemaking, Eric shared,

> I feel like one factor that is increasing my EDTSE is learning about it in class. Throughout the week after this lesson in class, I have been trying to look at things through a science mindset as well as an engineering mindset. It is interesting how they go hand-in-hand with one another but are somehow very different at the same time.

Alex statement exemplifies the need to teach about engineering design before introduction to the SEPs. Considering engineering design separately and then in connection with the SEPs facilitates the sensemaking of engineering design separate from inquiry. Thus, the SEPs can be used by scientists and engineers differently. A later focus on engineering design in the standards transitioned the participants to engineering design in the standards. Alex demonstrated how sensemaking from engineering design to SEPs facilitated his sensemaking, “Last class, when it was broken down how engineering differs from science really helped me differentiate the two. I also learned about how I will transition my students into an engineering lesson.”

The instructor mentored participants by introducing teaching the EDP, the SEPs, and then ED in the standards. This knowledge facilitated sensemaking and resulted in EDTSE changes. Alex is an example of a participant who’s changing EDTSE as a result of knowledge mentorship. Alex stated, “I understand the design process well and believe that I could explain it to anyone and show them the importance of it.” This statement exemplifies the need for mentors who can teach the EDP separately and as a facet of the SEPs and state standards. The above statements also demonstrate the need for a mentor who can assist in metacognition and misconception in engineering design.

Scaffolded pedagogical tasks. Based on the analysis of the data. Mentors are needed to scaffold pedagogical tasks that facilitate sensemaking. The engineering design scaffolded a series of five tasks. A more knowledgeable other is needed to scaffold the task and assist in task completion. At each time point, participants recognized that the previous task aided their ability to accomplish the next. They also recognized the time they had spent preparing and learning to accomplish the task was necessary for their EDTSE progression. For example, Scott described how his lesson planning was affected by his sensemaking of the intent of the standards. Scott shared, “Looking through the example lessons and trying to plan my own has gone a long way toward clearing up the goal of these standards for me.” Isabelle demonstrated how the task of writing a lesson plan was affected by her sensemaking of engineering design teaching separate from inquiry teaching. Isabelle explained,

> I feel like now that I’ve written a lesson plan…this wasn’t as bad as I thought it was. But I’m also fearful that when I go over, I’m going to have done it wrong because I couldn’t switch my thinking.

The instructor was able to mentor the participants by identifying the specific sensemaking strategy that was lacking and assisting the participants in practicing until their confidence increased. For example, Jana mentioned her sensemaking stumbling block, then the instructor could assist in removing the block through practice and discourse. Jana described her problems with lesson planning as an inability to problem frame. “I think I found out that I’m definitely not an engineer <laugh> …and as I was designing this lesson, I would keep going on the why instead of the what’s the problem.” Now that the sensemaking issue was identified, Jana was mentored on how she could focus on the problem by emphasizing the EDP.

All participants mentioned the tasks as facilitators of sensemaking. The tasks were scaffolded so learning was not too difficult but achievable with mentor support. Creating a lesson plan, micro teaching of lesson plans, authentic teaching, and video-self monitoring with feedback were all mentioned as facilitators of sensemaking. For example, Alex supported microteaching as a facilitator of sensemaking. She stated,

> Sharing our lesson plans last class influenced my numbers. It was nice getting feedback and hearing that I am on the right track with engineering design. I also liked hearing other ideas because it gave me more ideas for my own future lessons.

Isabelle, added, “The experience of hearing my peers engineering design lesson plans have helped me.”

Participants also discussed the importance of authentic teaching. Receiving feedback from students during authentic teaching was a sensemaking facilitator. It assisted participants in making changes to the lesson throughout the day. Student observations also assisted in shifting efficacy beliefs. Chris shared his experience and the observations and feedback he received. His observations of a student engaged in the lesson provided him with confidence. Chris had previously been worried that his lessons would not be good enough to impact students positively.

> There’s one student, my teacher’s fourth period that has an IEP, and he can’t really focus for about more than a minute on his assignments. An aid has to follow him around all day. When I did my engineering lesson, I was going around the room helping different people, when I got to where he was, he was basically as caught up as every other student. So, I think that the hands-on engaging was just really good for him.

This comment connected with Emily, and she realized, “the troubled students that I’ve heard not great things about from my mentor teacher were so engaged in the hands-on activity and the learning that classroom management was not an issue.” Isabelle thought of two students in her class that are English language learners. She shared how learning about ED affected them and the amount of effort they put into the assignment. She felt they had done more work during the ED lesson than any she had previously observed.

> Because they didn’t understand the words that were all in the worksheet, but they tried their best and they wrote things down using Google Translate.

Mike shared that by explicitly including engineering design, students were able to make sense of the science core ideas they had been studying. Mike had observed the students the days leading up to his lesson and during his teaching, he observed that students were able to make sense of the previous science lessons once they initiated in ED using the physics content.

> I had been observing the classes up to the engineering lesson and we were talking about Newton’s second and third laws and they were starting to get it but not super get it…not able to answer everything. But then as soon as we started applying it to…here’s your problem, you need to solve this problem. They said, oh, that’s how it works. And then they showed that they understood it and it was really cool actually. I already thought that engineering was fun but it actually helps the students to understand these concepts too.

Authentic teaching facilitated participants sensemaking engineering design teaching by observing students’ engagement and science content understanding. This particular sensemaking resulted in an EDTSE shift that marks the transition between the efficacy emerging and maturing stages of development.

Video self-monitoring was another task that facilitated sensemaking leading to efficacy progression. The instructor mentored students by providing opportunities to view the video through a different lens. The instructor provided feedback after watching the video and allowed participants to reflect on the teaching experience after receiving instructor feedback. After watching the video, Nora shared that it allowed her to reflect on her experience removed from the anxiety of the teaching moment. Removing herself from anxiety allowed her to sense make the authentic teaching.

> I think it’s hard to view the lesson as just the lesson itself. I came into that lesson with a lot of stress, and so I analyzed the lesson afterwards through that lens of stress. Watching it from a more unbiased position allowed me to see it through a different lens – which made some differences in my answers about the lesson.

Watching the video from a different perspective allowed Mike to focus on curriculum enactment and student engagement. Mike shared,

> Watching the teaching video from the perspective of a student made me realize that I did better than I thought I did. Before watching the video, I thought about what I had done wrong and what I should have done differently, but as a student, I realized I taught in an engaging way as evidenced by the level of participation and enthusiasm of the students. By the end of the lesson, students could start brainstorming and articulating potential solutions that matched the criteria and constraints. I think that watching me teach from a student’s perspective helped me to focus less on what I think I should be doing and more on what the students were wanting and needing.

After the instructor mentored the participants by providing a scaffolded series of tasks, an emphasis on reflection allowed participants to make sense of their EDTSE. Malia explained that by scaffolding a series of “steps,” she believed she could replicate the process to continue teaching engineering design. Malia shared, “I understand the steps that we are required to take to successfully teach an engineering lesson and I believe that I am able to teach those things in an effective manner.”

Based on the analysis of interpretation of the evidence, a mentor is needed to scaffold tasks. By scaffolding the tasks, the mentor can isolate and address sensemaking stumbling blocks. Scaffolding allows for optimized collaborative learning. Each scaffolded learning event was recognized as a needed sensemaking step to understand engineering design teaching and develop their EDTSE. Based on the evidence, scaffolding engineering design tasks while providing mentor assistance to accomplish the tasks will increase preservice teacher EDTSE. The scaffolded tasks should eventually provide a mastery experience because participants considered authentic teaching to be the most beneficial in EDTSE development.

Modeled engineering design teaching. The data supports modeled engineering design teaching in the clinical class through experiential learning facilitates sensemaking of engineering design as an aspect of science teaching. The instructor recognized that participants would most likely not see engineering design during their clinical class assignment. A lack of mentor teacher modeling can result in a negative shift in participant EDTSE due to a lack of sensemaking. Eric explained,

> Just the fact that I didn't get any experience of what I was learning and then seeing it in a classroom setting, it wasn't the same thing adding up. So, my confidence went down…I haven't been able to see the application of what I've been learning.

Jana was the only participant who was able to observe an engineering design unit taught in the clinical class. Her description of watching engineering design exemplifies the need for mentor teachers to model engineering design. An important facet of observing engineering design in clinical is seeing the flow of an entire storyline vs. a single lesson plan. The other advantage is seeing the engagement and perseverance of students. Observation allows preservice teachers to compare inquiry-based learning with student-centered engineering design learning. Jana explained the benefits of mentor teacher engineering design modeling,

> I have been able to observe an entire engineering story line in my clinical and it has really helped me see how the entire storyline and flow and work together. I could really see how the students got engaged and excited about this engineering unit and I think that was very valuable to see. The students were learning good skills in this unit. I liked that the students did not give up on the engineering design process they really tried hard and were more engaged than I have seen them in other activities.

Because few preservice teachers can observe engineering design, it was necessary to model engineering design in the methods course. The instructor modeled engineering design as an intentional sensemaking facilitator of the unit. Experiential learning of modeled engineering design lesson facilitated sensemaking. Participants were able to better understand (1) the difference between inquiry and engineering design, (2) science content application, and (3) the benefits of engineering literacy. Eric’s description of experiential learning portrays all three.

> Last week was a very good example of engineering design. It allowed us to use what we learned from the week before about electricity, and then apply it to a real-life solution and create a windmill. It was a great demonstration on why it is important to teach both. It helps students see that some of the things they are learning in school will be useful later in life.

Experiential learning allows preservice teachers to sense make application from a student and a teacher lens. Scott describes the teacher lens as, “seeing how it all comes together in practice.” Two aspects of teacher practice that participants reported greater sensemaking following experiential learning was the “evaluate” vs. “design” a solution standard language and the amount of teacher guidance during engineering design lessons. Alex questioned,

> The strand I chose had evaluating solution design. How I am supposed to have my students evaluate solutions that have already been made? I would like to see an

idea of how to teach this in a way that benefits the students.

Tim described how modeling influenced his sensemaking of teacher guidance during engineering design. “You gave us all one problem to work on and then you gave us multiple ways to approach it. And so that’s been enlightening and that I know I can guide my students more than I thought.” The data suggests that experiential learning is most beneficial when done by content area. For example, Nora described how her confidence increased after seeing an “evaluate design solutions” would look in her content area. “After seeing how an engineering lesson is done in chemistry, I am more confident.”

In summary modeled engineering design teaching is an important aspect of sensemaking and a mediator of EDTSE through vicarious learning. Vicarious experience is a mediator of EDTSE. Due to the lack of teachers modeling engineering design in clinical courses, instructors used experiential learning to increase sensemaking of teacher practice by content area. Mentors are needed to model engineering design teaching facilitating sensemaking of teacher practice by content area.

