UNDERSTANDING MINDSET AND FEEDBACK DURING CLASSROOM PROBLEM SOLVING: A CASE STUDY WITH INSTRUCTIONAL GUIDE DOCUMENTS AND HIGH SCHOOL ENGINEERING TEACHERS

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ABSTRACT

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This study explored how instructional guide documents and high school engineering teachers understand the concept of mindset and the instructional practice of feedback as students engage in classroom problem-solving activities. From data analysis, several important conclusions were made. High school engineering teachers create a classroom climate wherein students believe in their ability to grow in learning through positive teacher-student interactions such as respectful relationships, holding high expectations for student achievement and creating an inclusive environment. Teachers may need guidance in creating a classroom where student persistence is supported, however. Through data analysis, conclusions around feedback were made. Teachers provide feedback through questioning students, making suggestions and explanations, re-directing misconceptions, and encouraging student work that is effective in solution-finding. Student motivation was confirmed to be an important aspect of engaging in engineering problems and teachers were found to motivate students by selecting problems that pique student curiosity through relevance or novelty.

INTRODUCTION

CHAPTER I

The intent of education, preschool through higher education, is not only construction of knowledge within and across various curricular areas but also the preparation of students to persevere through the problems they encounter during class activities after they leave the educational setting and enter the job market (Barrows & Tamblyn, 1980; Jonassen, 2010). To persevere, students benefit from self-regulation and growth mindset applicable to problem solving. Problem solving is integrated throughout learning when learning is applied in activities in the classroom setting and when accomplishing tasks outside the context of school (Grieff et al., 2014; Mayer & Wittrock, 2006).

Specifically, the United States (U.S.) has undertaken K-12 science curriculum reform efforts with the purpose of broadening the reach of science education to prepare students for the increasing demand in scientific knowledge and technical proficiency. In the recent past, the National Research Council (NRC) developed the National Science Education Standards with the intent of defining science literacy and making scientific knowledge available to all students (Hurd, 1998; NRC, 1996). However, these standards fell short of the idealized goal because many students who subsequently entered the job market did not possess the requisite technical knowledge and skills to enter high-demand, technical fields of work (NRC, 2012). The nation responded to the call to action with the Next Generation Science Standards (NGSS), a current reform effort that expands science practices to include engineering design processes as a learning outcome for students (NGSS Lead States, 2013). Yet, even after this sweeping initiative, the U.S. systems of education are not producing students who are adept in solving ill-structured problems, an essential skill and practice in highly technical work (Greiff et al., 2014; Jang, 2016; Moore et al., 2015).

Though science and engineering share many of the same practices, the goals of engineering differ from the goals of science and thus, the processes of engineering are also unique. The goal of science is to ask questions and construct explanations whereas the goal of engineering is to define situations and solve problems (NGSS Lead States, 2013). Additionally, the processes of science are embedded in systems of research whereas the processes of engineering are embedded in systems of industry (Cross, 2021; Kusiak, 1999). Engineering processes do not undergo the scrutiny of philosophers. Instead, engineering processes serve the inventive and industrious nature of humankind and undergo the scrutiny of economic systems.

Statement of Problem

High school engineering courses focus on technical work, i.e., the concepts and practices of design and development via thinking skills and problem solving integral to learning and living evident in education and the economy. Consequently, educational leaders need to optimize their engineering teachers' instructional practices to foster growth in their students' problem-solving skills (Bransford et al., 2000; Greiff et al., 2014). Based on progressive policy reforms, educational leaders must acknowledge and attend to the critical components of problem solving; engendering the impulse for engineering students to pursue and persevere in difficult problem solving, entails meaningful and mindful learning experiences that occur within an interpersonal realm and supportive relationships.

Hattie and Yates (2014) describe the importance of the relationship between the student and teacher. In order to learn to solve a problem, a student must feel safe and secure in taking risks and experiencing failure. These two important parts of the learning process offer opportunities for students to gain insights and inspirations by recognizing their mistakes, revising their attempts, and reveling in their achievement. In order for students to be open to new ideas and receive appropriate instruction, students must trust their teachers. Thus, teacher beliefs and pedagogical actions during engineering classroom problem solving may impact student knowledge and skills as they progress through a design lesson. Furthermore, teacher beliefs and pedagogical actions may impact student attribution of and individual expectations for their own ability to solve problems. Teacher beliefs are important to learning because beliefs influence teachers’ actions and decision-making (Fang, 1996; Richardson, 1996).

Teachers’ beliefs associated with their students’ capabilities to learn concepts and skills influence teachers’ pedagogical actions. When teachers perceive intelligence, ability, and effort as genetic factors that influence learning, teachers hold a bias and are less likely to assist students with perceived lower intelligence, ability, and effort (Howard-Jones, 2014). Rattan et al. (2012) provided an example of this bias when they found that teachers’ perceptions (i.e., teacher mindset), influenced teacher feedback (i.e., supplemental instruction, comforting behaviors, and motivational support), given to students when engaging in mathematics lessons. The researchers found that teachers with a fixed mindset demonstrated comforting behaviors, rather than process-oriented or corrective instruction, to students with perceived low abilities in mathematics. As a result, these students demonstrated lower motivation in mathematics and lowered expectations for their own performance. De Kraker-Pauw et al. (2017) added to these understandings around teacher mindset and feedback suggesting that teachers should be aware of their mindset and how it influences their own behaviors, especially the types of feedback they provide to students. Furthermore, Yeager and Dweck (2020), in their review of controversies surrounding mindset research, reported several studies that attempted to show the correlational connection between student mindset and achievement demonstrated the difficulty in coaching teachers to support student growth mindset. They concluded that future mindset research should focus on understanding teacher influence on student mindset. Therefore, in order to reform science and engineering education to increase student learning, analysis of teacher understandings of their own beliefs and biases evident in their practices must first occur (Battey & Franke, 2015; Darling-Hammond & Baratz-Snowden, 2007; Fishman et al., 2003; Nathan et al., 2010).

Purpose of the Study

The purpose of this study is to explore (a) current understandings of the concept of mindset according to state and district instructional guiding documents and high school engineering teachers and (b) understand feedback practices as students engage in classroom problem-solving activities according to state and district instructional guiding documents and high school engineering teachers. Understandings of mindset and perception of feedback can equip and empower both teachers and policy-makers to become more aware of beliefs and actions in order to increase learning and enhance teaching practices.

Research Questions

This study will answer two questions:

1. How do state and district instructional guide documents and high school engineering teachers understand the construct of mindset?
2. How do state and district instructional guide documents and high school engineering teachers perceive the role of feedback as students are engaged in classroom problem-solving activities?

Significance of the Study

The primary significance of this study will be to add to understandings of teacher mindsets and teacher feedback contextualized in classroom problem-solving activities. A secondary significance will be teacher discovery of their own potential biases embedded within their beliefs, specifically their mindset, that may be manifested in their pedagogical actions. As teachers participate in this study, they will gain knowledge of the construct of mindset. Understanding mindset may help teachers realize a potential need for change in their instruction or it may help teachers notice the features of feedback, i.e., supplemental instruction, comforting behaviors, and motivational support, they provide or do not provide to their students. Teachers will also understand the importance of the types of feedback they give to their students as this feedback impacts student motivation, engagement, and pursuit of solutions to difficult problems (Dweck, 2006, Hattie & Yates, 2014).

Understanding mindset and feedback has potential implications in student learning of problem-solving behavior and student persistence through a problem. Teacher mindset may matter in creating an optimal instructional climate and community of learners where problem solving can occur. Teachers do not understand the construct of mindset and they do not know how to strengthen the development of growth mindset in the science, technology, engineering, and mathematics (STEM) classroom (de Kraker-Pauw et al., 2017). Though the need for student facility in problem solving is acknowledged by educational policy-makers in the U.S., the method for accomplishing this goal is not clearly understood or identified. One of the goals of the NRC is to focus on improving instructional practices that will help achieve the learning goals of NGSS (NRC, 2012). This study may help educators to understand and facilitate effective learning in the high school engineering classroom and, thereby, achieve this very influential goal.

Definitions

***Belief* -** "psychologically-held understandings, premises or propositions about the world that are felt to be true" (Richardson, 1996, p. 104-105)

***Feedback* –** "information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding" (Hattie & Temperley, 2007, p. 81)

***Growth Mindset* –** "the belief that intelligence can be developed, for example, through personal effort, good learning strategies, and lots of mentoring and support from others" (Dweck & Yeager, 2019, p. 482)

***Intelligence* –** "the ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria (such as tests)" (Merriam-Webster, 2022)

***Problem Solving* -** "cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver" (Mayer & Wittrock, 2006, p. 287)

Problem Space – "a set of knowledge states (the initial state, the goal state, and various possible intermediate states), a set of operators that allow movement from on knowledge state to another, and local information about the path one is taking through the space (e.g., the current knowledge state and how one got there" (Novick & Bassok, 2005, p. 326)

CHAPTER II

Literature Review

Overview

Three areas of scholarship were reviewed for this study: mindset, feedback and problem solving. Mindset and feedback are important to this study because these constructs serve as broad units of analysis that may relate to student problem solving. These constructs were included in the first two sections of the following literature review. Problem solving is important to this study because it provides a specific context for the classroom space in which engineering teachers instruct. An understanding of problem solving also provides insight to learner activities and outcomes for the high school engineering classroom. Problem solving was reviewed in the third section of the following literature review. The final section of this review synthesized the literature and introduced a framework for relating the constructs of mindset and feedback as these constructs converge with problem solving and formed a framework for instruction within the high school engineering classroom. This synthesis created a conceptual framework for analysis of the data collected throughout this study.

Mindset

Some students welcome a challenge and some students avoid a challenge. The second half of this assertion, as it relates to the K-12 classroom setting, is troubling when student aversion is directed toward potentially rewarding, yet challenging, paths of study such as STEM-related career fields. Additionally, some students develop a negative attitude, and therefore less likelihood of perseverance within mathematics and science disciplines as these subjects require effort (Jones et al., 2000; Watt, 2004). When investigating elementary school students, researchers found that negative attitudes toward mathematics and science began in elementary school and were influenced by negative teacher attitudes towards these same subjects (van

Aalderen-Smeets et al., 2012; van Aalderen-Smeets & Walma van der Molen, 2015). Osborne et al. (2003) added to these findings and showed that student attitudes did not improve as students promoted into secondary school. In the secondary years, student attitudes can worsen, causing greater resistance to the pursuit of learning in mathematics and science. These findings are troubling, given the economic importance of and need for a STEM workforce (Osborne & Dillon, 2008). Research in student attitudes toward STEM careers has generated much interest in understanding the cognitive domain of student choice and preference. Various researchers suggested that implicit theory, or mindset may be the answer to understanding student avoidance of difficult learning pathways such as mathematics and science (Burkley et al., 2010; Dweck, 2006, 2008; Murphy & Thomas, 2008; Nix et al., 2015; Wang & Degol, 2013).

Understanding of mindset types was developed through years of research in the field of cognitive psychology and grew from findings related to implicit theories. Initially, mindset research was inspired as researchers attempted to understand why students of same ability had different responses to failure. Some students attributed failure to ability-focused reasoning and attempted to avoid seeming incompetent. Other students considered failure as part of the learning process. The attributions around failure led to understandings of implicit self-theories (Elliott & Dweck, 1988). Implicit theories are assumptions that people make about themselves, people around them, and the world around them. Implicit theories form a conceptual framework from which success and failure and ultimately, future goal orientation is determined (Dweck, 1996; Dweck & Yeager, 2019). Implicit theories are commonly termed mindsets as the term “mindset” is simpler to understand for people working with children outside of the field of cognitive psychology, i.e., parents and teachers. In mindset theory, a person with a fixed mindset believes that personal characteristics such as intelligence, ability, extroversion, self-regulation or effort, are immutable, or unchanging. This fixed status is related to the perception of these characteristics as unchangeable, inherited traits (Mrazak et al., 2018). Because a characteristic in question is perceived as fixed, a person with the fixed mindset would not pursue completion of a task that required the characteristic. As the task becomes difficult, difficulty would signify to the person that the limit of their ability has been reached within the domain of the required characteristic. An example of this type or personal appraisal would be when a student withdraws from a difficult problem situation within an engineering classroom because, as difficulty is encountered in the problem space, the student believes that he or she does not possess the requisite ability to solve the given problem.