Positive discourse. Positive discourse is an important element of verbal persuasion. Positive verbal persuasion in the form of positive discourse and feedback, facilitated sensemaking of engineering design teaching. One way the instructor initiated Positive discourse was through focus groups. Focus groups allowed participants to share experiences of sensemaking issues and clinical teaching experiences. Thus, positive discourse provided from mentors mediated clinical teaching anxiety. Anxiety is one aspect of physiological states that can mediate efficacy.

During the focus groups when participants were asked probing questions about their efficacy, the discourse often switched to participants wanting specific questions answered about engineering design teaching. The participants' questions were insightful and demonstrated the amount of sensemaking done during the week. By creating open discourse, the instructor facilitated sensemaking by answering questions. For example, Mike wanted to know, "Can you turn a science lesson into an engineering lesson?" and Isabelle asked, "How do I enrich after we engineer?" Isabelle asked, "Lots of them again weren't about comparing design solutions. So, I'm still curious on how to best go about that." Mike added, "I'm really confused on what a lesson would look like in context of a whole standard." Isabelle asked, "When we're teaching science, we try to have supporting phenomenon as the base of each episode. Right? So, do we have supporting problems?" Asking questions and collective sensemaking repeatedly resulted in participant comments such as "aha," "now I understand," or "I feel better now." Having specific questions answered about lesson planning was an element of the unit that facilitated sensemaking through positive discourse. Through open discourse and sharing of ideas, participant can ask and receive answers to questions from a mentor that facilitate sensemaking.

Openly sharing ideas with peers can also facilitate sensemaking by creating connections to other aspects of science teaching. For example, Mike realized that ED problems presented to students should be culturally based to increase equity. He noted that this is usually accomplished using phenomenon but realized this could be done in ED by using problems in culturally relevant lessons. It now made sense that the classic "egg drop" physics problem was not equitable unless it was tied to a problem the students wanted to solve in their community. This sensemaking occurred during a positive discourse and was evidence that Mike's EDTSE was influenced by his desire to include equity in his lesson planning.

> I feel like in lot of my classes and even in this class we talk about using examples or problems that are practical and real and like relevant to the students so culturally basing your problem. So, I feel like the classic thing is an egg drop in physics. But that's not really that useful. It's not really that good unless its problem is relevant.

Thus, open discourse best facilitates sensemaking when mentors create positive environments. The positive environment is also influenced by peer, teacher, instructor verbal persuasion. Positive feedback (verbal persuasion) from the teacher facilitated sensemaking of how engineering lesson should be taught which influenced EDTSE. Two examples of positive teacher feedback were Malia and Isabelle. Malia shared,

> I believe that I am capable of teaching an engineering design lesson because I really do understand how they are supposed to be taught. After getting feedback from my practicum teacher, I feel like I'm going to be successful in teaching these types of lessons.

The teachers feedback mediated Malia's belief in successful teaching. Isabelle reported increased anxiety the previous week because she was worried her mentor teacher would be "mean" and provide negative feedback. She shared her experience of the communication between them during and after teaching. Malia explained,

> This teacher never taught an engineering standard before. And so, I was really nervous but then I taught the lesson…And she's said, I think you did so well. At the end of the day, she gave me this sticky note and she's said these are the things that you did really well that I'm really impressed on. You're in such a good place and these are the things that you should be working on. And it was just a sigh of relief.

Malia statement provides another example of mentor teacher's mediating EDTSE through positive discourse. Because the instructor could not predict teacher feedback to provide positive social discourse, the instructor viewed participant video to provide positive discourse. For example, participants reported receiving positive feedback from the instructor influenced EDTSE Alex shared,” I enjoyed reading my feedback from the instructor, which also made me feel more confident in my abilities.” Instructor positive feedback also mediated the internal discourse of the participants. Some participants had been very harsh in their estimation of successful teaching of engineering design. Isabelle statement supports the need for preservice teachers to engage in positive discourse from a mentor. Isabelle shared,

> After reading the feedback you gave me, I was surprised that you had scored me the way you did. I think my biggest thing is that I need to stop comparing myself to others and focus on myself. Mainly because it seems I am doing better than I think I am!

In summary, positive discourse from mentors was an aspect of the unit that facilitated sensemaking of task completion. Preservice EDTSE was mediated through verbal persuasion, including answering questions, negotiation of task competency, and open discourse peer sharing of ideas.

Mediating tools. Mediating tools enhanced activity and were typically either conceptual or practical, so professional learning supplies, materials, software, and exemplar lesson plans acted as practical tools while professional learning concepts, discussions, and reflections acted as conceptual tools (Grossman et al., 1999; Longhurst et al., 2022; Van Duzor, 2011). Participants were provided with needed mediating tools as an element of the unit that facilitated sensemaking of task completion. Research supports having access to tools will mediate their ability to transfer learning from professional learning to classroom practice (Campbell et al., 2014; Chao et al., 2017; Longhurst et al., 2017). However, participants outside of physics reported a lack of online lesson plans that could be used to facilitate lesson plan development. There was a deficiency of engineering design lesson plans aligned to state standards outside the physics content area. Participants described the desire to have readily available lesson plans aligned to state standards in their content area. Participants recognized their dependence on resources to help their EDTSE. Nora explained,

> I really heavily relied on resources because on my own I could not come up with activities in my head. So, having other already created activities that go along with certain things. I just took that, and it helped me change things around that I wanted to do more. But having that base of something out there is much easier.

Admittedly, finding engineering lesson plans aligned to state standards was not easy. Although there were websites offering lessons, most were mostly physics based. Many lesson plan providers focus on structural engineering, which was more difficult for the students to fit into chemistry and biology content. Few lessons supported the evaluate design solutions SEP. Jana suggested that creating and teaching ED as part of physics content was easy. “The physics standards are pretty easy to find engineering problems for the lesson plans. I feel pretty good about coming up with ideas.” Alex, a biology major, described the lack of biology engineering design curriculum resources. Alex shared, “Trying to create my lesson plan that I will be teaching took me hours to find a lesson.”

Professional learning should include practice using tools for later use in classroom practice or for continued adaptation of curriculum materials (Longhurst et al., 2022). Practice using lesson plan guides to develop curriculum adapted to state standards acted as both practical and conceptual becoming a bridging tool. Bridging tools act as both practical and conceptual mediating tools. The final lesson plan could serve as both a practical tool that could be replicated, or a bridging tool that could later be used to develop the lesson into a full storyline.

Mike described using the state core guides in building lesson plans as an element of the unit that influenced EDTSE. Core guides are state documents that assist educators in developing curriculum based on state standards. They act as bridging tools between standards and class curriculum. Participants in the methods course had previous experience with using and interpreting the core guides as a tool. Mike specifically mentioned the many tools the participants had access to and recognized that they affected his present EDTSE and could be instrumental in his future enactment,

> I think the factors that are influencing my self-efficacy are the existence of the Core Guide, engineering lesson idea websites…especially the core guide makes me feel I will be successful.

Video recording of teacher practice, the lesson template, core guides, and curriculum websites were mediating tools that facilitated learning and transfer. Using tools to initiate reflection, such as video self-monitoring, improved instruction through instructor validation of fidelity and supports previous research (Alexander et al., 2012; Bishop et al., 2015). Participants who used video self-monitoring led to a shift in teaching self-efficacy. Research suggests these shifts are positive (Newman-Thomas et al., 2012)., however this research suggests that in the moment views following video-self monitoring was often responsible for negative shifts. These negative shifts can be seen as progress retrospectively. Emily is one such example of a participant who reported decreased EDTSE following video-self monitoring. Her statement suggests that even though she reported decreased efficacy, shifts in efficacy reported negatively are seen retrospectively as progress. Emily explained, “I didn’t realize how much videotaping would help my teaching and then re-watching it would help me notice things I needed to work on, but also help me recognize that I am doing a good job teaching.”

Sociocultural environment reflection. The investigation was situated in two sociocultural environments (methods course and clinical class). Putney and Broughton (2010) suggest preservice self-efficacy research should continue examining self-efficacy through a Vygotskian lens of development over time and should examine the role of sociocultural reflective dialog in the developmental process. The data suggests that the sociocultural environment, which included reflective dialogue and non-verbal communications, was an element of the unit that influenced participant efficacy. The environments were responsible for negative and positive efficacy shifts that could be seen retrospectively as progress. Including the clinical class as an aspect of the research was necessary because preservice teachers develop their EDTSE in many sociocultural environments. Because the sociocultural environment influenced sensemaking, preparing and practicing engineering design across spaces and paradigms was intentional. Participants reported that several sociocultural environments were not supportive of change. Malia’s statement exemplifies working with teachers that are not teaching engineering design, possibly communicating that engineering standards are not important.

> My teacher talked about how there is no time for the engineering standards, but I noticed he was still using the old standards when he gave me the next lesson to teach.

Isabelle statement also demonstrated a resistance to change communicated through inaction.

> My teacher that I observed, I almost saw like a superiority. I've been doing it this way for so long, why should I change what I've been doing if it's working?

Tim statement is another example of alternate engineering design paradigms that do not foster engineering design as an aspect of science teaching. Tim shared,

> My mentor teacher wasn't so much like, why are you trying to teach engineering? She's, okay, I get it's a requirement, so I'll accommodate you. But this is a science class. So, the worksheet we used still had a bunch of more science-based questions. I was able to wrestle a couple engineering questions in there, but a lot of it was still, hey, this is a science class, let's focus on the science.

Another important aspect of school sociocultural climates are the professional learning communities (PLCs) within content areas. The sociocultural climate of the clinical class influenced participants perceptions of working in future PLCs to coordinate scope and sequence of curriculum and a belief that other educators would not welcome engineering design curriculum. Tim's statement demonstrated decreased efficacy based on the sociocultural climate of his clinical that was not welcoming to engineering design. Tim shared,

> I also think about the fact that we're going to be going into these schools teaching and nobody else is doing it and the importance of professional learning communities and collaborating with other teachers and if they're not doing it, why would I want to be doing it if nobody's going to be collaborating with me on it in my school….

This powerful statement reflects the social environment highly influences EDTSE the participants foresee teaching in. Their experience in clinicals was influencing the lens through which they anticipated negative feedback from their future collaborators. Nora is an example of a participant who felt the sociocultural environment negatively influenced her teaching of engineering design. She described her mentor teacher's refusal to include engineering design in a chemistry classroom. The sociocultural environment influenced sensemaking by limiting enactment. Nora described.

> I had a hard time working with my mentor teacher with this assignment. When we talked about me teaching an engineering design lesson, I don't think she understood what that fully meant.…I think I could have done a better job if I had more control over the lesson and if it were my own classroom.

Different sociocultural environments can have different value systems and criteria for measuring success. Therefore, as participants navigated between engineering design environments, the criteria for successfully teaching engineering design can change. Tim is a participant that articulated his concern. His lens of success was viewed from the social perspective of his mentor teacher.

> I was just thinking that when we do our clinicals, …our mentor teachers fill out an evaluation form. They're going to be evaluating based on what they think are best practices but when their best practices and our best practices don't line up, I'm nervous that I'm going to get a poor review from that teacher just because we're on different criteria.

Tim's insightful comment describes the experience of preservice educators teaching in a sociocultural environment with specific constraints and the effects on self-efficacy. Due to the number of clinical classrooms communicating a non-example of engineering design, discourse in the methods course centered on navigating and reflecting on sociocultural limiting factors.

Reflection leading to sensemaking of environmental concerns could positively shift participant EDTSE. An example of sociocultural environment concerns leading to sensemaking and EDTSE was Tim. Tim described the difference in his engineering design lesson compared to the typical science lesson observed during clinical class time.

This comparison in the same environment led to an observation of student engagement. Tim shared a student reaction to his engineering design lesson, “I could not tell you the number of times students have asked me if I can be their full-time teacher”. He explained that he had been thinking a lot late about the amount of frustration he felt during clinicals and how at first, he was letting the sociocultural parameters of the classroom negatively affect his EDTSE, but he was able to reason that his frustration was a good thing because it meant that he was motivated by student engineering literacy skill and knew the SEEd standards well. After reflection on the comparison of sociocultural environments effect on sensemaking, Tim stated his frustration with clinical teaching was good because he recognized his frustration was motivating him to teach using reformed science methods that include engineering design.

This research confirms efficacy development as an interpersonal process in sociocultural environments. The engineering design unit included elements of differing engineering design paradigms that communicated the importance of engineering design. Reflecting on the different sociocultural environments as an element of the engineering design unit facilitated EDTSE development.

Chapter Conclusion

Question one asked how preservice teachers describe their EDTSE at different time points of an engineering design unit. Through triangulation of data sources from all time point descriptions, participants describe their EDTSE as a developmental process on a continuum of onset, developing, emerging, and maturing. The existing preservice teacher efficacy development model did not fit the unique constraints of science preservice teachers due to the lack of engineering design modeling in clinical classrooms. Therefore, a modified preservice teacher EDTSE model was developed to describe secondary science more accurately. Interpersonal development is not linear but wavelike, shifting highs and lows depending on task competency analysis. Participant sensemaking informed individual task performance, intwining EDTSE beliefs and skill. Scaffolded tasks can produce positive and negative shifts that were seen retrospectively as progress with continued mentor sensemaking supports.

The stage of EDTSE development was interpreted from participant descriptions at time points corresponding to scaffolded tasks. Misconceptions, ignorance, and lack of experience describe the onset of EDTSE. This developing stage is characteristic by vicarious learning, EDP knowledge, and application to content standards. Individuals must be able to apply engineering design to standards to continue development. A shift from vicarious to mastery experience, lesson plan development, and micro-teaching indicate an emerging EDTSE. The maturing stage represents a shift to teacher practice through a mastery experience. Authentic teaching including explicit EDP language where preservice teachers can observe student engagement and learning is needed to reach the maturing stage. Continued development in the maturing stage can occur during student teaching if preservice teachers have the autonomy to enact engineering design curriculum. Limited autonomy to teach engineering design during the clinical class can confine participants to the emerging stage of development. Using the developmental model compared to quantitative instruments may better describe preservice teacher beliefs entwined with pedagogical skill and can assist professional learning developers with providing needed support for continued progression.

Research question two asked which elements of an engineering design unit facilitated participant sensemaking leading to increased EDTSE. Preservice teachers progressed in the stages of EDTSE through mentor supported sensemaking elements. The engineering design unit included elements that facilitated sensemaking and lead the development of EDTSE. Mentorship was the primary element that facilitated sensemaking. Through a Vygotskian lens, mentorship is the guidance a mentor (more knowledgeable other) provides that facilitates collaborative sensemaking. Mentorship took many forms, including providing engineering design knowledge, scaffolding pedagogical tasks, modeling engineering design teaching through experiential learning, positive discourse, providing access to mediating tools, and sociocultural climate reflection. Each mentorship form facilitated sensemaking leading to EDTSE because each was determined to align with a source of efficacy (verbal persuasion, physiological states, vicarious experience, and mastery experience).

CHAPTER V

DISCUSSION, CONCLUSION, AND IMPLICATIONS

This chapter synthesizes the findings described in chapter four from journal entries, focus groups, instructor notes, video observation, and journey maps. It also provides implications, recommendations, and explores future investigations. Eleven preservice teachers enrolled in a methods course at a university in the western U.S. described their engineering design teaching efficacy journey over an engineering design unit. The methods of instruction used at five time points correspond to mileposts along the journey. The conclusion, implications, and future research recommendations are based on the analysis of preservice educators' descriptions of their EDTSE journey at each milepost.

Overview of the Study

The purpose of this mixed method case study was to explore and describe preservice teacher engineering design teaching efficacy over the delivery of an engineering design unit in a methods course. Understanding and describing preservice educators' EDTSE is essential to understanding the enactment of state science standards, specifically standards inclusive of the "design a solution" practice. Curriculum developers and professional learning providers wanting to increase the appropriation of engineering design in science classrooms should understand EDTSE as a developmental process (Putney & Broughton, 2010) requiring mentorship from more knowledgeable others (Vygotsky, 1978). Preservice educators' initial lack of experience and low EDTSE could explain why most science teachers report feeling unprepared to teach engineering (National Science Board, 2014). The *Framework* states engineering design is an essential element of science education. Still, before this vision can be fulfilled, professional learning developers may want to understand how science teachers with little engineering design experience can develop a mature EDTSE. This study provides a valuable description of how professional learning providers can assist in developing participant EDTSE to a mature stage of development. Preservice teachers that do not develop mature efficacy may return to pre-methods course levels of efficacy after student teaching (Wagler & Moseley, 2005). Due to the lack of preservice science teacher experience with ED, enacting reforms in science education should address teacher self-efficacy in preservice programs (Czerniak & Lumpe, 1996).

For the reasons listed above, the research questions that guided this study were as follows.

1. How do preservice teachers describe their EDTSE at different time points of an engineering design unit?
2. Which elements of an engineering design unit facilitate preservice teachers' EDSTE development?

Teaching engineering design as part of science standards can help to fulfill the need for an engineering-literate populace (National Academies of Sciences, 2020). Teaching science and engineering literacy is essential for students to apply problem-solving (Kaya et al., 2017). When science educators include engineering in their teaching (as in the NGSS), they experience a shift in science instruction to include more student-centered pedagogies and effective learning transfer (Boesdorfer, 2017; Christian et al., 2021; Romero-Ariza et al., 2021).

Research by Van Haneghan et al. (2015) suggests “tracking, examining, and influencing what teachers believe about outcomes related to engineering education is an important area of research” (p. 8). Failure to study preservice science educators’ development of EDTSE may result in knowledge gaps and potentially a lack of enactment. Preservice teachers have unique needs and constraints, including enacting a curriculum when their mentors have likely never taught engineering. Describing how preservice science teachers develop engineering efficacy in methods courses is essential as a precursor to understanding science teacher enactment of the NGSS or state science standards (Nesmith & Cooper, 2021)

Discussion and Interpretation

Strengthening efficacy beliefs is essential for preservice educators seeking to enact curriculum reforms (Czerniak & Lumpe, 1996). Thus, when studying science education reforms which include engineering education, researchers in this study used a mixed method case study emphasizing qualitative methods to describe preservice educators’ EDTSE. This allowed for rich descriptions of the participants’ experience during an engineering design unit in a methods course. Research suggests it is essential to prepare for integrating science and engineering by first describing what it looks like at the state level (Hutner et al., 2022). The analysis in this chapter hopes to describe what integrating science and engineering looks like in a methods course in a western U.S. state. The analysis presents answers to the research questions in order. The first research questions will be answered using the analysis of preservice teacher EDTSE changes that occurred over the development and delivery of the engineering design unit. The second research question will be answered using the analysis of elements of the engineering design unit that influenced preservice teacher EDTSE. Elements of the unit that influence efficacy will be described using a Vygotskian lens that considers both sociocultural influence and traditional aspects of Bandura's Social Cognitive Theory (1997, 1993).

Theory in Analysis

Bandura's Social Cognitive Theory (1977, 1993) describes self-efficacy as an individual's internal motivation and drive for accomplishment. Related to an individual's well-being, self-efficacy embodies perceptions of personal achievement and the ability to master specific tasks or attainments (Bandura, 1977). Bandura suggests that four primary sources contribute to an increase in self-efficacy, including mastery experiences, vicarious experiences, social persuasion, and emotional or psychological states, with mastery experiences being the most influential and psychologic states the least influential (Bandura, 2015). The stages of the intervention aligned with the sources of efficacy to ensure all sources were addressed. Teacher journals include nomothetic and ideographic descriptions of EDTSE using the construct of confidence, motivation, the expectation of success, and anxiety as related to the sources of teaching efficacy (Yoon et al., 2014; Yoon Yoon et al., 2014).

Socially constructed meaning-making of personal and social experiences are responsible for teacher conceptions of engineering design (John-Steiner & Mahn, 1996). This research employed a sociocultural lens to planning the intervention and analysis of

EDTSE over time, time points, and shift descriptions. Bandura's (1993, 1997) self-efficacy theory is also used to describe preservice educator EDTSE. This unique lens allows for the addition of language to describe efficacy as a developmental process where meaning-making is constructed through mentor/mentee relationships, instructor/student relationships, and peer language reflective dialog (Putney & Broughton, 2010, 2011a). Vygotsky (1978) suggests efficacy, traditionally thought of as an interpersonal process, can develop into an intrapersonal process through a "long series of developmental events" (p. 57). These "developmental events" were replicated in this study as methods of instruction targeted over five time points. Because developmental learning envelops individual and group dimensions (Souza, 1995), efficacy development may not be linear or predictable (Putney & Broughton, 2011a). EDTSE may develop wavelike with shifting highs and lows depending on the intervention stage (developmental event). "How a person learns a particular set of knowledge and skills, and the situation in which a person learns becomes a fundamental part of what is learned" (Putnam & Borko, 2000, p. 4). To discuss the situation, learning, and beliefs, the "Preservice Teacher Efficacy Developmental Scale" (Putney & Broughton, 2010, p. 12) was used to analyze the preservice teacher development of EDTSE over the development and delivery of the unit. Efficacy is described as a three-stage developmental process progressing on a spectrum from the onset, developing, to maturing (Putney & Broughton, 2010). Although efficacy develops on a continuum, there can be situational fluctuations (Goddard et al., 2004), described as shifts that occur at each stage.