In consideration of a fixed mindset of personal attributes, the attribute of intelligence is particularly important because measures of intelligence (such as IQ scores) predict learning outcomes (or achievement) in the school setting. In general, intelligence can be considered as cognitive performance (Kovacs & Conway, 2019). However, this quality is difficult to define and different theorists have defined it in different ways, inculcating the importance of the value of this cognitive quality to various cultural functions (Sternberg, 2019). An example of broader consideration of intelligence is provided by Sternberg (2019) where he relates it to facility in solving problems. He claims that intelligent behavior is: “recognizing the existence of a problem, defining the nature of the problem, mentally representing the problem, formulating a strategy to solve the problem, monitoring the strategy’s effectiveness during problem solution, and evaluating the effectiveness of the strategy after problem solution.” This description of intelligence directly relates this personal attribute to learning objectives of the high school engineering classroom and emphasizes the importance of mindset around the characteristic of intelligence in the context of classroom problem solving.

Growth mindset is an alternative belief to the fixed mindset. When a person has a growth mindset, the person believes that characteristics such as intelligence, ability, extroversion, self-regulation or effort can change and improve through application of these qualities and through perseverance in difficult tasks (Dweck, 1999, 2006). This alternative belief increases the likelihood of persistence in completing a difficult task such as finding a solution to a problem. Thus, mindset is important in the K-12 educational setting because it predicts a student's likelihood of undertaking difficult learning tasks (Haimovitz & Dweck, 2017). An example of growth mindset would be when a student continues in his or her work on a difficult problem within an engineering classroom. As difficulty is encountered in the problem space, the student appraises failure situations as an integral part of the learning process and continues to pursue a solution to the given problem.

To summarize, mindset informs on how an individual responds to challenge and failure and if an individual attributes a setback to a particular personal characteristic. Mindsets exist around characteristics such as intelligence, ability, extroversion, self-regulation and effort (Mrazak et al., 2018). In addition, mindsets, both growth and fixed, are not discrete conditions. They exist on a continuum with any given individual measurement of mindset depending upon an individual's current understanding of the characteristic being considered (Yeager & Dweck, 2020).

Mindset as Teacher Belief

Mindset is a personal belief about personal qualities. Teachers have mindsets, either fixed or growth, that have the potential to influence pedagogical practices and classroom instructional behaviors (Howard-Jones, 2014). The broader construct of teacher belief has been studied and refined for decades resulting in isolation of teacher belief from other closely related constructs such as teacher attitudes and teacher knowledge (Richardson, 1996). Teacher beliefs are described as "psychologically-held understandings, premises or propositions about the world that are felt to be true" (Richardson, 1996, p. 104-105). Teacher beliefs also inculcate cognitive functions such as assumption, prediction of the future actions of people, and support of decision-making (Borg, 2003; Goodenough, 1963) and these cognitive functions drive classroom practice (Nespor, 1987; Richardson, 1994). Nespor (1987) conducted a field-based teacher belief study wherein eight middle school teachers were observed, video-taped, and interviewed, each teacher spending approximately 20 hours with the research team. In this study, the middle school teachers described how their beliefs impacted their instructional decisions. This study used a grounded theory approach that confirmed the long-held assumption that teacher belief impacts teaching practice. The importance of the effects of teacher belief was further supported by extensive research conducted by Richardson (1994) and her collaborative team of elementary and middle school campus leaders and educational researchers. In this study, teachers engaged with researchers through collaboration in professional development sessions that built understandings of student reading comprehension. This exploratory study was conducted with teachers spanned across multiple fourth through sixth grade campuses, involving multiple reading teachers over a period of three years. Among the many insights that evolved from the research, the importance of change in teacher belief as a precursor to change in practice, was confirmed. In other words, for teacher professional development and growth to occur, a change in belief must occur. Furthermore, teachers hold implicit theories about many qualities of the school context and student learning and teachers bring these theories to their pedagogical practice (Borg 2003; Richardson, 1994). Thus, teacher belief may be an important construct for consideration within the high school engineering classroom and may have implications for student learning in problem-solving classroom situations.

One important area of student learning impacted by teacher beliefs is that of student achievement. Teacher beliefs around student performance are embodied in expectations of student outcomes. Good (1987) reviewed research on teacher expectancy and created a model describing how teachers communicate low expectations to their students. Good conclusively supported the understanding that teachers treat students differently based on their beliefs about student ability. Murdock-Perriera and Sedlacek (2018) supported this early study with their review of research on teacher expectancy. These researchers added to the understandings of expectancy beliefs in identifying the effects of teacher expectancy such as biases in perception, confirmation, and attribution. Teacher expectancy can be communicated to students if the teacher perceives a certain student learning ability, seeks to confirm that perception, and attributes the ability to immutable student characteristics.

The effects of teacher expectancy beliefs have been found to relate to another interesting aspect of belief. Sometimes, implicit theories align with a community, such as a professional community that holds particular standards for learning and understanding. Thus, beliefs can be personal or community epistemological understandings around the acquisition of knowledge that are peculiar to a subject matter or nomay such as engineering (Fang, 1996). Richardson (1996) summarizes the research findings on the origin of teacher beliefs and suggested the following categories: personal experiences, experiences with schooling and instruction and experiences with formal knowledge. The category of formal knowledge is of interest within a professional community because beliefs are socially-constructed propositions developed within a community of practice (Green, 1971; Lehrer, 1990).

Epistemological understandings about learning the discipline of a professional community may influence the development of beliefs of teachers from non-traditional pre-service backgrounds. Pre-service teachers bring life experiences and epistemological stances that impact their future success as a teacher. This finding applies to non-traditional pre-service students who often have professional experience as they are entering teaching after a first career. Crow et al. (1990) studied non-traditional students who were career changers who left occupations in business-oriented fields to pursue a second career in education. These career changers were enrolled in a one-year graduate program in education. Through interviews conducted before, during, and after the graduate program, this research team found that teachers with previous successful careers who switched into teaching due to dissatisfaction with their previous career, had an unsuccessful transition into teaching. This finding illustrated that, in order to be successful in education, a need for a functional epistemology must be specific to the learning environment. Novak and Knowles (1992) examined both elementary and secondary school teachers who made career changes into education after prior work in different industries. These researchers found results similar to Crow et al., confirming that experiences within previous occupations influenced the teachers' beliefs. These studies indicate that teacher beliefs, which developed within a professional discipline, influence career changers' perspectives toward students and may not lead to an effective teaching stance.

Mindset Influence on Student Learning

Yeager and Dweck (2020) reviewed multiple studies to explore the link between mindset and student achievement. They referenced large-scale studies conducted by government organizations (such as state education agencies and school districts) and studies conducted by university-based researchers and even the private international association, the Organization for Economic Co-operation and Development (OECD). From this comprehensive review, they determined that student mindset does impact achievement, higher achievement correlating with a growth mindset. This relationship is not seen in every case, however; there is heterogeneity in the relationship. For example, cultural attributes were found to be associated with the correlation of fixed mindset and high achievement. This relationship may be due to student learning in a context that does not support learning from failure. Students in mainland China demonstrated this situation. Within this culture, failure in learning outcomes accompanies very high risks for future success. When tested for mindset, these students were found to have a high correlation between a fixed mindset and higher achievement (Yeager & Dweck, 2020).

Mindset theory has received criticism for encompassing too many social-cognitive aspects of learning. Tempelaar et al. (2015) found that student effort beliefs play a large mediation role in student motivation to achieve academic goals. This research team examined first-year university students (ages 17 – 31) who engaged in a problem-based curriculum. For six years the team collected empirical data, discovering student beliefs existing in multiple domains such as: implicit theories of intelligence, effort beliefs, achievement goals and academic motivation. Tempelaar and his team found that student valuation of effort in attainment of a goal cannot be separated from the function of student achievement. An example of this relationship may be achievement measurement with assessments associated with high stakes grade promotion, graduation, or college admission. Thus, the context of school may prohibit student valuation of failure as part of the learning process, an important tenet of growth mindset. Tempelaar et al.'s findings are important within the context of classroom problem-solving situations because a person's experience of effort determines his or her self-regulation (Brehm & Self, 1989; Brehm et al., 1983; Eisenberger, 1992; Hockey, 2011; Inzlicht et al., 2014; Kurzban et al., 2013; Molden et al., 2016), and self-regulation is an important cognitive function for facility in problem solving (Mayer & Wittrock, 2006).

Studies have shown that the mindset of parents does not affect the mindset of the learner (Haimovitz & Dweck, 2017). For example, Gunderson et al. (2013) conducted a study of U.S. parents of children seven and eight-years of age wherein no significant relationship was discovered between the mindset of parents and the mindset of their children. To establish this claim, the mindset of the parents and their children was measured and compared. As the children developed, between one and five-years of age, the parents were regularly interviewed regarding the types of praise that they offered their children. As these children continued to grow, between seven and eight-years of age, the mindset of the children was again measured. Through this prolonged and regular interview process, this team established that children who received more praise that affirmed them as a person rather than praise that affirmed their learning processes had fixed mindsets. Haimovitz and Dweck (2016) conducted a similar study of parents of children nine-12-years of age and found similar results. Thus, a parent can have a growth or fixed mindset and the outcome of the learner is not changed. Furthermore, the type of praise offered to children predicts the mindset type.

These findings seem to contradict understandings about teacher expectancies. Expectancy in success is known to benefit students who are at-risk for low achievement (Hattie & Yates, 2014). If the teacher has the expectation that learning will occur or that learning is difficult or that the student will succeed, a student mindset may be pushed toward a growth mindset. In this case, the teacher mindset would influence the student mindset. In trying to reconcile this discrepancy in understandings, Haimovitz and Dweck (2017) conducted a review of research regarding the causes of mindsets in children. In this review, the researchers acknowledge that there may be a broader social movement in appropriate praise for children that influences parent and teacher praise of student actions. This historical influence, the self-esteem movement, may contextualize the findings in current research. From this review, they developed a postulate regarding causal factors in student mindset. The reinforcement that creates a growth mindset is one that focuses on the process of the task. For example, a praise statement such as, “You worked hard to complete that puzzle,” emphasizes the work effort required to complete a puzzle. A person statement such as, “You are smart and can finish puzzles quickly,” emphasizes a perceived fixed quality such as intelligence and quickness (Haimovitz & Dweck, 2017). The student hears the praise, understands the nature of the praise and creates an attribution, an underlying reason for success. The student succeeded because the student worked or succeeded because the student is smart. One of those reasons is effort; another reason is intelligence. The message given by the parent or teacher is processed and predicts future motivation.

Sun (2015) added more understandings to classroom practices that promote growth mindset. Through a survey of 40 middle school teachers of mathematics, Sun found that student growth mindset is supported when teachers engage in the following response practices: focus on and evaluation of student thinking, praise and evaluation of the learning process, and opportunities for revision of work that deepened understandings (Sun, 2015). Therefore, the development of student mindset depends upon the response to a difficult learning task, this response being mediated by the student meaning-making of the experience which is guided through the use of feedback.

The findings around mindset relate to other understandings in pedagogical practice as well. One area that seems to influence mindset is that of the student and teacher relationship. For a growth mindset to develop, the student must learn from mistakes and, despite difficulty, continue in pursuit of a solution to a problem. Hattie and Yates (2014) described the importance of the relationship between the student and teacher in this situation. These relationships create advantage for students over time. Learning requires trust in the teacher because students must be open to experience new ideas and accept that current understandings need revision. Accepting that current understandings may be wrong creates risk for a learner. When seeking solutions to difficult problems, students must be willing to accept this risk and make mistakes. When they make mistakes, they must be willing to try again and thereby learn from the failed and subsequently revised experience.

Hattie and Yates (2014) also report that interpersonal judgements impact student achievement and student trust in teachers. When students see teachers as supportive, students seek help by asking questions. Help-seeking behavior indicates resilience in students and predicts future achievement. Students with ego or performance orientation seek to "look good." They seek to demonstrate ability and they do not seek help. Older students tend not to ask questions because they do not want to be perceived as low in ability. These assertions align with the findings of Dweck and confirm that students with a fixed mindset attempt to avoid finding solutions because they do not want to reveal their perceived fixed trait (Dweck, 2006). These assertions also seem to contradict the assertions of Haimovitz and Dweck (2017) around mindset of the parent and teacher. Though Haimovitz and Dweck found that the mindset of the teacher and parent does not predict student mindset, the judgments of the teacher do matter in student help-seeking behavior. This finding is interesting because interpersonal judgement may be communicated to students through expression or feedback given by the parent or teacher and not merely a hidden belief such as mindset.