Elements of an Engineering Design Unit

The elements of an engineering design unit that influence preservice teacher EDTSE are those sociocultural elements that facilitate sensemaking. Mentors provide sensemaking guidance between what a teacher can do independently (too easy) and what a teacher cannot do (too hard). This space is described by Vygotsky (1978) as the Zone of Proximal Development. Preservice teacher mentorship can be provided by teacher development instructors, peers, and mentor-assigned teachers that act as the more knowledgeable other. When studying the enactment of preservice teacher engineering design curriculum, the replication of school-based mentors modeling engineering design was pivotal to the appropriation of engineering design (Capobianco & Radloff, 2022). Due to the lack of engineering design modeling by clinical assigned mentor teachers in this study, method course instructors can develop engineering design units and serve as engineering design mentors.

Mentoring during engineering design units can increase EDTSE through diverse ways, including providing engineering design knowledge, the scaffolding of pedagogical tasks, modeling using experiential learning, using positive discourse, providing access to mediating tools, and through sociocultural environment reflection. Although this list is not exhaustive of all the ways mentors can increase the sensemaking of engineering design, it does include the major elements of the engineering design unit in this study. Each of the mentor-provided unit elements was a mediator of efficacy development.

Mentorship facilitates sensemaking leading EDTSE by addressing the sources mediating efficacy. Mentors provide mastery experiences, vicarious experiences, social persuasion, and reflection on psychological states. Mentors scaffold tasks and provide the content and pedagogical knowledge to make sense of the tasks. This research supports the sensemaking description by Weick et al. (2005) as a sociocultural mechanism that facilitates change in activity over time, which activity leads to the progression of cognition. Initial task competency is analyzed through a physiological lens informed by social dialogue. Vygotsky (1978) suggests that individuals use past experiences to initiate sensemaking when introduced to learning. If individuals lack experience or they are rooted in misconceptions, task competency may be considered too difficult, and learning does not occur. Thus, mentors are needed to guide metacognition of engineering design experience and beliefs. Mentors can then provide vicarious and mastery experience tasks. Mentors continue to provide positive discourse (verbal persuasion) and consider physiological states such as teaching anxiety.

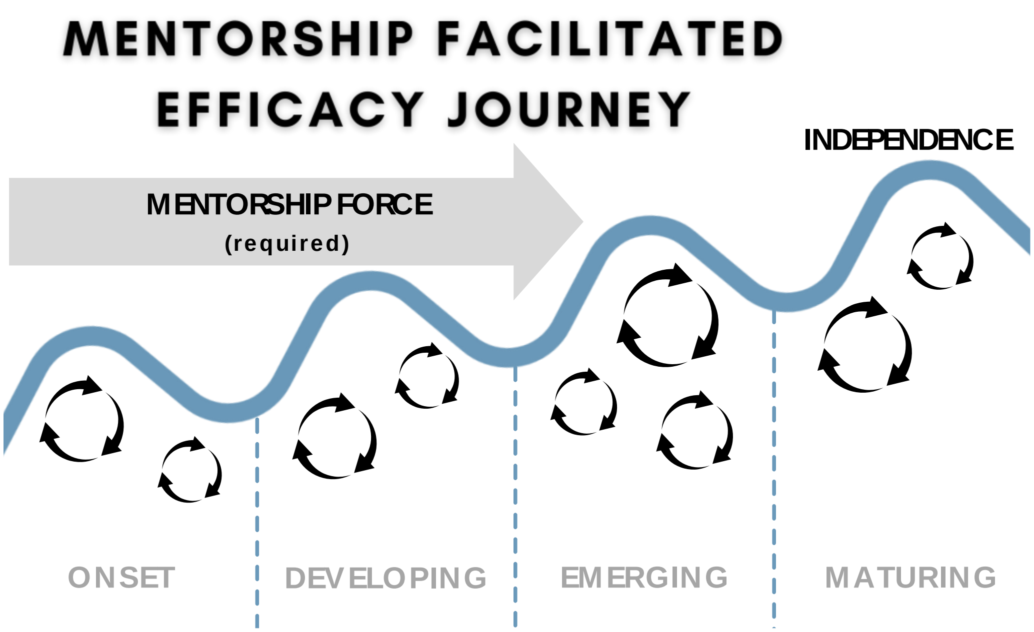
Mentors scaffold tasks from vicarious to mastery experience to ensure that the task is not too difficult for preservice teachers. Collaboratively informed task competency is facilitated by preservice teacher sensemaking. Task competency analysis leads the development of EDTSE. With each mentor-introduced task, a teaching efficacy cycle develops, and the mentor provides new resources from which the individual assesses teaching competence. This supports previous research that task analysis initiates cyclical efficacy development (Tschannen-Moran et al., 1998). Thus, continued mentorship through a series of tasks while providing the necessary sensemaking resources to accomplish the tasks is needed for EDTSE progression. Mentorship continuing through a series of tasks supports research that efficacy is developed and maintained over a period of time (Putney & Broughton, 2010, 2011; Ward et al., 2020). However, it adds to the research that preservice teacher EDTSE is built and maintained through collaboration with a mentor through a series of tasks until the preservice teacher recognizes their need for varying levels of autonomous enactment. Highly efficacious preservice teachers report having positive mentor relationships and teaching supports (Capa Aydin, 2005), and this research adds that the teaching supports can be further described as mentor-facilitated sensemaking of a series of task analyses.

Engineering Design Teaching Self-Efficacy Description

The analysis of EDTSE over time supports previous research that describes efficacy as a developmental process through time (Putney & Broughton, 2010, 2011). Preservice teachers' EDTSE over an engineering design unit in a methods course is described as a progression of efficacy onset, developing, emerging, and maturing stages on the *Engineering Design Teaching Self-Efficacy Progression Model* (see Figure 9). The primary determination of the EDTSE stage is preservice teacher sensemaking of scaffolded tasks competency analysis leading to EDTSE progression. Preservice teacher EDTSE progresses as a wave with shifting highs and lows depending on interpersonal negotiation of task competency. The following descriptions of the stages and task accomplishments can assist professional learning developers in applying the *Engineering Design Teaching Self-Efficacy Progression Model* to describe individual stages. Describing stages of efficacy development instead of statistical increases can assist professional learning providers with understanding the unique needs of individuals and the mentor supports that must be in place to enact engineering design in secondary science classrooms.

Figure 9

Engineering Design Teaching Self-Efficacy Progression Model



The onset stage of development describes preservice teachers that report a lack of experience, misconceptions, and general unawareness of engineering design and its inclusion in state standards. This supports research that suggests preservice teachers begin methods courses with little understanding of engineering design (Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Kim et al., 2019). When preservice teachers are introduced to engineering design separately and as an aspect of standards to accomplish a pedagogical task, a cycle of EDTSE ensues. Task competency analysis may result in negative or positive efficacy shifts. However, fluctuations in EDTSE are evidence of progression when coupled with continued mentorship from a more knowledgeable other (Vygotsky, 1978). Providing continued mentorship through each stage is essential because research by Loucks-Horsley and Styles (1996) suggests preservice teachers need continued mentorship, or they may return to preintervention methods of instruction.

The developing stage is characteristic of preservice teacher observation and experiential learning of engineering design by content area. The development of EDTSE can be domain and content specific. The developing stage aligns with vicarious engineering design experiences. Preservice teachers negotiate teacher practice in connection to the language and intent of state standards. Research by Daugherty and Custer (2012) suggests that much engineering design learning is focused on doing engineering design activities but suggests the learning of engineering design would be more effective if tied to standards and content-specific learning objectives. Thus, this research suggests experiential learning by content area can be used to promote a student and teacher perspective on engineering design aligned with the curriculum.

The emerging stage represents the preservice teacher transition to teacher practice. Micro-teaching with mentor and peer feedback provides a transition from vicarious to mastery experiences. During the emerging stage, the preservice teacher focuses on curriculum enactment. To progress to the efficacy emerging stage, the evidence suggests a self-created lesson plan be created and micro-taught to peers. Research suggests preservice teachers need opportunities to develop content and pedagogical content knowledge (Aydin-Gunbatar et al., 2018; Kilty & Burrows, 2019; Love & Hughes, 2022).

The Maturing stage is achieved when preservice teachers have successfully taught an engineering design lesson and received student feedback on engagement. In this stage, preservice teachers focus on teacher practice in relation to student understanding and the class's sociocultural experience. The maturing stage emphasizes mastery experience and the development of outcome expectancy. Preservice teachers with the autonomy to enact engineering design curricula during student teaching may continue to develop within the maturing stage.

When seeking to increase teaching self-efficacy, research suggests authentic teaching experience is needed (Can, 2015; Cinici, 2016; Ferguson & Sutphin, 2019). When studying teacher professional development, Nagle and Bishop (2021) reported teachers need to practice with students as a part of professional learning to bring about lasting change in practice (Nagle & Bishop, 2021). Although some studies report preservice teachers decreased in self-efficacy following authentic instruction with students (Polat et al., 2021), this study supports no apparent teaching shock (Flores, 2015), possibly due to the mentorship of scaffolded tasks. Based on this research, using video self-monitoring as a mediating tool improved instruction and created shifts in efficacy. Research by Bishop et al. (2015) supports the need for instructor feedback to ascertain fidelity (Bishop et al., 2015). Self-reported results of successful engineering teaching were not enough to determine actual pedagogical skills to teach engineering design; thus, video monitoring from a mentor assessed the preservice teacher's explicit engineering design teaching. Research by Johnston et al. (2019) suggests how a science teacher talks about engineering reflects understanding and affects student conceptions of engineering. Thus, explicit engineering design language used while teaching was assessed during the video to measure the successful teaching of engineering design.

After reflecting on observed student engagement and cognition, participants developed outcome expectancy. Outcome expectancy describes a teacher's confidence to use and apply effective teaching methods that will positively impact student outcomes (Ward et al., 2020). Preservice educators' mature EDTSE resulted in the belief that engineering literacy and problem-solving were needed skills for classroom students.