Teacher mindset, a belief that influences teaching practices, may hold potential for the development of interventions aimed at promoting student learning. Teacher mindset may create classroom atmosphere, or social community, wherein effort and self-regulation are supported. Studies around teacher delivery of student mindset interventions, however, have not been found to impact student achievement. In fact, mindset interventions provided to teachers have shown to be ineffective (Yeager & Dweck, 2020). Future research should focus on teacher preparation in the task of supporting a growth mindset in students.

Beliefs of Science and Engineering Teachers

Since the inclusion of engineering standards is a relatively new curriculum addition in the U.S. systems of education (NGSS Lead States, 2013), there exists limited research on the beliefs and practices of engineering teachers. Thus, understanding of engineering teachers' practices may be informed by appropriating understandings learned in the study of science teachers since science and engineering teachers often serve in both capacities within a school. The beliefs of science teachers influence both instructional practice and student outcomes (Bryan & Abell, 1999; Loucks-Horsley et al., 2009). This statement is illustrated by a case study conducted by Bryan and Abell (1999) who investigated the pedagogical practice of one pre-service elementary school teacher through interviews regarding her reflective science teacher learning. Through case analysis they demonstrated how this future teacher's beliefs influenced concepts of science teaching. The connection between beliefs about science and practice in science instruction was thus established. Loucks-Horsley et al. (2009) emphasized this connection. This research team compiled a comprehensive manual for professional development of science and mathematics teachers based on both theoretical considerations and practical considerations for optimizing teacher growth and learning. In this text, the researchers encourage professional development leaders to consider the knowledge and beliefs of teachers as they build their professional development sessions because teacher beliefs hold influence over science instruction.

The current national goal in education outcomes calls for broader racial and gender representation within the professional fields of science and engineering. Social biases embedded within implicit theories of science and engineering teachers may undermine the actualization of this goal (Nosek et al., 2009; Pilotte et al., 2012; Yaşar et al., 2006). Studies have shown that teachers hold biases regarding who will succeed in their classrooms, and these biases endure through intentional professional learning on engineering instruction (Nathan et al., 2010; Nathan et al., 2011). Nathan et al., (2010) found that students' family backgrounds, prior experiences and academic achievement influences instructional decision-making of students' classroom teachers. For example, high school engineering teachers were found to hold social biases that influenced areas such as instruction of students, recruitment of students, and even assessment of student work. Thus, future approaches in science and engineering education reform should include the analysis of teacher understandings of their own biases and practices (Battey & Franke, 2015; Darling-Hammond & Baratz-Snowden, 2007; Fishman et al., 2003).

Though teacher beliefs are an important factor in understanding instructional practice, teacher conceptions of the content are also important. For example, studies have explored science teacher understandings regarding the nature of science. This work is important because science teachers should understand science practices. These studies have improved the field of science education by improving teacher articulations of science, and subsequently, improved science instruction (Honey et al., 2014; Katehi et al., 2009; Stohlmann et al., 2012). Since current national reform efforts extended science to include principles of engineering and engineering practices (NGSS Lead States, 2013), as with research in understanding teacher conceptions of science, teacher conceptions around engineering principles also will help to define and refine instructional practices in this domain.

This suggested type of study is demonstrated in the exploratory research conducted by Mercado and Sengupta-Irving (2017). These investigators worked with high school engineering teachers and captured their conceptions of engineering as they grappled with the differences in goals and outcomes of high school engineering curriculum. Four themes emerged from their study: failure, procedural learning, serving society, and achievement inversion. The teachers reported that failure, in the engineering class, is emphasized as a learning condition. Learning, itself, was embedded in procedures that were not prescribed, as in science learning, but rather created within a design process. Since the goal of engineering is to solve human problems, engineering emphasizes a goal of serving society. Finally, the teachers in the Mercado and Sepgupta-Irving (2017) study indicated that achievement is accessible to students who are not the typical, and predictable achievers. The teachers speculated that this exception may be because these students were more accustomed to experiencing failure and accepted that outcome as a pathway to success whereas typical achievement-oriented students avoided failure and, therefore, struggled in the problem-solving processes of engineering design (Mercado & Sengupta-Irving, 2017). Engineering practices inculcate themes, or domains of learning, that are unique due to the goals of engineering. Teacher understandings around pedagogical practice in support of student mindset may form a critically necessary stance that supports the unique goals of engineering instruction.

Feedback

One hallmark of quality classroom instruction is the practice of feedback for student learning. Feedback is information provided to students regarding performance in a learning activity and has a purpose of improving skills such as problem solving (Hattie & Temperley, 2007; Shute, 2008). Feedback, however, does not have to come from a teacher. Anyone involved in a learning process, such as a parent or friend, can provide feedback. The student can even seek information independently from a book or other source that informs the student on performance. Feedback can take different forms and purposes. When the feedback extends the understandings of the learner, rather than just providing a statement of correctness of the student performance, the feedback has an instructional purpose (Sadler, 1989). Instructional feedback can take various pathways such as telling the student to seek different information, suggesting a new approach in understanding, and verifying correct or incorrect thinking.

Feedback improves acquisition of knowledge and attainment of skill (Azevedo & Bernard, 1995; Bangert-Drowns et al., 1991; Corbett & Anderson, 1989; Epstein et al., 2002; Moreno, 2004; Pridemore & Klein, 1995). Moreno (2004) studied college students and found that explanatory feedback (explains a problem rather than merely providing a correct answer), reduces the cognitive load on the learners and improved deep learning. Pridemore and Klein

(1995) found similar results with junior high students. Student achievement (measured by a post-test score) was higher when the students received elaborative feedback rather than correct-answer feedback or no feedback.

The ultimate purpose of feedback is to bring a student's current knowledge state closer to the desired goals of understanding. Feedback causes reflection on the student response to a problem or performance and may also elicit elaborating on the response, thereby confirming the response as correct or in need of revision (Mory, 2004). Additionally, Anderson and Kulhavy (1972) found that when used as a reinforcement technique, feedback had little effect on increasing the frequency of a correct response. When testing a group of college students using the PLATO computerized learning platform, they found that feedback influences learning outcomes by providing a correct answer when an incorrect answer was given by the student. Through the PLATO application, students were instructed on population genetics. The experimental group of engaged in a series of lessons followed by a questionnaire to assess for learning. The platform provided feedback to the students after each response of the questionnaire. The researchers of this study found that students had improved outcomes when corrective feedback followed student responses (Anderson & Kulhavy, 1972).

Mory (2004) attributes feedback to a constructivist theory of learning because it helps to shape and build knowledge. This aspect of feedback places the guidance of student responses into a social cognitive domain of learning as the teacher plays the role of a thinking mentor. There are several mechanisms, suggested by the literature, explaining how feedback accomplishes its function. Feedback may resolve a gap in knowledge, signaling to the learner how to reconcile thinking on a particular topic, thereby motivating a student to continue in learning (Locke & Latham, 1990; Song & Keller, 2001). Additionally, feedback may reduce the learner's cognitive load, a function especially adaptive to struggling learners (Paas et al., 2003;

Sweller et al., 1998). An example of this type of feedback would be providing a correct example of a problem or a functional model in a problem-solving task. Thus, through providing correct information, correct models, and worked examples, feedback provides the cognitive tools for learning.

According to Hattie and Temperley (2007), feedback answers three questions: "Where am I going?," "How am I going?," and "Where to next?" The first question, "Where am I going?," has to do with learning goals. This type of feedback provides specific learning goals that serve to focus student attention. This type of feedback is important, especially when the goals are challenging. Students may be distracted to refocus efforts into another, less demanding task and, thereby, diminish their self-regulation toward the established goal (Locke & Latham, 1984). The second question, "How am I going?," informs about progress within a performance task and indicates need for adjustments. Since this question answers current status in performance relative to a standard of performance, this type of feedback often relates to testing (Hattie & Temperley, 2007). The final question "Where to next?," addresses a sort of closure to the current task and a look forward to future tasks. The student may receive information on their overall processes in the completed task and future endeavors that they may attempt. For example, a student may focus on automaticity of skill, fluency or self-regulation within future tasks.

Types of Feedback

The research on feedback provides much variability in description of the construct and mechanisms by which it functions (Shute, 2008). Black and Wiliam (1998) categorize feedback into two types: directive and facilitative. The directive category provides information to the student on needed adjustments while the facilitative category supports the student in identifying the needed adjustments. Though these two categories provide very general understandings of typology, Shute (2008) through a review of research, identified eleven feedback types. Examples of these types include: verification, try again, error flagging, elaborated, hints/cues, informative, and bugs/misconceptions. No feedback was also attributed to a feedback type. Shute's typing of feedback responses allows for more clarity in potential categorization of observed feedback or reported feedback.

Hattie and Temperley (2007), in their review of research on feedback offered in classroom learning situations, developed a conceptual framework wherein they categorized feedback into levels based on the effectiveness of the feedback. This distinction in categorization is important because the method creates a category that is not merely descriptive but, in contrast, assigns value to functionality of the category. The first level is the task level, or feedback-task (FT), wherein the feedback addresses the correctness of the learner task or product. An example of this feedback would be a teacher confirming a student answer or providing information about what is missing in the student answer. The second level is the process level of feedback, or feedback-process (FP). With this type, the teacher would address the correctness or need for change in the student process to arrive at a product or answer.

The third level provided is at the self-regulatory level, feedback-regulatory (FR). In this type of feedback, the teacher provides information to the student that confirms their confidence in moving forward in a task. This type of feedback is evaluative in nature. For example, a teacher may confirm the knowledge a student has demonstrated and then prompt the student to continue in the process or task. The final level suggested is the self-level of feedback, feedback-self (FS). This type of feedback assigns identity to the student. For example, a teacher may say that a student is smart or quick.

The levels of feedback suggested by Hattie and Temperley (2007) correlate with the assertions of Haimovitz and Dweck (2017). Haimovitz and Dweck, through their review of research on mindset, found that feedback that addresses the processes undertaken by a learner are more effective in developing a growth mindset in students. Feedback that focuses on attributes of the student self (such as intelligence) induce a fixed mindset in a student. Hattie and Temperley (2007) found that FP and FR levels of feedback are most effective in developing mastery of a task while FS is not effective for improving student learning in the K-12 classroom. However, most teachers apply feedback at the task level (FT) which is only effective for mastery of task or learning when followed by FP or FR feedback (Hattie & Temperley, 2007).

Conditions of Feedback

Conditions exist under which feedback delivery is optimized. Phye and Andre (1989) argue that immediate feedback is optimal because the learner can correct misunderstandings quickly. This is not always the case, however. Kulhavy and Anderson (1972) tested the performance of 192 junior and senior level high school students after both immediate and delayed feedback was given to the students. Later testing showed that extending the time between response and feedback actually improved knowledge retention. Feedback can be delayed for days and that delay improves learning outcomes. The delay in response improves the interference caused by the error response. If the feedback is too closely paired with the incorrect response, interference occurs and learner confusion ensues. If the feedback is delayed, then the correct response has cognitive space to reside (Kulhavy & Anderson, 1972; Mory, 2004; Shute, 2008). An example of the importance of timing is emphasized by consideration of feedback offered concurrent to an activity. Concurrently administered feedback might be counterproductive. Corno and Snow (1986), found that feedback given to students as they are engaged in a problem-solving activity actually inhibited learning. An example of counterproductivity of feedback is discussed by Cross (2021) in his textbook on engineering design. According to Cross, there are guidelines associated with feedback provided during problem-solving design activities in professional settings, specifically in the design stage of brainstorming. The most important rule is that team members are not allowed to offer criticism of a proposed design. The purpose of brainstorming in design is to allow for many possible creative solutions to come forward. Creativity must be allowed to flow from a design team and thus, in this critical stage, criticism of solution possibilities is not allowable (Cross, 2021).

Another condition that impacts the effectiveness of feedback is that of specificity or amount of information provided to the learner. Specific feedback provides information to the learner that is necessary to correct the performance task or thinking (Goodman et al., 2004). Specificity improves the effectiveness of feedback as the learner receives information to guide the correct response or improve the performance. This idea is supported by a meta-analysis of research on feedback conducted by Bangert-Drowns et al. (1991). In this comprehensive study, this research team found that intentional feedback applied to specific knowledge is the stimulus for correcting learning errors. Too much information can be provided, however. This idea describes the complexity of the feedback. If a response to a student performance is lengthy and complicated, the learner will not improve. Optimal feedback should be brief and provide enough accurate information for the learner to improve the task (Shute, 2008).

Problem Solving

Problem solving is an essential practice in engineering and problem-solving classroom activities are the modality for student learning of this critical skill. Because skill in problem solving is a desired learning outcome in high school engineering classrooms (NGSS Lead States, 2013), a deep understanding of this activity will help educators achieve the goal of teaching this skill. Understanding the process of problem solving is aided by an understanding of the nature of a problem. Problems can be understood in parts that comprise the overall construct. Since problem solving is a process, it continues along a pathway of time. Beginning with the condition called the problem state, a solution is sought by the solvers and the solution path unfolds. The solution and the problem state can never be truly separate states because possible solutions (provided by the problem solvers) drive the process forward (Cross, 2021). The end is the goal state, the condition in which the solution is discovered (Newell & Simon, 1972; Novick & Bassok, 2005). Though this first understanding seems simple, problems are not simple. The literature outlines three additional aspects of problems: constraints, criteria, and the problem space. Constraints intervene in the process and can be thought as limitations that impede the solution path. They may be physical limitations, time constraints or social constructs. Criteria are elements that dictate inclusions of final goal state, production time, or production elements such as materials or location (Newell & Simon, 1972; Novick & Bassok, 2005). The problem space includes all factors within the time and space continuum in which problem solving occurs and, therefore, includes all elements of the problem-solving process already mentioned as well as social factors intrinsic to the process or problem solvers (Jonassen, 2010; Newell & Simon, 1972).

Characteristics of Problems

Various characteristics of problems have been identified and studied. Characteristics such as dynamicity, abstraction, continuity, complexity, and structuredness are examples of defined problem qualities. When problems are dynamic in nature, the factors intrinsic to the problem change over time (Jonassen, 2010). An example of dynamicity could be as simple as the changing value of light as the sun moves across the sky, impacting the problem space. A more complex example of dynamicity would be the preparation of a policy brief while awaiting forthcoming decisions from a voting body. In the latter case, the problem goal itself, is dynamic, even as the solution is being devised.

Abstraction is another quality of problems. Abstraction indicates the degree to which a problem represents actual problems (Bassok, 2003). The quality of abstraction is important for problems that are contrived and administered in school settings for the purpose of learning. A puzzle is an example of a problem with much abstraction because puzzles do not represent real life problems.

Problems can also have varying degrees of continuity. Continuity describes the stability of the problem, or how the whole problem resists change over time (Bassok, 2003). Real-life problems have less continuity. This idea was proposed by Wood (1983) in a review of literature in problem structure as Wood created a framework for understanding problem complexity in a learning situation. Roth & McGuinn (1997) added to the understandings of the differences between real-life and classroom problems. In their review of research in problem states given to students, they concluded that real-life problems exist in a larger problem space where constraints are dynamic as problem elements and resources ebb and flow into and out of the problem space. Criteria and goal state may also change due to changing needs or values. The dynamic nature of real life causes the problem to lose continuity. Problems developed for the school setting usually have a high degree of continuity because these problems, their goals, their criteria, available materials, and factors impacting the problem space change very little as solutions are sought by students, the problem solvers.

Another important problem characteristic is that of structuredness. Structuredness can be thought of as a continuum from many known problem elements (well-structured) to many unknown problem elements (ill-structured). In a well-structured problem, the solver begins with an initial state with known factors and conditions. The process of reaching a goal state of a well-structured problem includes contending with known constraints and finding a pathway to the known, desired goal state (Wood, 1983). Ill-structured problems are more complex and include unknown criteria and dynamic factors. The goal state, itself, is variable in the ill-structured problem as constraining elements are often unknown and pathways to solutions are negotiated by social concerns of the problem solvers (Roth & McGinn, 1997). This social-contextual understanding of the problem space was explored by Kramer (1986). In applying principals of cognitive development, she argued that reasoning, as a mental facility, develops within a social structure in both children and adults due to the social nature of investigation, an activity wherein problem solving occurs.

Types of Problems

Problem-solving situations have been categorized into types. An example of problem types was provided by Jonassen in 2000. He describes problem types such as: logic problems, algorithms, story problems, troubleshooting, policy analysis, dilemmas, and design problems, to name a few. Each identified problem type is not discrete, however. Various problems may have characteristics of more than one typology thus adding complexity to categorization. Design problems are found in many industrious human activities as well as human endeavors outside of paid employment (Greiff et al., 2014; Jonassen, 2010). Design problems are of particular interest due to their prevalence in professional settings and the dependency of industry on this particular type of problem. The purpose of design is, in a general sense, product development (Cross, 2021). For example, if an automotive manufacturer desired to develop a new type of vehicle that utilized electricity as an energy source, the engineers in that company would research and design to the established criteria. In another example, if a pharmaceutical company desired to develop a novel vaccination, the scientists on staff would design a process for producing the needed vaccine as they concurrently developed the effective particles that comprise the antidote.

Design problems, in the professional sense, are ill-structured due to the many unknown problem elements. These problems are also dynamic as priorities change throughout the process and multiple factors enter the problem space (Jonassen, 2000). The processes of design are normative, which means that all design follows a generalized process. The following phases have been identified: exploration of the problem, generation of solution ideas, evaluation of solutions, and communication of the developed solution (Cross, 2021), though different industries have specialized the general process into more detailed and specific sequences that incorporate the various valued criteria and processes inherent in those industries or domains of knowledge (Mayer, 1992; Sternberg & Frensch, 1991). Smith (1991), in arguing for industry-specialized problem solving, gives an example of a domain-specific problem-solving process:

> Examples in genetics include writing down an explicit definition key for the allele symbols used, drawing all possible separate gametes, and drawing a Punnet square. These tools are very powerful in achieving quick and accurate problem solutions, but their implementation requires an adequate understanding of the content domain, of the events represented, of the criteria which must be met in order for them to be properly applied, and of how the techniques must be modified to accommodate various nuances in problems. (p. 10)

Genetics problems have specific symbols that must be understood (allele symbols), theoretical understandings that must be applied (gamete separation) and even practical tools to help make sense of the problem space (Punnett square).

Cross (2021) provides detail on the generation of solution ideas (also known as brainstorming). The brainstorming phase of the design process is noteworthy due to its creative nature. There are rules for brainstorming sessions: no idea can be criticized by the design team, many ideas must be generated, no limitations or constraints are placed on potential ideas, ideas must be presented in a brief manner, and design team members are allowed to improve ideas put forward by others. When the brainstorming rules are followed with rigor, many potential solutions will come forward. Jonassen (2010) claimed that as design proceeds and decisions are made, decreasing degrees of freedom exist within the process, however. This observation is interesting because, even though there is an initial burst of ideas, the design process as a whole, creates an overall increasingly self-constraining spiral. As design decisions are made, fewer decisions are allowable or needed. Designer beliefs influence the process as these beliefs direct each decision (Jonassen, 2010).

Expertise in Problem Solving

Greiff et al. (2014), in a research-based persuasive argument, contended that educational systems should prioritize instruction in domain-general problem-solving skills, or problem solving that does not require a great deal of specific content knowledge. Expertise in problem solving is traditionally domain-specific, however. (Mayer, 1992; Smith, 1991; Sternberg & Frensch, 1991). Professionals within the workforce develop skill in problem solving only after they have acquired specific factual knowledge. Gick (1986), in a review of research on problem-solving strategies, generalized problem solving into the following simplified model: representing the problem with a constructed model, seeking a solution, and then analyzing the determined solution by comparing it to the goal state. These processes are enhanced when domain knowledge provides expertise and facility in the skill of problem representation.

Problem representation is critical to problem-solving ability. It occurs when the problem solver constructs an internal mental representation that serves as a model for the problem or proposed solutions (Mayer, 2003; Mayer & Wittrock, 2006; Nathan et al., 1992). Nathan et al. (1992) illustrated the importance of problem representation when they provided algebraic word problems with students within a computer-based program. The program allowed students to represent the problem situation more fully by creating a real-world schema aligned to the given problem. Students were more successful in solving the problems when they developed their knowledge of the problem through developing a visual representation within the program. This study confirmed the importance of mental representation of problem elements in the overall process of solving problems. Given this understanding, more factual knowledge in a specific domain enhances expertise in problem solving (Jonassen, 2010) because the factual knowledge provides cognitive access to potential problem scenarios and schema.

Knowledge Required for Problem Solving

In order to solve problems, various types of knowledge are applied by the problem solver. As mentioned above, domain knowledge is the understanding that the problem solver has about factors effecting the problem that cannot be accounted for in generalized procedures for solving problems (Jonassen, 2010). When a problem solver develops domain knowledge, it is more likely that learned problem-solving processes will continue beyond the classroom. Because one goal of education should be to prepare students with facility in problem solving into all domains of life (professional and personal) (Autor et al., 2003; Griffin et al., 2017; Greiff et al., 2014; Jonassen, 2010; OECD, 2012), transference of this skill is important in the high school engineering classroom.

Mayer and Wittrock (2006) compiled a comprehensive review of research in problem solving, defining this cognitive function. In this review, they indicated types of knowledge in addition to domain knowledge, that influence the processes of problem solving. These researchers describe the following: factual and conceptual knowledge, strategic knowledge, procedural knowledge, and beliefs (metacognitive knowledge). According to these investigators, each knowledge type influences particular processes in the overall context of problem solving. Knowledge of facts and concepts influence mental representation of the problem. Knowledge of strategies and procedures influences planning and monitoring of the problems solving space. Beliefs and metacognitive knowledge of the problem solver influence self-regulation throughout the problem task (Mayer & Wittrock, 2006).

The construct of belief is important because it describes the mental state that causes peoples' actions (Richardson, 1996) and beliefs held by the problem solver are an important part of metacognitive knowledge. Beliefs can impact motivation to continue in the processes of problem solving as beliefs are related to self-regulation throughout the process (Mayer & Wittrock, 2006). Novick and Bassok (2005) compiled a review of research on problem solving, as this cognitive function is currently understood by researchers and theorists. They summarize their findings in research with the suggestion that much effort is needed to more clearly and comprehensively understand the role of student beliefs in the problem-solving processes. Student beliefs about their own ability is especially important. To illustrate the importance of consideration of ability in predicting academic achievement, Greiff et al. (2013), examined 855 students in grades five to11. These students were measured in both ability (factor g) and complex problem solving. They found that problem solving is a more accurate predicter of high achievement in the educational setting than factor g (ability or fluid intelligence). These findings represent a juxtaposition of thoughts assumptions around the importance of ability and academic achievement, especially when considering the importance of failure in the overall process of solving a problem. These findings emphasize a need for more understandings around student and teacher beliefs regarding student ability, motivation and effort especially as these characteristics apply to student problem solving. Thus, beliefs about a person's own ability and intelligence may impact motivation and should be explored as a potential support for problem solving within the high school classroom. Future findings may offer insight in how to improve support of student learning in problems solving for improved achievement outcomes.

Transference of Problem Solving

Transference of facility in problem solving is important in educational settings because extending this skill beyond the scope of school enables students to join a technical workforce

(Greiff et al., 2014; Jonassen, 2010). However, transference has been found to occur under certain problem space characteristics. As mentioned above, the ability to solve problems depends on schema development, or internal problem representation within the learner (Novick & Bassok, 2005). If the learner practices with developing schema for problems, transference of schema-making enables future facility with problem solving (Jonassen, 2010). Other aspects of problem representations that affect transfer are abstraction and continuity. Abstraction is the degree to which the problem represents actual problems and continuity describes the stability of the problem or how much it resists change over time. Problems given in the classroom setting tend to be more abstract and have high continuity and are, therefore, easier to solve. In addition, these problems are usually domain-general. Nevertheless, even though classroom problems do not represent real-life problems, they do have transference to other areas of problem solving (Bassok, 2003).