Describing the stage of development may be more beneficial than measuring statistical increases in efficacy because the progression model entwines preservice teacher efficacy and practice. This supports research that describes teacher self-efficacy as intertwined with teacher practice and developing through reflective interpersonal negotiations of task analysis (Bandura, 1993; Putney & Broughton, 2010; Tschannen-Moran et al., 1998; Yoon Yoon et al., 2014). For example, research by Smith et al. (2021) studied in-service teachers during a masters level maker space course. Over the 15-week course, teachers from varying content areas were found to increase in EDTSE, with most participants reporting their ability to contextualize making to their content area standards. By applying the *Engineering Design Teaching Self-Efficacy Progression Model*, it would suggest the participants were able to reach the efficacy development stage. To progress to the emerging stage, these educators would need continued mentorship to develop a curriculum aligned to their content standards, transferring vicarious learning to mastery learning through microteaching of their curriculum. For another example, research by Crawford et al. (2021) reports increased teacher efficacy resulting from 45 hours of an intervention focused on developing and delivering nanotechnology curriculum. Applying the progression model to this study would suggest the participants developed a maturing efficacy because teachers developed and tested the curriculum in their classrooms while reflecting on student engagement and conceptual understanding. The teacher developed outcome expectancy supporting the development of a mature EDTSE.

Recommendations

This mixed method research aimed to describe preservice teacher EDTSE over the development and delivery of an engineering design unit in a methods course at a university in the western U.S. Researchers analyzed the elements of the unit that influenced EDTSE and analyzed descriptions of EDTSE at each time point of the unit. Based on the interpretation of the analysis, recommendations to increase preservice and in-service science teacher EDTSE are discussed.

Teacher Preparation

This research supports developing in-depth engineering design units in science methods courses in the context of science and engineering practices to increase engineering design pedagogical content knowledge as recommended by Love and Hughes (2022). Previous research recommends intentionally including engineering design pedagogical knowledge units to increase EDTSE (Aydin-Gunbatar et al., 2018; Hill-Cunningham et al., 2018; Kilty & Burrows, 2019; Kim et al., 2019) because preservice teachers are resistant to change once established (Hoy & Spero, 2005) often returning to preintervention methods of instruction (Loucks-Horsley & Styles, 1996).

Based on this research, engineering design pedagogical knowledge was a facilitator of sensemaking that led the development of EDTSE, and thus, it is a recommended inclusion in engineering design units. Nesmith and Cooper (2021) suggest that learning about engineering design in methods courses will increase EDTSE. Still, this research indicates the intent must be to reach a maturing stage, so engineering design is enacted as a part of regular science instruction (DiFrancesca et al., 2014). When researching enactment, it was reported that an emphasis on efficacy during an intervention was responsible for increasing sustainable change and enactment (Blonder et al., 2014; Blonder & Mamlok-Naaman, 2016). This research supports teaching engineering design in methods courses to increase the later enactment of engineering design.

Science methods instructors may consider using the *Engineering Design Teaching Self-Efficacy Progression Model* to analyze engineering design units that scaffold learning events to develop efficacy. Due to the number of mentors not modeling engineering design lessons during clinical or practicum experiences, it is recommended that teachers serving as mentors receive professional learning that includes an emphasis on EDTSE because research by Simsar and Jones (2021) suggests that mentor teachers with higher science self-efficacy play a pivotal role in mentee efficacy development.

Based on this research, it is recommended that curriculum developers create content area teams to develop engineering design resources, including lesson plans, aligned to NGSS and state standards. Because of the number of methods course students who expressed a desire to know about engineering design by content area, it is recommended that teacher education programs require a course by major from an engineer working in that field. For example, it is recommended that biology majors take an introductory course in biological engineering. If that is not possible, it would be recommended to include a session or task in the methods course to meet with engineers in their field to be taught about current engineering design applications by content area. For example, chemistry teachers could interview a chemical engineer to learn how chemistry is used to solve problems. Learning engineering focused on content may overcome the misconception that engineering design is only for structural physics (bridges and rockets).

This research supports previous research suggesting that the EDP and applications should be taught before introducing standards to facilitate a more nuanced understanding of the science and engineering practices and decrease misconceptions (Cunningham & Carlsen, 2014). Introducing tasks that scaffold the development of engineering design curricula aligned to state standards may facilitate sensemaking. This research supports research by Lewis et al. (2019) that suggests creating a curriculum in positive social environments will allow participants to collaborate and receive the support needed to enact the curriculum.

Inservice Professional Learning

Preservice educators and in-service teachers represent groups that display efficacy onset, supporting previous research that teachers begin engineering design professional learning with little understanding of engineering design (Nesmith & Cooper, 2021). Therefore, all the recommendations for teacher preparation apply to in-service professional learning. Based on this research, teachers may progress to the efficacy maturing stage quicker after professional learning if they receive continued mentor support through the efficacy maturing stage (enacted self-created lesson plan that results in EDTSE increase). The EDTSE progression model allows professional learning developers to assess and describe individual EDTSE growth resulting from a professional learning experience. Therefore, based on this research, it is recommended that professional learning use the model to describe EDTSE developmental stage instead of measuring statical growth alone. Doing so may lead to continued mentorship from a more knowledgeable person through the maturing stage of development. Teachers that teach more than one science content may need continued mentorship as they apply engineering design to multiple content standards due to the finding that applying the EDP to curricula was found to require domain specific knowledge.

Limitations and Assumptions

Limitations of the study include the small sample size of eleven preservice teachers. However, it does consist of all preservice science teachers before beginning their student teaching at a university in the western U.S. The course instructor served as a researcher, and preservice educators may have felt inclined to report positively. To help negate this effect, the classroom procedures and assignments are intended to replicate and continue classroom norms established during the first science methods course. Classroom practice followed a pattern of individual reflections turned in on Canvas following the weekly session. At the beginning of class, an open discussion was held on the previous week's application to self (student hat) and future classroom practice (teacher hat).

Preservice educators concurrently participated in a required clinical course where they developed and taught lessons, wrote observations and reflected on their classroom experience. A potential limitation is the lack of positive support from mentor teachers who have not yet received professional training on the newly established state SEEd standards and the engineering practices during the clinical class. Mentor teachers may experience low EDTSE themselves. A group discussion about the familiarity of the participants' mentor teachers with engineering design helped participants reflect on the mentor teacher's comments. To mediate mentor teacher feedback, students received feedback on their lesson and instructional methods from the methods course instructor. All preservice educators, participating or not, were required to complete all the assignments serving as data instruments as part of the normative classroom experience.

Criterion-related validity was addressed using student engineering experience. Preservice educators were asked to reflect on and report prior experiences with the EDP. It is assumed that students with more engineering experience are more likely to initially report higher engineering design self-efficacy than those with less engineering experience.

Future Research

It is recommended that future research continue describing preservice and in-service teacher development of EDTSE using qualitative methods. Research by Smith et al. (2021) found that weekly journal entries provided greater insight into EDTSE development in comparison to pre/post quantitative surveys. The study's emphasis is on a qualitative approach allowed for in-depth descriptions of science teachers tasked with enacting state standards and sociocultural influences. The addition of a Vygotskian (1978) lens in research allowed for a rich description of participant efficacy progress occurring in the zone of proximal development with more knowledgeable others (Putney & Broughton, 2010, 2011). Therefore, this lens may increase understanding of how multiple sociocultural environments affect efficacy. *The Engineering Design Self-Efficacy Progression Model* (see Figure 9) can be used to describe the stage of teacher efficacy progression. Researchers can provide greater depth in understanding using the progression continuum than pre, post, and delayed post-EDTSE survey descriptive instruments since efficacy can develop over time with wavelike fluctuations (Goddard et al., 2004; Putney & Broughton, 2010).

Because EDTSE was found to develop over time with mentorship, future research could include quantifying the number of secondary science teachers by state and district teaching engineering standards to assess the need for professional learning. If teachers are not including engineering design standards in their curriculum, then it is recommended to evaluate the reasons. Research is often conducted to study the integration of STEM and maker space in secondary education. However, it is recommended that more research be conducted on preservice and in-service science teachers enacting engineering design in the NGSS and state science standards based on the percentage of preservice teachers in this study that reported few mentor teachers' inclusion of engineering design. Researchers studying secondary science teachers in the broader context of STEM can still include engineering design in their standards. Based on the research results, further research could focus on EDTSE as a precursor to engineering design curriculum enactment. Longitudinal studies could be conducted on the engineering design units in methods courses and the attained EDTSE stage on later implementation. This could allow curriculum developers and professional learning providers to better assess the mentoring needs of teachers when enacting engineering design.

Conclusion

In conclusion, preservice educators develop EDTSE during engineering design units with a wavelike progression. The fluctuations are evidence of progression when coupled with continued mentorship that facilitates sensemaking. Preservice educators can progress from the efficacy onset, developing, emerging, to maturing stages on a continuum of efficacy cycles. Each stage is associated with a task scaffolded by a mentor. A mentor facilitates sensemaking by including the necessary content and pedagogical knowledge to accomplish the tasks aligned with the sources mediating efficacy. Preservice teacher interpersonal negotiations of task competency initiate a cycle of efficacy which leads EDTSE progression. Preservice educator belief in task competency is pivotal in the developmental process.

Descriptions of the stages in the developmental process can assist professional learning developers in applying the *Engineering Design Teaching Self-Efficacy Progression Model* (see Figure 9) and describing the needed sensemaking supports guided by mentors. Mentors are needed to act as a more knowledgeable other guiding sensemaking in the Zone of Proximal Development (Vygotsky, 1978). Describing stages of efficacy development instead of statistical increases can assist professional learning providers with understanding the unique needs of individuals and the mentor supports that must be in place to enact engineering design in secondary science classrooms.

Based on this research, when describing EDTSE, the sociocultural learning environment was intertwined with what was learned (Putnam & Borko, 2000). These findings support research that explains classroom practice as a social endeavor with complex relationships between teacher beliefs and reforms in teaching practices (Putnam & Borko, 2000). Based on interpretation of the case, the EDTSE journey during an engineering design unit is a progression of developmental stages that require mentorship through social sense-making. It is the belief of this author that describing engineering design teaching efficacy as such will lead to better supports for science teachers enacting engineering design leading to increased enactment and greater student engineering literacy.

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APPENDICES

Appendix A

Institutional Review Board (IRB) Approval

Preservice Teacher Engineering Teaching Efficacy

You are invited to participate in a research study by ***Dr. Max Longhurst in TEAL at Utah State University.***

The purpose of this research is to investigate preservice science teacher's engineering design teaching efficacy over the course of a science methods engineering unit. Your participation is entirely voluntary. This form includes detailed information on the research to help you decide whether to participate. Please read it carefully and ask any questions you have before you agree to participate.

Your participation in this study is voluntary and you may withdraw your participation at any time and for any reason by notifying the class instructor or principal investigator.

If you take part in this study, you will be asked to participate in all normal class activities and assignments and will involve using class assignments as data. Weekly journal entries, a journey map, and a teaching video are all normal class assignments that will be included in the study and graded based on completion for the course. Focus groups will be held during the first fifteen minutes of class.

This is a minimal risk research study. That means that the risks of participating are no more likely or serious than those you encounter in everyday activities. The foreseeable risks or discomforts include a possible loss of confidentiality. To minimize those risks and discomforts, the researchers will store data on password protected software. All identifiable data will be replaced with pseudonyms. Students who choose not to participate in the study will not be penalized during the science methods course.

We will collect your information through Canvas assignments and audio recordings of focus groups during class sessions. Class assignments used as data sources will be journaling, journey maps, and video recordings of teaching. Online activities always carry a risk of a data breach, but we will use systems and processes that minimize breach opportunities. These class assignments and audio recording transcripts will be securely stored in BOX. Audio and video recordings will be deleted following analysis and transcription which shall not exceed the length of the course.

Although you will not directly benefit from this study, it has been designed to learn more about preservice science teacher engineering design efficacy and the development of engineering design units to promote the inclusion of engineering practices in science classrooms.

The researchers will make every effort to ensure that the information you provide as part of this study remains confidential. Your identity will not be revealed in any publications, presentations, or reports resulting from this research study. We will collect your information through Qualtrics and Canvas. Online activities always carry a risk of a data breach, but we will use systems and processes that minimize breach opportunities. This data will be securely stored in a restricted-access folder on Box.com, an encrypted, cloud-based storage system.

Your participation in this research is completely voluntary. If you agree to participate now and change your mind later, you may withdraw at any time by notifying your instructor. If you choose to withdraw after we have already collected information about you, we will not collect future data. You will still be expected to complete all class assignment.

The Institutional Review Board (IRB) for the protection of human research participants at Utah State University has reviewed and approved this study. If you have questions about the research study itself, please contact the Principal Investigator at max.longhurst@usu.edu. If you have questions about your rights or would simply like to speak with someone other than the research team about questions or concerns, please contact the IRB Director at (435) 797-0567 or irb@usu.edu.

Dr. Max Longhurst
Principal Investigator
(435) 797-3041; Max.Longhurst@usu.edu

Laura Wheeler
Co-Investigator
801-710-2011 laura.wheeler@usu.edu

By clicking "I Agree" and signing below, you agree that you are 18 years of age or older and wish to participate. You agree that you understand the risks and benefits of participation, and that you know what you are being asked to do. You also agree that if you have contacted the research team with any questions about your participation and are clear on how to stop your participation in this study if you choose to do so. Please be sure to retain a copy of this form for your records.

______________________________ _________________________________ __________________

Participant's Signature Participant's Name, Printed
Date

Appendix B

Time Point Grading Protocol

Time Point Grading Protocol

Student ______________________ Date _________________________

Time Point ________________________ Source _________________________

Teacher EDTSE Statements.
0 = Not present, 1 = low EDTSE, 2 = Limited EDTSE, 3 = Moderate EDTSE, 4 = Substantial EDTSE 5 = High EDTSE
Rate each variable and include evidence that contributes to the rating.

Variable	0	1	2	3	4	5
Confidence						
Anxiety to teach						
Motivation						
Expectation of success						
General EDTSE						

List statement of the method(s) of instruction that contributed the EDTSE estimated above.

List statements that describe changes in EDTSE.

Appendix C

Video Observation Protocol

Video Observation Protocol

Student _________________________ Date ________________________

Time Point 5 following classroom teaching Source Video vs. Journal Entry

Instructor perceptions of student confidence, anxiety, motivation, and success

0 = Not present, 1 = low EDTSE, 2 = Limited EDTSE, 3 = Moderate EDTSE, 4 = Substantial EDTSE 5 = High EDTSE

Rate each variable and include video observations that contribute to the rating

Variable	0	1	2	3	4	5
Confidence						
Anxiety						
Motivation						
Successful Teaching of ED						
General EDTSE						

Compare video rubric to Journal entry 5. Is there any difference, and if so, what are they?

1. Confidence

2. Anxiety

3. Motivation

4. Expected success vs. instructor rating of success

5. General EDTSE

Appendix D

Video Assignment

Video Assignment

During your student teaching, you will need to be able to reflect on your ability to accurately teach concepts and impact change in students (Ppat). To complete this assignment and to prepare you for student teaching, you will need to upload a video (20-30 minutes) to a google file and make the link sharable so I can view the file. The video will be of you teaching your engineering design lesson. Please do not video the students in the class. Please keep the video on you as much as possible. If you begin to move around the room to work with students, please stop the recording first. To become a reflective practitioner, please answer the following questions immediately after teaching the lesson. Wait a week, then watch the video of you teaching and reflect again. This assignment is graded based on completion only.

**Before you video yourself teaching in the classroom, the mentor teacher will send out an email to the class notifying the parents that you will be recording yourself for educational practices and that the video will be deleted after I have viewed it.

Before watching the video, please rate and comment on the following.

***** Please provide specific examples of why you answered the way you did to justify each rating.

1. Your confidence to teach engineering design (0-5)

2. Your level of anxiety to teach engineering design (0-5)

3. Your motivation to teach engineering design (0-5)

4. How successful were you in teaching the engineering design process and concepts related to your chosen standard (0-5)

5. In general, how would you rate your engineering design teaching self-efficacy (0-5)

Now watch the video and imagine that you are one of the students or an observer in the class. Please answer all the previous questions but do so from the perspective of an observer.

Answer questions 1-5 again

Did any differences exist after watching the video?

Why do you think?

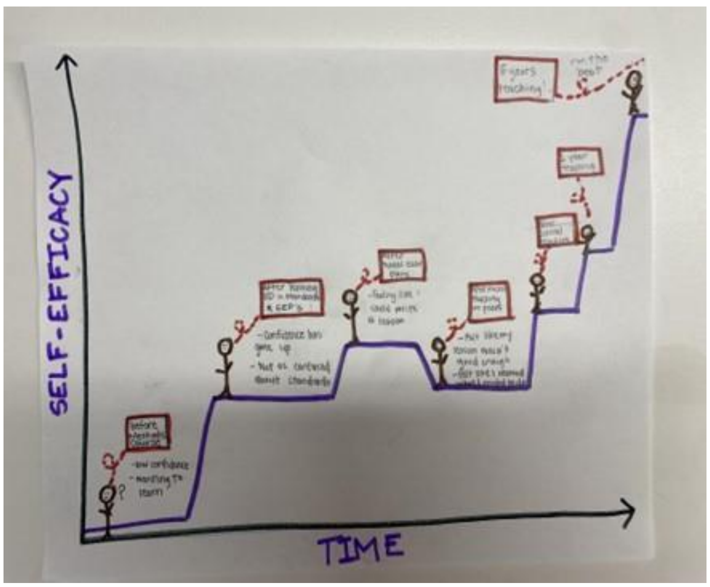
Appendix E

Journey Map Images and Transcripts

Journey Map Images and Transcripts

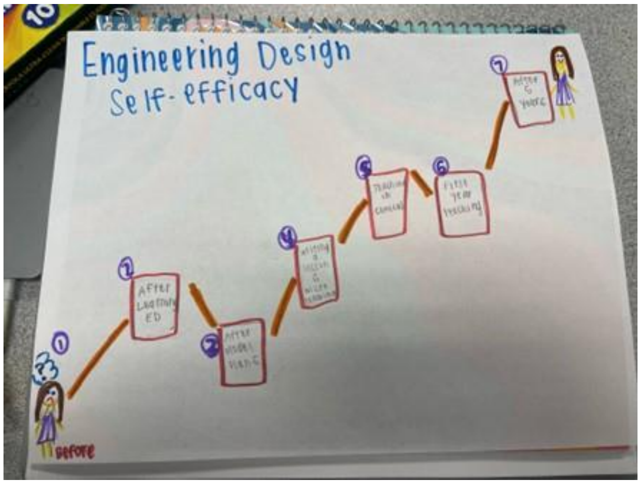
Jana

Here is my journey graph over time and how my self-efficacy has changed. Before my methods course, I was confused. I had low confidence, but I was wanting to learn. My confidence grew a lot. After I was able to learn engineering, design and SEPs, because I felt like I knew more of what I was doing, my confidence went up a little bit more after it was modeled in class, and I felt like I could write a lesson. It went down after I micro taught to my peers because I felt like my lesson wasn't good enough compared to everyone else's, but I still felt like I could do what I needed to. My conference went up a lot more after I taught my clinical and I can just only see it going up as I keep teaching. So, after five years, I'm gonna be the best teacher and I'll have a very high self-efficacy.

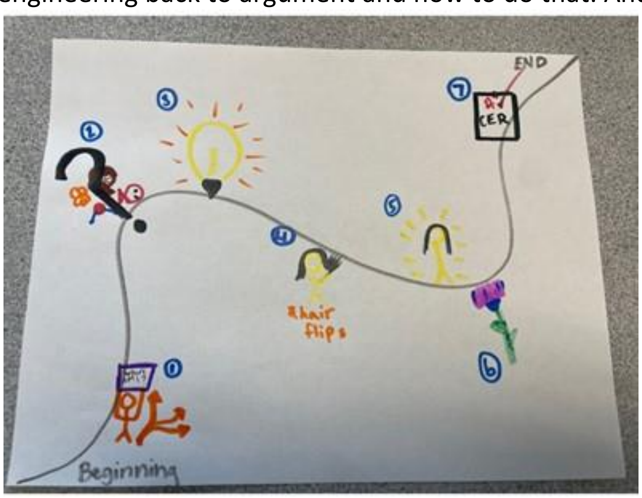


Alex

So, here's my map. And I'm here before I have before learned anything. I'm sad and confused, Self- efficacy's low, the lowest it's been, and then after reading about it , it goes up. But then following that after modeling it drops because I am confused, and I was feeling like I was on the wrong page. But then after I wrote a lesson, when I micro taught it, my efficacy went up and then went up again after teaching because I gained more confidence and experience. My sixth is after my first-year teaching. I'm expecting it to go down because I'm just assuming that there is gonna be problems, but I'm gonna learn from those experiences. Then after five years it goes up.