> When people encounter a novel problem, they might be reminded of a problem they solved previously, retrieve its solution, and use it, possibly with some adaptation, to solve the novel problem. This sequence of events, or "problem-solving transfer," has important cognitive benefits: It saves the effort needed for derivation of new solutions and may allow people to solve problems they wouldn't know to solve otherwise. (p. 343)

Transference depends on similarities or differences between the novel problem and previously solved problems but, nevertheless, prioritization of domain-general problem solving may facilitate the transfer of the skill as students leave the K-12 education setting and pursue more content knowledge in a specialty area.

Because design problems are intended to meet an external demand, they may be good practice for understanding the concept of design and the overall purpose of engineering professions in the high school engineering classroom. Design is a critical task of the engineering profession and high school engineering teachers and curriculum designers should incorporate design problems into lessons in the high school STEM classroom (Greiff et al., 2014). High school students may not be getting enough practice with problem solving, however. The Programme for International Student Assessment (PISA) is a triennial assessment administered to students of more than 40 countries. PISA is administered by the OECD, an organization with the stated goal of assisting nations in the identification and development of "the knowledge and skills that drive better jobs and better lives, generate prosperity and promote social inclusion" (OECD, n.d.). In the 2012 cycle of the PISA, domain-general problem-solving skill was assessed with results indicating that, amongst the tested nations, educational institutions may be neglecting instruction in domain-general problem solving (OECD, 2012). This finding is important because domain-general problem solving is a skill that can be more broadly applied and transfer into any domain of content (Greiff et al., 2014).

Problems given to students in the school setting are well-structured (Jonassen, 2010). The complexity of a high school design problem is limited because criteria are provided to students and materials needed to perform the design function are often known and prescribed. These problems are also high in continuity because external factors do not often impact the problem space of the classroom. Class time is limited and, therefore, purposefully changing factors of the problem introduces more complexity and does not often occur. Finally, the problem goal state does not typically change in a high school design problem. One factor of a high school design problem may be less structured, however. Each student brings a system of beliefs, experiences and varying degrees of domain knowledge to the problem space and thereby increases the complexity of solution-finding. Though problems given in the high school classroom seem prescriptive, students bring diversity of thought and beliefs to their assigned problems and disrupt the structuredness. Students add necessary complexity and in doing so, better enable transference of this very important skill of problem solving.

Synthesis of Literature

Several important propositions emerge from the reviewed literature that may suggest a relationship between teacher understandings of mindset and student engagement in problem solving with feedback serving as an intermediary factor that influences student pursuit of solutions to problems (See Figure 1.). The first factor within this conceptual framework is the influence of teacher content discipline on teacher beliefs. Good (1987) found that teachers held beliefs around student learning within a particular discipline or professional practice. Fang (1996) identified these beliefs as community epistemological understandings about the acquisition of knowledge within the discipline. High school engineering teacher beliefs established within their prior work may impact their mindset and may influence the feedback they provide to students.

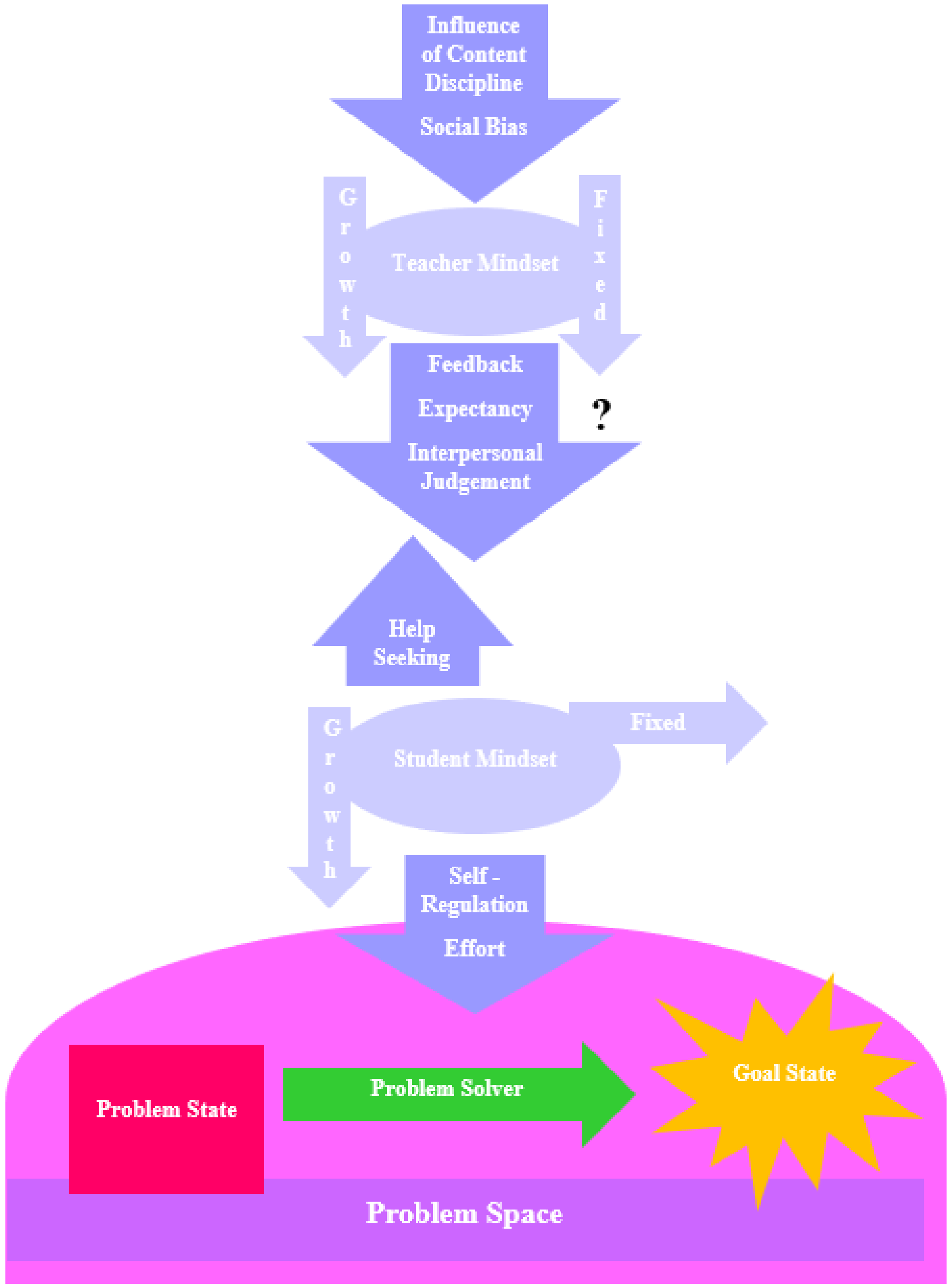
Teacher mindset influences instructional practices and classroom behaviors (Bryan & Abell, 1999; Howard-Jones, 2014; Loucks-Horsley et al., 2009). Though the beliefs of teachers do not directly impact the mindset of the student, the feedback provided by teachers does influence student mindset (Rattan et al., 2012; Haimovitz & Dweck, 2017). This proposition may be supported by research in the relationship between teacher expectancy and student achievement. When teachers expect students will succeed, student achievement improves (Hattie & Yates, 2014). In this case, expectancy can be thought of as a belief, or mindset. Students benefit by positive teacher interpersonal judgments as they tend to ask for help when teachers are seen as supportive (Hattie & Yates, 2014). Studies have also found that teachers have social biases based on implicit theories of science and engineering. (Nosek et al., 2009; Pilotte et al., 2012; Yaşar et al., 2006). Teachers predict who will succeed in their classrooms based on their social bias. Even targeted professional learning on engineering instruction does not change these biases (Nathan et al., 2010; Nathan et al., 2011).

Student beliefs are also a part of this proposed conceptual framework for understanding the constructs of mindset and feedback within the context of problem solving. Student beliefs are an important part of metacognitive knowledge because beliefs relate to motivation, effort and self-regulation, important characteristics for facility in problem solving (Mayer & Wittrock, 2006). Problem solving is a core process of engineering design, a core national goal of student preparation for future careers and facility in this skill is not limited to success in employment. This skill is also important to future success in personal activity (Greiff et al., 2014; Jonassen, 2010).

When the aforementioned constructs are thus related, a relationship forms between them so that they may be viewed as variables in a causal sequence with problem-solving behavior as a final, desired effect (see Figure 1). Though no such cause-and-effect assumptions or hypothesis is suggested, the relationships between teacher mindset, feedback and student problem solving are thus established and this relatedness creates a framework for understanding future observations of interrelatedness of these constructs and context.

Figure 1

Interrelatedness of Mindset, Feedback and Problem-Solving


Influence of Content Discipline
Social Bias
Growth
Teacher Mindset
Fixed
Feedback
Expectancy
Interpersonal Judgement
?
Help Seeking
Growth
Student Mindset
Fixed
Self - Regulation
Effort
Problem State
Problem Solver
Goal State
Problem Space

CHAPTER III

Methodology

This study investigated state and district documents and high school engineering teacher understandings and practices of mindset and feedback. Though the specific mindset of participating teachers (either growth or fixed) was ascertained through discovery, I did not initially seek to discover that teacher characteristic. Instead, I discovered how participating teachers understand mindset and feedback practices as they thought about their classroom within the context student problem-solving situations.

Research Design

The design of this study inculcated considerations of researcher epistemological stance when implementing the methodological approach. This stance determines the fundamental views regarding creation of new knowledge and the forms of acceptable methods and data to be collected (Willis, 2007). This study was conducted from a postpositivist perspective as I sought truth within observations made from the data collected. Aligning with the postpositivist stance, the goal of this study was not to develop new theory but rather to compare observations made within this study to currently held theory around teacher mindsets and teacher feedback. Careful analysis of state and district documents, interviews, and journal entries informed my new knowledge.

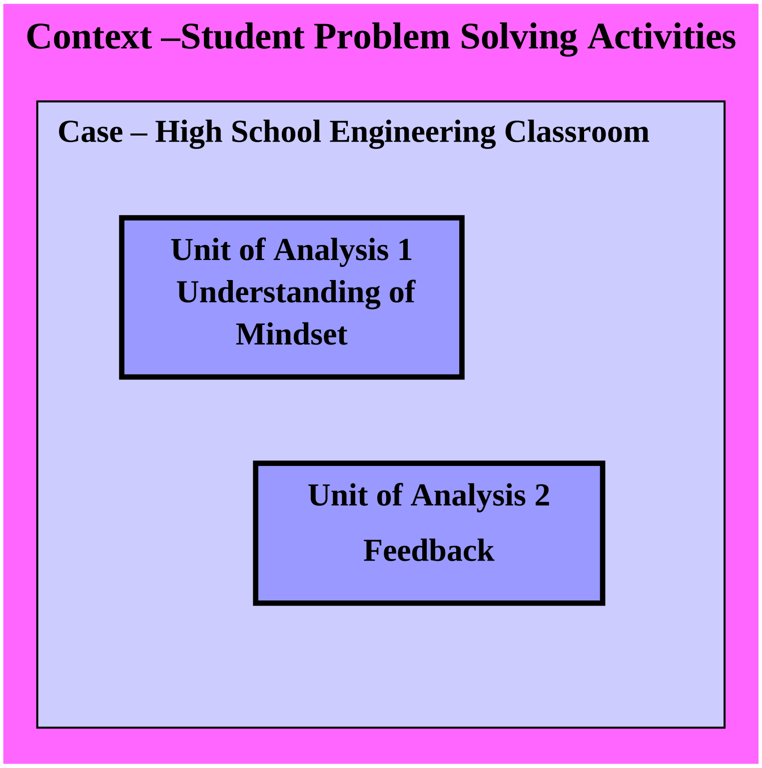
This study was a qualitative design, implementing a case study approach. The qualitative nature of the methodology implies that the analysis of data sources provides rich description of the phenomena in question. Through analysis of text acquired state and district documents, interviews, and journal entries, I identified themes. According to Creswell (2009), qualitative research is a process by which the design of the study may change as new information is discovered. Aligning with this statement, identified themes within the data provided me with rich descriptions of the phenomena in question, and the discovery process altered my originally planned data collection questions. However, the units of analysis remained as originally planned.