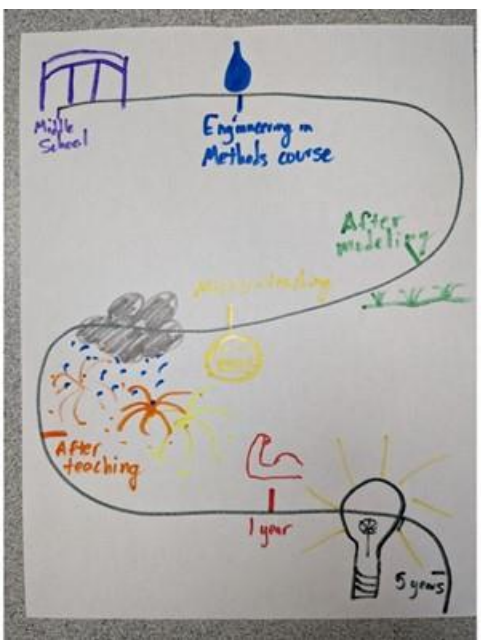


Emily
This is my journey map. And so we start here at the beginning and that says, where am I? There’s a bunch of different roads to go on because I was just like, when I sync those, I didn’t know how to approach it and I didn’t know what to do. And I didn’t do engineering. I haven’t had engineering classes. So I was just really nervous and lost. And then once we started learning about it more, I started to question how does this apply to biology? How does engineering, what does it do? And once we got to make a lesson and kind of teach our peers and talk about it more like bulb started to go off, especially, I think I emailed you a lot about what to do in my classroom. And that started sparking a lot of a lot of ideas with how I can approach engineering design in my classroom. And then after I taught it once to my family, I kind of was like, okay, I know what I can approve on. And so I did the hair flip because I felt a little more confident in my ability to teach engineering in my biology classroom. And then after number five, after I taught it to my clinical class, I felt like I was glowing because my flowers glowed. And so, I was like really excited about that. Excited to incorporate engineering inside my own classroom where like at one point I was really kind of against it. And then this number six is one year down the line I’ll be doing my glowing flowers in my classroom, and it will kind of be full circle. I’m consistently tying engineering back to argument and how to do that. And I’m good at it.



Tim

So I'll start at 1. In middle school I drew a very artistic picture of a bridge here because in middle school I was told that I was going to be good at engineering because I did well in math. And so, I thought engineering was just making bridges. 2 is when we started talking about engineering in this methods course. I drew this as like a, a bead of sweat. I started getting nervous just because I feel like I never really understood what engineering was supposed to be. So it did make me nervous. Let me move on to 0.3. This is after we did some of the modeling lessons in class this horizontal line would be brown for just dirt. But then these little sprouts coming up, I feel like represented my budding confidence, like thinking, okay, I can do this. So then after Microteaching I tried to do the emoji that's like just kind of like gritting teeth because I did not feel good after Microteaching. I felt like I, there's no way I could teach this. I was so disorganized, my thoughts were everywhere. But then after, after teaching, you can see my very artistic fireworks. I felt pretty good after at least I felt like it didn't go as badly as I feared it would. And I think there were some good things that came out of it. But I still have this rain cloud raining on my fireworks because I don't feel like I reached my potential necessarily. And then I'm hoping that this is my flexibility. Do that after one year of teaching, I will have my engineering lessons more or less pinned down the principles and DCIs and, and the activities that I want to use. I hope I'll have them down. And then after five years of practicing teaching, I feel like that's when like the light bulb moment will hit. Or rather, not that it will hit, but that it will just be that I'll have the confidence and experience and lesson plans necessary to just teach very well.



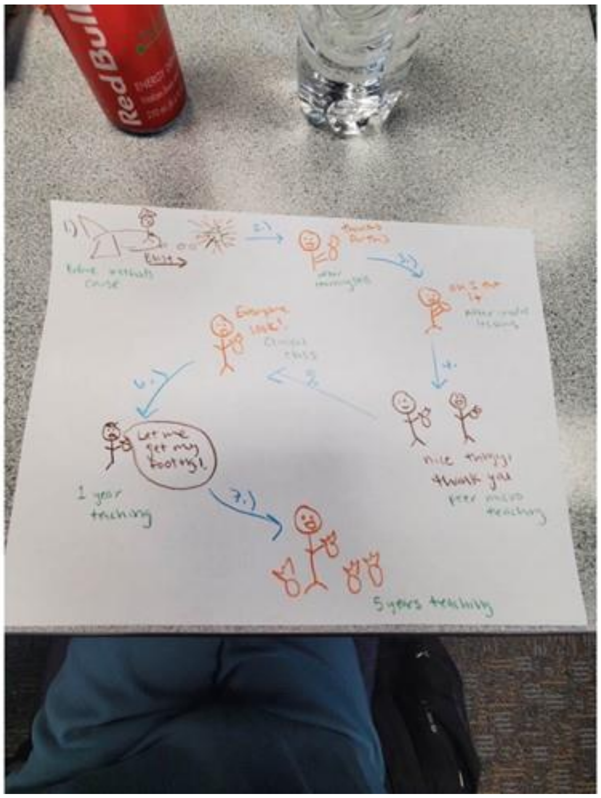
Chris

On my journey, Mark number one is where I'd consider myself more oblivious before I had any real background. As you can see, I'm pretty content just down there in the ravine, whatever. Here is where I was kind of starting to be taught more of the techniques and I was looking at the problem ahead of me, but no real understanding as to how I was gonna get there. And on 3 is where I started to consider maybe a little practice or so, but just not really having a real way out of the problem yet. Around four I was starting to see other examples, get some of the tools from our methods course. That's where I have a way up, I just need to work on it. You know, five is more, alright, I'm getting there.

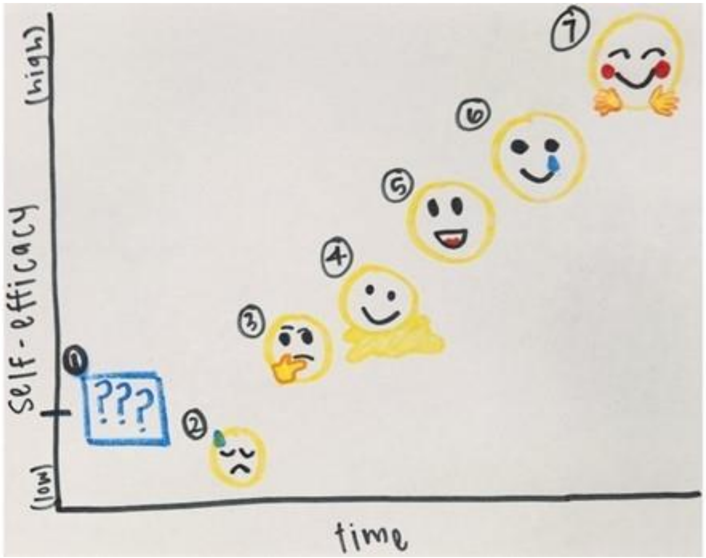
I know what I need to do. I just gotta be there. That actually puts six over here as to where I overcome my own problem. I've understood it. I've basically got this understanding of the tools. This is where I've seen myself in about a year, so able to accomplish it. Whereas seven over here is actually five years down the line where I see myself able to just not just get myself through and like understand completely, but rather hopefully in a place where I can help others who are newer to get to that point as well.

Nora

So at the beginning here we're before the methods course, I drew a little guy, he's on a ship and he's blasting and exploding this planet because he's blasting it into oblivion is the joke. Because the joke is I was oblivious about engineering practices at all. He's oblivious into oblivion. And then after being introduced to it, it was kind of like being handed this for an object that is exciting to have, but I don't know what to do with it. We got a little guy with a pineapple saying thanks for this. And then when you move over here to after we get the model lessons and now, he's going, oh, I, I eat it. That's what I'm supposed to do with this. He kind of understood now what the point is and how it works. And then moving on to 4 with the micro-teaching we got some validation now and we understand how it works a little bit and how we can help each other out so they're happy and sharing their fruit together and that's all exciting. And then the clinical class we have, he's very excited to show off his pineapple in this situation. Just like how I was so excited to share the lesson that I made. And so this is one year into teaching. He's a little upset, but he's missing his leg and he says, let me get my footing because probably gonna be a rough time my first-year teaching, but I think that as long as I can get my footing, it's gonna be okay. And I'm still holding that little guy, my little pineapple. And then after five years teaching, he's really happy, he's successful and he's got multiple pineapples kind of representing that I can hopefully continue to make more engineering design lessons and be really happy and successful.

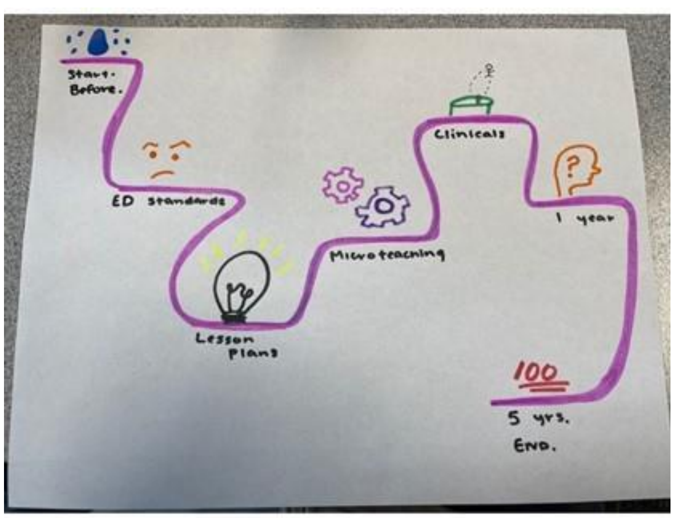


Malia
So, first being introduced to engineering design. Not really knowing anything about it before methods class, just hearing about engineering design, I had a lot of questions, but I also felt like I knew enough about engineering that I could teach it. So it's a little bit higher. It's not completely at zero. Since being introduced in our methods class, I was very confused. I didn't understand how I would be able to do that. I didn't think I could. And then I felt like after being introduced to some of the lessons and having an experience and seeing it, it kind of got up more. And then this was teaching it to our peers and developing a lesson plan. It went up a little. The emoji is melting because it's kind of when I realized I was having a hard time understanding it and being able to develop a lesson, but that didn't hinder me from thinking that I couldn't teach a lesson. After teaching it in my clinicals class, I felt a lot better. I felt happy. I felt like I was capable of doing that. And then for my first year of teaching, this is more of like a proud, happy face where it's like one tier of joy and I did it and I was capable of teaching. And then after many years of teaching it, just feeling very proud, feeling like I'm capable of doing it and doing it multiple times. And just having more confidence in doing that as well.



Isabelle

This is a water droplet. This is me growing, getting more droplets of knowledge with the realization that I wanna be a teacher and that I'm excited to start our methods course. This is me learning about the engineering design standards because it's a little confusing, something I had never done before. And here is us doing our lesson plans and model lesson planning. The light kind of shown and the light bulb represents me kind of getting it and understanding how to implement it into my own classroom. This is the gears turning after I wrote my own lesson plan and taught it to my classmates, then getting their feedback, seeing how I can make it better. This is me jumping on the trampoline after having taught my engineering plan in my clinicals. It was just super fun, super exciting. And so I'm just jumping for joy. After my first year of teaching, I'm going to assume that I'm going to have a lot of questions on how I can make it better and more efficient. And then I would like to think that by year five I will be at a hundred percent always looking to improve things but have a pretty solid grasp on everything.