Case study is a research methodology common to fields such as political science, sociology, business, and education. Case study reports on complex social phenomena and enables investigators to understand real-life events in a holistic and meaningful way (Yin, 2009). It is an appropriate method for conducting research when the following conditions are met: the research questions are posed as "how" or "why" questions, the investigator is not controlling the events or phenomenon in question, and the focus of the research is a contemporary issue. Further, case study as a methodology seeks to develop understandings within established contextual boundaries where the phenomena under question occur. The contextual boundaries for this study were specific and therefore, this investigation met Yin's criteria for a case study. In this study, I wanted to understand how state and district documents and engineering teachers understood mindset and feedback practices as these practices were applied in the specific context of student problem solving situations (Figure 2). I exerted no experimental control over the context of the case though I did select participants based on similarity rather than differences in order to narrow the scope of the case and create clearer boundaries for the context of the study.

The issue under study also qualified this investigation as a case study. The issue was the contemporary understanding of mindset and feedback. In discovery, more data were collected than necessary to answer the questions posed. As the investigator, I decided upon and selected the data for creating the desired understandings. Finally, this study relied on established theory of mindset and established conceptual frameworks of feedback. Thus, the contextual features of this study aligned with Yin's (2009) technical definition of a case study.

Figure 2

Case Design



Ethical Considerations

To ensure an ethical study was conducted, established guidelines for protection of human subjects were followed. The first step was the detailed plans for collecting and reporting information gathered from human subjects and subsequent approval of this plan through the Texas Christian University (TCU) Institutional Review Board (IRB) as well as the IRB of one of the school districts wherein participating teachers practiced. Participant anonymity was protected as teacher identity was reported through a pseudonym. After responses were acquired and transcribed, each study participant was provided an opportunity to check their individual response for accuracy. Finally, each participant was provided an opportunity to read the final reporting of their individual response to confirm the information and analysis as accurate, according to their perspective. In order to protect the teachers who chose to participate, other participant identifying factors such as teacher name, district name, campus name and teacher ethnicity were not reported. Some participant identifying factors, however, were deemed of interest to this study because discoveries of teacher mindset may relate to these identities. The following characteristics were reported: number of years in industry prior to becoming a teacher, type of work in industry and number of years teaching. These factors provide detail in understanding teacher mindset and classroom feedback practices in the context of student problem solving.

Researcher's Role

My role as investigator was that of an insider to both the subject of study and the institution in which some of the teachers worked (Gall et al., 2015). This position brought complexity to the interpretive nature of data collection and analysis. From a historical perspective, I served as a science and engineering teacher for 17 years. Though my service in this position brought insight to the study context, it also may have biased how I interpreted the results. My current position is within one of the school districts in which participants work. I engage with the participants as a non-evaluative instructional specialist. This professional relationship may have influenced the interviewer/interviewee protocols and analysis of the findings and thereby brought bias into the study. Researcher reflection and reflexivity mitigated the potential bias of my position and role as I analyzed my findings and controlled for biases in the interpretation of the data (Gall et al., 2015). Thus, I regularly checked my observations for potential biases and ethical issues that may have emerged.

A sensitive issue considered throughout this study was teacher preparedness in the areas of mindset and feedback. One instrument requested for review as an artifact was the current instructional frameworks published by one of the districts wherein some of the teachers worked. I asked the teachers to share their knowledge of the concepts of mindset and feedback, especially as they related to the context of student problem solving. These data may inform the district of professional development and instructional preparedness regarding the teacher participants. Nevertheless, the engineering teachers were fully informed of all data analysis protocols and procedures as they related to their current roles in this school district.

I was careful to avoid coercion to influence the participating teachers' stance or beliefs regarding mindset. My role was to lead discovery of current understandings and not influence or change the teachers' beliefs and practices. It may have occurred that this study caused personal reflection on the concept of mindset or practices of feedback. Though I did not attempt to influence change, change may have occurred, as the participating teachers initiated their own growth as a result of new learnings. In a sense, this study served as a form of professional development because, through participation, teachers were asked to reflect deeply on their beliefs regarding their students and their practices as students are working to solve problems.

Site Selection

This study was conducted with four separate engineering teachers from four separate high schools. Three of the teachers worked within one district which was a large, urban school district. The fourth teacher worked in an adjacent smaller suburban district. Both school districts were located in the southwest region of the U.S. The specific content area of interest for this study was high school engineering and the context that informed the broader units of analysis was student problem solving within the engineering classroom. I did not actually observe the engineering classrooms. Instead, I asked teachers to describe and think about student problem solving that occurred in their engineering classrooms. Specifically, I asked the teachers to describe their mindset and feedback practices in these situations.

Sampling Procedures and Data Collection

Purposeful sampling technique guided my selection of both participants and artifacts that informed the study. Purposeful sampling was appropriate for this case study because depth of information was sought, rather than broad or generalizable findings (Patton, 2015). The specific type of purposeful sampling was typical case sampling, which enabled description of what was normal to the phenomenon under question (Patton, 2015).

Participants

All participants were teachers of high school engineering content. They were carefully selected with priority given to participants who reflected the following common criteria: greater than three years of teaching experience, a designation of “proficient” or higher on the state evaluation instrument, Texas Teacher Evaluation and Support System (TTESS), and prior experience in a technical field of work such as engineering. The number of years of teaching experience is important because this selection criterion eliminates the potentially confounding factor of teacher inexperience. Poor instructional practice may also confound the findings. Therefore, I sought teachers who were deemed to meet the professional standard of “proficient” in instructional practice, as defined by the teacher appraisal tool developed by the State of Texas (TTESS). This teacher evaluation instrument includes dimensions of instructional practice such as: achieving expectations, content knowledge and expertise, communication, classroom environment, classroom culture, and goal setting (TEA, 2022). Teachers deemed “proficient” on this instrument were likely to have standard knowledge of instructional practice and communicate that knowledge in interviews. Prior experience in a technical field such as engineering was important to this study due to findings in the review of literature. Teacher beliefs, such as mindset, originate in communities of practice (Green, 1971; Lehrer, 1990).

Engineering teachers with professional experience expanded my findings pertaining to teacher mindset.

In order to select four teachers, I used the following procedure. Step One: an introductory e-mail (See Appendix A) was sent to 58 high school engineering teachers within the State of Texas who worked outside of my home district. The list of 58 engineering teachers was developed through searching publicly available campus webpages. From this initial introductory e-mail, one high school engineering teacher was selected for the study. After approval from my home district, I identified eight high school engineering teachers. For these 8 teachers, I sent a solicitation e-mail that generally stated the purpose of my study and offering of professional learning credit. If the teachers indicated they were interested in learning more about my study, I sent the introductory e-mail. The introductory e-mail briefly described the study protocols and participant requirements. Study requirements included: availability of upcoming problem-solving activities within the teachers' planned lessons, availability for teacher time to engage in journaling, and availability for teacher time to engage in two individual interviews and one focus-group interview. Teachers were informed that they would receive eight hours of professional development credit for participation in the study. They were assured that their employment status and performance evaluation would not be influenced by participation or non-participation in this study or subsequent study findings. A timeline for the planned occurrence of each required activity was also communicated. To assess if each potential participant met the selection criteria established for the study, selection criteria were communicated in the initial e-mail (Appendix B). From teachers who responded, indicating that they are willing to participate, four engineering teachers were purposefully selected with priority given to those who aligned most closely with the established criteria.

Step Two: after four participants were selected, a second round of e-mail communication was sent to the selectees (see Appendix C), serving as a notice that the teacher was selected to participate. With this communication, the selected participants received the Study Participant Consent Form (see Appendix D), administered through the Qualtrics application. A live internet hyperlink was generated for the consent form and this link was included in the second e-mail.

Once selected, the total time required per participant was no more than seven hours and 20 minutes. Teacher participant time allocations are detailed in Table 1.

Table 1

Teacher Participant Time Requirements

Activity	Time Required (Minutes)
Scheduling Interviews and Planning Times for Journaling	60
First Interview	60
Second Interview	60
Focus Group Interview	120
Journal Entry One	20
Journal Entry Two	20
Journal Entry Three	20
Journal Entry Four	20
Member Checking/Manuscript Review	60
Total	7 Hours, 20 Minutes

Descriptive Analysis of High School Engineering Teachers. Four high school engineering teachers participated in this exploratory study. Each teacher shared the selection criteria characteristics established for this study: three or more years teaching experience, “proficient” performance standard on the Texas Teacher Evaluation and Support System (TTESS), and work experience in a technical industry such as engineering. Each of the four participating engineering teachers taught various high school engineering courses in a Texas public high school during the course of this study. Three of the four teachers were employed by a large, urban school district that serves more than 70,000 students in grades kindergarten through high school. The fourth teacher was employed by a smaller suburban district that serves approximately 7,000 students in grades kindergarten through high school. For each teacher, the number of years of experience within the technical field and number of years' experience in teaching varied. Table 2 provides details of the teaching and industry experience.

Table 2

Participating Engineering Teacher Experience

Pseudonym	Teaching Experience (years)	Industry Experience (years)	Type of Industry Experience
Antonio	11	9	IT Specialist/Railroad Engineer
Hector	16	3	Thermal Processing (electrical)
Johnathan	9	27	Engineering Analysis/Development (aerospace)
Sandy	24	9	Electrical (military)

Data

Data were collected through documents and interviews (two individual teacher interviews, one focus group interview, individual teacher journaling). Table 3 outlines the types of data collected and the timeline for data collection.

Table 3

Types of Data and Collection Timeline

Data Source	Data Collection Task	Data Type	Nov 2021	Dec 2021	Jan 2022	Feb 2022
1	TAC RULE §149.1001 Teacher Standards (TTS)	Document				
2	TAC RULE §235.61 Pedagogy and Professional Responsibilities Standards, Grades 7-12 (PPR)					
3	Secondary Certificate Standards for Engineering 7-12 (SES)					
4	District Instructional Framework (DIF)					
5	Individual Teacher, Preliminary	Interview				
6	Teacher Focus Group					
7	Teacher Reflective Journal					
8	Individual Teacher, Final					

Documents. To guide selection of document artifacts, I used professional judgement based on the review of research conducted for this study, personal experiences within the field of engineering education and knowledge of both State of Texas and school district professional standards. Selected document artifacts provided detailed information regarding the phenomenon of interest to this study and enabled insightful analysis (Gall et al., 2015). Four documents were analyzed to inform this study (Table 3). The number of documents selected to support my findings is important because the use of multiple information sources increased reliability and validity for the study (Patton, 2015).

Descriptive Analysis of State Documents. The Texas State Board of Educator Certification (SBOE) is the professional teacher certifying unit of the Texas Education Agency (TEA). SBOE developed standards that serve different functions in the qualifying processes of both beginning and practicing educators in Texas. These documents represent intended teacher knowledge because they are standards of practice for beginning and practicing educators. For beginning teachers, this knowledge is confirmed through the process of certification testing. For practicing teachers, this knowledge is confirmed through administrative evaluation practices. The instructional knowledge and practice standards stated within the state documents are published in the Texas Administrative Code (TAC). TAC is a publicly accessible and periodically revised document that serves to guide the practices and policies of independent school districts and other state-serving institutions such as alternative teacher certification providers and universities that offer teacher certification programs. The state documents evaluated in this study were accessed from the TEA website and analyzed through the interpretational analysis process described above. The TAC reference number for each document is included, where applicable.

The state documents analyzed for this study were: TAC RULE §149.1001 Teacher Standards (TTS), TAC RULE §235.61 Pedagogy and Professional Responsibilities Standards, Grades 7-12 (PPR) and Secondary Certificate Standards for Engineering 7-12 (SES). The TTS are performance standards for currently employed Texas teachers that inform teaching practice in areas of training, appraisal and professional development (TAC §149.1001, 2014). The PPR document has a similar intent but is broader in scope. These standards also "inform proper teaching techniques, strategies, teacher actions, teacher judgements, and decisions by taking into consideration theories of learning, understandings of students and their needs, and the backgrounds and interests of individual students" (TAC RULE §235.61, 2018). The final state document analyzed for this study was the SES. This document was not published within the TAC but, rather, was discovered as an inclusion in individual content area standards, included under the different content areas on the TEA webpage. The content area of focus for the SES is secondary engineering and therefore is relevant to this study.