Mike

Here is before I learned anything about engineering, but actually part of the reason why I want to do science teaching is because I know that the classes that I've had where we have done engineering things, it's been super fun. So just been imagining. And I had been imagining teaching and just doing super awesome things. So, I drew myself flying in a dream. But then having learned a little bit about what engineering, just like learning what the expectations were, started to feel a little bit nervous and maybe a little bit confused. And then as I tried to make the first one, I felt like I was a little bit getting lost in the forest and definitely the goal coming then going out of focus. But then as we practiced and as I saw it modeled, it was like, oh, I am not so confused. I'm walking out with the forest and not lost.

And then I feel like in clinicals and having just taught it I know I have a clear direction and I know where I want to be going with it. So I'm feeling a little bit better about it. And I think by the time I get to my first year of teaching after I haven't done it, I'm gonna feel pretty confident and that I'll be able to get better and better. So, I drew myself walking upstairs. And then I think after a few years of teaching I am gonna be able to do cool things and have a focus. And I decided to draw a hang glider versus wings because now I have the specific tools to know what I want to do. And I think by then I'll have even more idea of what I want to do and like how to do it and not just like, oh, I think we could do cool things, but know how to do cool things and make it useful and actually make it realistic versus just dreaming about

*Image not captured from video

Eric

I decided to map my confidence level on the journey map with the engineering unit and you can see how it's kind of initially confused at the beginning. I have never seen it I don't think I've ever been taught and it's very messy. Obviously having never seen one I'm at a zero or close to it. Then we first learned about them in class. It was pretty cool. It's a good way to teach. My confidence goes up a little bit and then I remember as we started to plan our lesson after watching and feeling that confident feeling immediately disappeared because it was that easy to say that I wasn't good at thinking like an engineer. Then we moved into talking about engineering units in class and how to make them affective especially after that as we continue to plan and when we were able to get feedback my confidence increased a little bit after. Overall I feel like it went down because it brought to mind how easy it is to think like a scientist for me, and not like engineer. I have to force myself to think like an engineer. which is a good thing because it teaches good skills and puts science and engineering in a more positive light. Afterwards I remember observing an then teaching and that's when my confidence from then on only went up. It never decreased. I feel that I would be confident teaching a unit and even incorporating little mini engineering lessons out of more scientific ones, but overall I think it's been great to see my confidence go up.


Confidence level
Have never seen Engineering lesson
First learned about them
Started planning one
First dedicated classroom instruction
Peer Feedback
Observed an Engineer Lesson
Finished creating engineering Lesson

Appendix F

Efficacy Over Time by Participant

Table F-1

Efficacy Over Time by Participant

Time Point	**0**	**1**	**2**	**3**	**4**	**5**
Construct	**Name**		Emily			
C	3	3	2	4	4.5	3
M	2	4.5	4	4	5	5
ES	4	5	5	5	3.5	3
A	4	3	3	3	2	1
			Chris			
C	2.5	3	4	3	4	3.5
M	4	5	5	4	5	5
ES	3.5	4	3.5	3	3.5	4
A	5	5	5	5	4	3.5
			Nora			
C	1	1	2	2	4	3
M	5	5	5	4	5	4
ES	4	4	3	4	3	3
A	5	4	3	5	2	2
			Alex			
C	3	3	2	3	4	5
M	5	5	5	5	5	5
ES	3	3	3	3	3.5	4
A	2	4	5	4	3	2
			Tim			
C	2	4	2	3.5	3	4
M	4	5	4	5	4	3
ES	3	3	2	3	2	2
A	3	3	4	3	2	2
			Malia			
C	3	4	3	4	4	4
M	3	5	5	5	5	3
ES	4	4	4	4	3	3
A	4	3	4	3	2	3
			Mike			
C	3	3	4	4	3	4
M	4	4	5	5	5	4.5
ES	3	3	4	4	3	4.5
A	1	1	0	0	1	1
			Eric			
C	3	4	4	4	4	4
M	5	5	5	4	4	4
ES	4	4	4	4	4	4
A	3	2	2	1	1	1
			Jana			
C	2	4	4	2	4	3
M	5	5	5	5	5	5
ES	4	4	3	4	2	1
A	5	4	3	4	2	2
			Scott			
C	3	4	4	4	3	4

M	4	4	4	4	3	4
ES	4	4	4	4	4	4
A	4	4	3	3	4	3
			Isabelle			
C	2	2	3	4	3	4
M	3	4	3	4	4	4
ES	3	2	3	3	3	3
A	5	5	5	3	5	1

CURRICULUM VITAE

LAURA WHEELER

801-710-2011
Thewheelers2000@yahoo.com

EDUCATION

Ph.D. May 2023
Education, Utah State University
Specialization: Curriculum and Instruction
Concentration: Science Education
Dissertation: *The Engineering Design Teaching Self-Efficacy of Preservice Secondary Science Teachers*.
Chair: Max Longhurst

M.Ed. June 2019
Master of Education, Western Governors University
Physics Education

B.S. December 1999
Weber State University
Earth Science Teaching
History Teaching

EMPLOYMENT HISTORY

Utah State University

Graduate Teaching Assistant
Utah State University, Logan UT
June 2020 – Present
Research Assistant
Course Instructor

Public School Teaching Experience

Davis School District, Farmington, UT
South Davis Jr. High School, North Layton Jr. High
1999 – 2003

Science Teacher

Morgan School District, Morgan, UT
Morgan Middle School, Mountain Green Middle School, Morgan High School
2010 – 2020
Science Teacher

- Communicated frequently with parents, students and faculty to provide feedback and discuss instructional strategies.
- Planned and implemented integrated lessons to meet national standards.
- Attended and facilitated IEP meetings for students and families.
- Encouraged creative thinking and motivated students by addressing individual strengths and weaknesses based on standardized testing results.
- Developed and implemented lesson plans that addressed general students as well as those with individualized 504 plans as part of integrated classroom.
- Evaluated and revised lesson plans and course content to achieve student centered learning.

UNIVERSITY TEACHING

UTAH STATE UNIVERSITY, LOGAN, UT (2020-2023)

SCED 3400/5820 - Secondary Science Teaching Methods I
(Fall 2021, Fall 2022)

SCED 4400/6305 – Secondary Science Teaching Methods II
(Spring 2021, Spring 2022, Spring 2023)

SCED 3300 - Secondary Science Clinical Teaching I
(Fall 2021, Fall 2022)

SCED 4300/6720 – Secondary Science Clinical Teaching II
(Spring 2021, Spring 2022, Spring 2023)

ELED 4020 – Elementary Science Methods
(Fall 2022)

ELED 1010 – Introduction to Elementary Education
(Fall 2020)

AWARDS & INVITATIONS

Teacher of the Year Graduate Student Award (2022). Teacher Education and Leadership, Utah State University, Logan, UT.

International Speaking Invitation (2023). Indonesia.

RESEARCH

Research Interest:
Professional learning and three-dimensional science teaching

Research Projects:

Smart Foodscapes: USDA Seed Grant. Utah State University

Gear UP: Utah State University

Early childhood international standards comparison to Timms: Utah State University

PUBLICATIONS

Tofel-Grehl, C., Braden, S., Penrod, C. **Wheeler**, L., Hansen, T. (2022). Eco chess: A classroom game exploring energy transfer within an ecosystem. *Science & Children.*

Trundle, K.C., Hagevik, R., **Wheeler,** L.,Vela, K.N., Parslow, M.& Joy, D.N. (2022). The 3-H social and emotional learning cycle and the three sisters garden, *Science Activities*, DOI: 10.1080/00368121.2022.2147892

Wheeler, L., Hagevik, R., & Trundle, K.C. (2022). The birds and the bees, the flowers and the trees. *Science Scope*.

Wheeler, L., Hagevik, R., & Trundle, K.C. (in press). BEE ambassadors of pollen. *Science Teacher*.

CONFERENCE PRESENTATIONS

Hagevik, R., TrundleVela, K. N., Parslow, M., Trundle, K. C., Hagevik, R. Joy, D., & **Wheeler, L.** (2023, April). Science and mathematics identities and connection to nature—impact on students' interest in STEAM careers. Accepted for presentation at the annual meeting of the AERA, Chicago.

Hartono, H., Sofendi, S., Knowles, R., Trundle, K. C., Silvhiany, S., Hagevik, R., **Wheeler, L**., & Inderawati, R. (2023, January). Indonesian preservice teachers' awareness, uncertainty beliefs, values, and behaviors related to climate change. Presentation at the annual meeting of the ASTE, Salt Lake City.

Trundle, K. C., Hagevik, R., **Wheeler, L.,** Knowles, R., Silvhiany, S., Inderawati, R., Ma, H., & Lazi, S. (2023, April). Indonesian preservice teachers and climate change: Awareness, beliefs, values, and behaviors. To be presented at the annual meeting of NARST, Chicago.

Trundle, K. C., Hagevik, R., **Wheeler, L.,** Knowles, R., Silvhiany, S., Inderawati, R., Ma, H., & Lazi, S. (2023, April). Indonesian preservice teachers and climate change. Accepted for presentation at the annual meeting of the AERA, Chicago.

Vela, K. N., Parslow, M., Trundle, K. C., **Wheeler, L.,** Joy, D., & Hagevik, R. (2023, January). How do students' science and mathematics identities and their connection to nature impact their desire to pursue STEAM careers? Presentation at the annual meeting of the ASTE, Salt Lake City.

Wheeler, L., Trundle, K. C., Vela, K. N., Joy, D., Parslow, M., & Hagevik, R. (2023, January). Gardening connects me to nature: Middle school students STEM capital. Presented at the annual meeting of the ASTE, Salt Lake City.

Wheeler, L., Trundle, K. C., Hagevik, R., Vela, K. N., Joy, D., & Parslow, M. (2023, April). Nature capital effects on middle school nature identities. To be presented at the annual meeting of the NARST, Chicago.

Wheeler, L., Hagevik, R.,. The Next generation of engineers. (2023, March). Presented at NSTA, Atlanta.

MANUSCRIPTS IN PREPARATION

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PROFESSIONAL AFFILIATIONS

Association of Science Teacher Education (ASTE)
National Science Teacher Association (NSTA)
Educational Research Association (AERA)
(National Association Research Science Teaching NARST)