Descriptive Analysis of School District Document. Though there were teachers from two separate districts, only one of the districts had an instructional guiding document for analysis. The District Instructional Framework (DIF) provides detailed guidance in the following general areas: learner and culture with descriptors, action components with descriptors and lesson structure. Each general area provides further details with dimensions of the following areas: the learner culture and action descriptors, and steps for the lesson structure. The goal of the document is to accomplish student achievement outcomes by providing a framework for creating an optimal learner-centered classroom environment.

Interviews. Interviews reveal the knowledge and understandings that are held within the mind of the interviewee (Patton, 2015). Through interviewing, my task was to discover understandings and perspectives that I could not directly observe within text of a document. The topics discovered from the interviews detailed below were intentionally elicited through an interview guide approach. I conducted each interview and followed the outline contained within the interview guides developed for this specific study (see Appendices E-H). The purpose in using these guides was to systematically collect a comprehensive set of data and avoid gaps in data that could have occurred with a less structured interview methods (Patton, 2015).

Teacher Individual Interviews. Each teacher was individually interviewed at the beginning and end of the study. This interview was conducted online through a Zoom application and was recorded in Zoom. The interview proceeded for no more than one hour. All recorded conversations were converted into a text document for analysis.

The final teacher interview was structured differently from the initial interview because I assumed that teachers would develop an understanding of the constructs under study due to their involvement in the study. Because of this potentially confounding effect I asked each teacher to describe their current understandings around the constructs and context under study. This interview was also conducted online through the Zoom application and was recorded in Zoom. The final interview required approximately one hour. All recorded conversations were converted into a text document for analysis.

Teacher Focus Group Interview. Each teacher was asked to participate in a focus group interview. This interview took place after the initial interview and before the final interview. The focus group interview was conducted for one and a half hours, through the Zoom application and was recorded in Zoom. All recorded conversations were converted into a text document which was subsequently analyzed. The teachers in the focus group were considered homogenous because they were all high school engineering teachers. The intent of the focus group was to gather understandings of the constructs under study within a social context. The understandings are assumed to have grown out of the discussion that occurred within the group and thereby produced high-quality information (Patton, 2015). Subsequent topics that arose during this discussion are described in the study findings.

Teacher Reflective Journal. For the purposes of this study, the teacher reflective journal was considered a type of interview. Teachers were asked to respond to journal prompts through the Qualtrics application. Teachers were directed to spend no more time than 20 minutes on each journaling time and to conduct their journaling after their workday officially ended. The journaling occurred concurrently with a student problem-solving activity. This activity was a normal part of the engineering curriculum and was not specific to this study. Journaling occurred four times throughout the time students were engaging in a problem-solving activity: before the activity began, at the beginning of the activity, as the activity was ongoing and at the closure (or end of the activity). The purpose of the journaling was to capture understandings of the units of analysis for this study (mindset and feedback) as teachers were instructing within the context of the study (student problem solving). The information gathered from journaling added to the knowledge gained throughout the study as it built understandings of the enactment of teacher knowledge of both mindset and feedback within the context of student problem solving. See Appendix H for reflective journal prompts.

Procedures for Recording and Managing Data

Documents

The documents to be analyzed for this study are static, official and unofficial publications, obtained from public-serving institutions. All documents published by the State of Texas are free and accessible to the public through the online TEA website. The DIF was accessed through the school district and is made available to all teachers and instructional specialists within the district. Since I am employed through the same school district, I accessed this document after receiving approval through the district IRB. All documents obtained and analyzed within this study do not require protection for privacy and they were not maintained with any special provisions. These documents are open source and were analyzed for content.

Interviews

All engineering teacher interview responses were recorded in a digital format (Zoom) and protected through security-sensitive and password protected digital cloud services. These cloud services were maintained under the care and protection of the investigator. A typed transcript was created from all teacher interviews. The transcripts were maintained in a Microsoft Word document file that is stored on the personal device of the investigator. This file was secured through a password protected hard drive on a device that was secured in the possession of the investigator at all times.

The teacher reflective journals were administered through the Qualtrics application. Teacher responses were maintained within a password protected Qualtrics account until they were downloaded into a Microsoft Excel file. The downloaded files were converted into Microsoft Word documents and subsequently secured on the investigator's laptop hard drive at all times.

Data Analysis Procedures

Interpretational analysis was implemented to examine the text data identified in this study. In this process, I examined text and grouped findings according to constructs, themes and patterns that brought sense-making to the information (Gall et al., 2015). The constructs under study (mindset and feedback) provided the broad units of analysis. These constructs were decided by me, the investigator, based in literature and on my experience within the field of high school engineering. Patterns in meaning were discovered that coincided with the conceptual framework described in the summary of literature section of this proposal (Figure 1). In answering each question, an inductive approach was used. For the inductive processes, findings were analyzed for how well they compared to the conceptual framework developed from the synthesis of literature for this study (see Figure 1). This framework is not considered to represent comprehensive discovery, however, and only served as a guide to discovery therefore some themes may have been deductions based on themes identified from within the analyzed text.

The following steps outline the procedure used in interpretational analysis. Step one: text data were generated from interviews through transcription of the interview results. Documents were analyzed in their original text form. Step two: a paper copy of all text was carefully read as initial references to the constructs of interest to this study were discovered within the text. As references to the constructs were discovered, they were highlighted on the document with a notation made in the margin, suggesting a possible theme within the data. Step three: the above process was repeated so that several iterations of reading and highlighting occurred with each document and interview transcript. The repetition helped to make sense of the information and revise and combine themes, and constantly comparing. This slow theme identification and conceptual framework comparison allowed for depth of thought and creative meaning-making from the data. Step four: after the paper process, I transferred the documents into the NVivo system and re-coded them, establishing the themes identified. Step five: within NVivo, I generated a query that combined all themes, by source, into a single document. I printed this document and reorganized larger themes that logically inculcated subthemes. I also broke down the identified statements into smaller phrases so that each specific phrase matched a theme. If a phrase seemed to fit into two themes due to prepositional phrases or actionable phrases, I coded it into both themes. Step six: after I was satisfied with larger themes and subtheme identification, I created a Microsoft Excel spreadsheet, retyping the themes within a larger table (see Appendices I-K). Step seven: Visualizations such as tables and graphic displays were created for reporting the findings, discussion and conclusions of this study.

Data Display

Data reporting is organized by construct within each research question. Findings from each data type were reported within broad categories created by the constructs of the study (mindset and feedback). Primary themes were sought within these constructs to create a broad category that was related to the broader conceptual framework of this study (see Figure 1). NVivo and Microsoft Excel was used to create both tables and visual representations of discoveries. Some of the visual representations were generated by the NVivo application and exported to the findings of the study while others were generated using Microsoft Excel. The tables and visual representations simplify explanations of thematic categorization of the findings and relationships discovered between the findings and the constructs under study. When reporting themes and subthemes, no order of representation and no hierarchical importance was assumed or implied through the presentation order. Analysis of each identified theme and subtheme was described including how that theme intersected with or deviated from the conceptual framework of this study.

Strategies to Establish Credibility

Several strategies were employed to establish credibility in this study. For each engineering teacher, multiple separate responses were collected, creating a triangulation of the data analyzed. Each high school engineering teacher engaged in a preliminary interview, journaling, a final interview, and a focus group interview. These multiple sources of inquiry ensured that responses and understandings acquired have a high degree of validity and they have the effect of confirming findings or explaining findings that may be discrepant (Gall et al., 2015). The multiple data sets created a whole picture of the teachers' understandings of the concepts of mindset and feedback. Because the responses occurred over time, teacher understandings may have evolved as they participated in the study. This change of understanding over the study time was expected and allowed for a rich and reflective description of the teacher's knowledge (Creswell, 2009). Detailed descriptions of findings also served to ensure the study findings are valid.

All teachers were provided an opportunity to check the data. As the final report was compiled, teachers were given a copy of the draft and an opportunity to member-check the findings to ensure that descriptions have were reported correctly and themes and patterns were described accurately. Member-checking is a technique that provides accuracy and authenticity to the investigation findings (Gall et al., 2015). This practice further establishes credibility of the findings. Finally, reporting of the findings are presented in rich descriptions with direct quotes from the teachers and analysis of the text of the artifacts collected. The rich descriptions provide evidence for claims made within the findings of the report and the use of rich-descriptions in the final report gives validity to the data analysis of the study (Creswell, 2009; Creswell & Miller, 2000).

Delimitations and Assumptions

Data collection occurred from October 2021 to February 2022. A potentially confounding effect on this study was the timing of data collection. This timeframe was adjacent to a major world event, the COVID-19 pandemic. This event had sweeping impact on in-person learning at schools across the U.S., including the school districts of the study participants. The effects of the pandemic may have impacted the perspectives that were voiced by the study participants. Though data collected included analysis of documents and teacher interviews, a major limitation of this study was the sample size of participating teachers. Only four teachers participated and therefore, findings from this study are not generalizable and the limited number of participants limits the scope of the findings.

For this study, an assumption about accurate self-reporting was made. I assumed that teachers reported their perspectives accurately, carefully, and thoughtfully. Another major assumption was that the perspective of the teachers under study was meaningful and could be made explicit through the methods of this study (Patton, 2015). Due to the prolonged timeframe of the study, teachers developed an understanding of the constructs analyzed and became reflective on their perspectives. All teacher understandings that were gathered were assumed to have developed throughout the study.

CHAPTER IV

Findings

Presentation of Findings

Findings are organized by research question, each of which deals with a specific construct, mindset for question one and feedback for question two. The context of classroom problem solving is analyzed and reported alongside the construct of feedback as understandings of feedback practices were concurrent with the student problem-solving context. The units of analysis and study context were examined as themes and subthemes were discovered within the data sources so findings are organized by these themes and subthemes. In general, findings from documents are reported first, followed by findings from interviews.

Research Question One: Mindset

Throughout analysis, careful consideration was given to ideas and phrases that indicated an expectation of knowledge (documents) or possession of knowledge (interviews) of mindset. Within the documents, three major themes were discovered: teacher-student interactions, classroom climate, and attitude toward engineering. Subthemes were identified for two of the major themes. Teacher-student interactions was subdivided into motivation and respect. Classroom climate was subdivided into the subthemes of expectations, inclusivity, reflective growth, and persistence. Statements and phrases from interviews which aligned closely with findings from the documents are reported following findings from the documents within each theme or subtheme. Two separate major themes were discovered exclusively from teacher interviews: teacher beliefs about student characteristics and teacher knowledge of mindset. These themes create the final sections of reporting for research question one.

Theme One: Teacher-Student Interactions

Teacher-student interactions are situations wherein some form of communication (verbal or nonverbal) occurs between the teacher and student. These situations were identified in phrases that relate to interpersonal communication that would indicate a potential for student growth.

Motivation. Statements and phrases coded for motivation either stated that the teacher will motivate students or, alternatively, implied interactions that would create student motivation. Table 4 provides phrases from documents identified for the subtheme of motivation.

Table 4

Theme: Teacher-Student Interactions

Statements and Phrases Identified in Documents for the Subtheme: Motivation

Document	***Reference (Statement/Phrase)***
TTS	plan instruction that…motivates students to learn
	communicate clearly and accurately…in a manner that encourages students'…best efforts
	validate each student's comments and questions, utilizing them to advance learning for all students
	provide them with support in achieving their goals
	promote complex, higher-order thinking, leading class discussions and activities that provide opportunities for deeper thinking
	support all students in their pursuit of social-emotional learning and academic success
	encourages students to be self-motivated, taking responsibility for their own learning
	set individual and group learning goals…communicate these goals with students and families to ensure mutual understanding of expectations
PPR	communicating teacher expectations
	interact with students in ways that reflect support
	communicate to all students… expectations of high-quality work
DIF	Goal-setting practices… to help students build self-confidence, self-belief, responsibility and ownership of their learning

Teacher-student interactions that create student motivation were also identified from the interviews. Johnathan, when describing his general perception of his engineering students, indicates that he motivates his students to pursue the difficult work required in his engineering classroom:

> … so obviously, I'm rather fond and biased towards them because, I mean, they stuck with me. This is their third year, so they're very… either interested in engineering or something is driving them to, kind of keep pursuing. This is not the easiest course that they could take by any means, in my school. …because, I mean, am I the hardest teacher? I don't necessarily believe so, but I am going to try to push them to that next level, if I can, so it's not just a question of walk in and do easy and so…

Hector also characterizes classroom interactions that help students improve their problem-solving skills.

> I believe students can get better. It's just a matter of desire. Do they want to get better? And so, for that, it's just a matter of interest, you know. If you have something, and you can present it in a way that interests them, then they're all into it.

Respectful Relationships. Teacher-student interactions were also found to convey an idea of respect for the students as relationships are built between student and teacher. The act of building relationships conveys a message of respect for students as the teacher takes time to understand nuances of the students' lives. Attribution of characteristics (or, in this case, lack of attribution) relates to mindset theory because mindset is a personal belief about personal characteristics. If a teacher, in building the relationship, makes no assumptions or interpersonal judgement, there exists openness for learning about a person. Teacher openness to learning is an instructive example for the student, modeling beliefs to make no personal judgements about the students' personal qualities. Thus, through respectful relationship-building, the teacher is modeling a growth mindset through making no prior assumptions or attributions. Table 5 lists statements and phrases within the subtheme of respectful relationship discovered in the documents.

Table 5

Theme: Teacher-Student Interactions

Statements and Phrases Identified in Documents for the Subtheme: Respectful Relationship

Document	***Reference (Statement/Phrase)***
TTS	interact with students in respectful ways at all times maintain and facilitate respectful, supportive, positive, and productive interactions
PPR	interact with students in ways that… show respect for all students use effective interpersonal skills (including both verbal and nonverbal skills) to… communicate the teacher's commitment to students
DIF	Respectful interactions are had between teachers and students Interactions… are inclusive knowing students academically, socially and emotionally such as learning about their families, cultures and interests instruct with… relationships

Sandy describes the importance of interactions that build respectful relationships with students when describing how feedback impacts students:

> If they (teachers) have a good relationship or a good foundation with that student, feedback is typically received very well, even feedback that is negative in nature. That puts them (students) in a positive direction. … I found that relationship is the big key on how a student receives feedback.

Johnathan adds to this understanding as he describes how he builds relationships, "…if I happen to stop by a game, or have seen their band performance… they get excited that you took the time out to see them…it actually helps go back to the relationship basis with the students…"

Theme Two: Classroom Climate

The idea of classroom climate was more broadly represented within all documents analyzed for this study. Classroom climate is distinguished from teacher-student interactions as climate is created with or without communication or interaction from the teacher and thus, statements and phrases identified for teacher-student interactions may also be identified for creating classroom climate. Several subthemes were assigned to the broader theme of classroom climate: expectations, inclusivity, reflective growth, and persistence. Teacher interview data found support in each theme and subtheme of classroom climate.

Expectations. The idea of high expectations for student learning was found to support growth mindset in students because each student is expected to learn which requires a belief in malleability of characteristics, both from the students and from the teachers. Statements identified in document analysis indicated that teachers should have knowledge of holding high expectations for student outcomes. Many statements and phrases were identified in the documents that indicated teachers would create a classroom climate where student achievement was expected (see Table 6).

Table 6

Theme: Classroom Climate

Statements and Phrases Identified in Documents for the Subtheme: Expectations

Document	***Reference (Statement/Phrase)***
TTS	promote complex, higher-order thinking… provide opportunities for deeper learning
	set high expectations and create challenging learning experiences
	work to ensure high levels of learning, social-emotional development, and achievement for all students
	demonstrate the belief that all students have the potential to achieve at high levels and support all students in their pursuit of social-emotional learning and academic success
	accept responsibility for the growth of all of their students, persisting in their efforts to ensure high levels of growth on the part of each learner
	maintain a strong culture of individual and group accountability for class expectations
	maintain a culture that is based on high expectations for student performance
	manage and facilitate groupings… to maintain student… achievement
PPR	communicate to all students… expectations of high-quality work
	ensure… elements of the classroom environment convey high expectations for student achievement

DIF	provide learner-centered instruction… to achieve the learner outcomes… to be successful in post-secondary work foster a safe environment… to excel and achieve at high levels ensure student growth and achievement build classroom communities with high academic expectations encourage their academic achievement high academic standards and expectations are held for all students instruct with rigor demonstrate… a passion to achieve their full potential as a lifelong learner provide high-quality and rigorous learning opportunities

Teachers interviewed corroborated upholding a classroom climate of expectations. For example, when asked how she would respond to student success, Sandy replied:

> I would tell them that I was proud of them. I would tell them that I like what they came up with. It looks great. I would ask him is they could do something differently, what would they do? I would get them to look beyond just their success to see if there's another way of getting it done or maybe they could improve upon it so they just don't stop at that, because you can always improve.

This response indicates that Sandy creates a climate of high expectations by communicating a belief in student growth. Johnathan describes a process of strategic pairing of students to accomplish high achievement from all students. With this method, he pairs high achieving students with students who may need help understanding a problem. This heterogenous grouping is effective because students "learn from each other (with) far better vernacular. I can say something a million times and I may not say it the right way to click with a particular student."

Inclusivity. A classroom climate of inclusivity conveys a message that all students will learn. No students within the classroom are excluded from potential growth in learning provided in this environment. Examples of statements of inclusivity discovered in the documents are included in Table 7.

Table 7

Theme: Classroom Climate

Statements and Phrases Identified in Documents for the Subtheme: Inclusivity

Document	***Reference (Statement/Phrase)***
TTS	use a range of instructional strategies… to make subject matter accessible to all students
	validate each student's comments and questions, utilizing them to advance learning for all students
	encourage all students to overcome obstacles and remain persistent in the face of challenges
	support the learning needs of each student
	work to ensure… achievement outcomes for all students
	demonstrate belief that all students have the potential to achieve at high levels
	create a community of learners in an inclusive environment
	teachers create a mutually respectful, collaborative, and safe community… by using knowledge of students' development and backgrounds
PPR	communicate to all students… expectations of high-quality work
SES	employ instructional strategies that build on the linguistic, cultural, and socioeconomic diversity of students
DIF	Active student engagement and achievement of subgroups are intentionally monitored
	create a classroom that promotes a culturally responsive learning environment
	student differences and unique strengths… are celebrated
	encourage… sense of belonging in the classroom
	high academic standards and expectations are held for all students
	environments are inclusive

Teacher interview responses also demonstrated knowledge of the importance of inclusivity. For example, when asked if a student could get better at solving problems, Johnathan replied, “I believe everyone is capable of getting better at solving problems.” This statement demonstrates a belief that all of his students can take part in this learning. Hector provides an idea of how feedback can impact students, “You know, I try to tailor to each student and how they are, you know, personally… you have some that are high… some that are low… and so I… tailor it to them to match.” This statement indicates that he believes all of the students can grow from feedback if the feedback is individualized to their diverse needs. Sandy conveys a similar sentiment, “I try to use motivation as a way to show them that they can be good at something. It just may not look like the person beside them or it may not be like their mom or dad.” Unique and individual student potential is nurtured through motivational statements.

Reflective Growth. A classroom climate of reflective growth was identified when statements and phrases indicated that students would receive some type of feedback, reflect on the feedback, and pursue growth based on that input. Table 8 details examples of statements and phrases of reflective growth identified in document analysis.

Table 8

Theme: Classroom Climate

Statements and Phrases Identified in Documents for the Subtheme: Reflective Growth

Document	*Reference (Statement/Phrase)*
TTS	encourage all students to overcome obstacles and remain persistent in the face of challenges, providing them with support in achieving their goals
	utilize learners' individual strengths as a basis for academic and social-emotional growth
	accept responsibility for the growth of all of their students, persisting in their efforts to ensure high levels of growth on the part of each learner
	maintain a strong culture of individual and group accountability for class expectations
	encourages students to be self-motivated, taking responsibility for their own learning
	set individual and group learning goals for students by using preliminary data
DIF	ensure student growth and achievement
	help students build self-confidence, self-belief, responsibility and ownership of their learning
	commitment to continuous improvement
	achieve potential as a lifelong learner

Antonio supported the idea of student reflective growth in his response to the question of how students get better at solving problems. “I think it’s all practice, practice, practice, practice in every instance… just the way of finding whatever works for you as a person or as a student… finding your path.” This statement implies that learning to solve problems is an iterative process with growth occurring through sequences of practicing problem solving. Hector also creates a climate for reflective growth when students are struggling with a problem. To encourage growth, he will, “try to push them to see how those relationships carry over. It’s different aspects and, once they see that this is just like that thing over there, and let them figure out those things on their own versus telling them…” Hector provides a learning environment wherein students are encouraged to independently create meaning out of their struggle.

Persistence. Finally, a classroom climate of persistence was identified in statements of understanding that failure, or potential failure, is a part of the learning process. Potential failure or difficulty in completing a task requires effort to overcome that difficulty so statements in valuation of effort were also coded for persistence. In document analysis, there were only two incidences of expectation of teacher knowledge of creating a classroom climate of persistence. These statements are provided in Table 9.

Table 9

Theme: Classroom Climate

Statements and Phrases Identified in Documents for the Subtheme: Persistence

Document	***Reference (Statement/Phrase)***
TTS	communicate… in a manner that encourages students' persistence and best efforts
	encourage all students to overcome obstacles and remain persistent in the face of challenges

The teachers had more to add regarding persistence, however. For example, Hector relates the role of effort in solving problems.

> …effort is going to be another big component because you have to try because nothing is going to be easy, and if it is easy, is that something that you would even want, you know… so the effort to me, is one of the biggest things about… not just problem solving, but everything that you want to do. You have to be willing to try and put in the work to figure it out.

Johnathan adds to this sentiment:

> Probably 95% is effort. I mean, not giving up. I mean, being willing to persevere. We all learn from mistakes, so I mean, why not take what you learn from that mistake and apply it, you know. That's the engineering design process.

Antonio also valued persistence when describing the role of effort in solving problems:

> Everything 100% effort. If you don't put forth effort into it, you're not going to solve anything. It's just not gonna… Listen, it's just like everything in life. You put in effort. You get what you give.

Later, Antonio added context to overcoming the difficulty of the high school engineering class:

> The engineering students, they come in here with an expectation that it's just going to be another elective class and they're going to have an easy way out… then, once they get here… they go through the math and the science and the physics and everything behind it. And then, after they get over all that, then they really enjoy it because they finally get that "aha!" moment. This is where it all ties together with real life.

Theme Three: Attitude Toward Engineering

Student attitude toward engineering was only identified in one reference within the documents, specifically, within the SES document (Table 10).

Table 10

Statement Identified in Documents for Theme: Attitude toward Engineering

Document	***Reference (Statement/Phrase)***
SES	how students' prior knowledge of and attitudes toward engineering may affect their learning

Teacher interviews added more understandings to the concept of student attitude toward engineering. Sandy related her students' thoughts, "…their perception of engineering is having fun and building things. They don't understand the process that goes into what it takes to be an engineering person…" Antonio adds:

> The engineering students, they come in here with an expectation that it's just going to be another elective class and they're going to have an easy way out… then, once they get here… they go through the math and the science and the physics and everything behind it. And then, after they get over all that, then they really enjoy it because they finally get that "aha!" moment. This is where it all ties together with real life.

Theme Four: Teacher Beliefs

Teacher beliefs was an understanding derived only from currently practicing teachers, therefore this theme was not identified in document analysis. Table 11 summarizes teacher responses, discovered in interviews, indicating beliefs about different student characteristics. Teacher beliefs were discovered as teachers were asked if students could improve in the different domains outlined below. Furthermore, the responses are categorized as growth (indicating that they thought students are able to grow in the domain) or inconclusive (indicating that the teachers were not certain that this characteristic is malleable). Full text of teacher quotes is provided in Appendix I.

Table 11

Teacher Initial Beliefs about Malleability of Student Characteristics

Domain	**Antonio**	**Hector**	**Johnathan**	**Sandy**
Problem Solving	*Growth*	*Growth*	*Growth*	*Growth*
Effort	*Growth*	*Growth*	*Growth*	*Growth*
Motivation	*Growth*	*Growth*	*Growth*	*Growth*
Intelligence	*Inconclusive*	*Inconclusive*	*Inconclusive*	*Inconclusive*
Ability	*Growth*	*Growth*	*Growth*	*Growth*
Self-Control	*Growth*	*Growth*	*Growth*	*Growth*

Sandy believed that, “intelligence is basically application, how you apply that, learning a skill. You definitely have to learn the skill to make intelligence work.” “Hector,” after reflecting on his former statements while participation in the study, indicated that he had come to a new understanding of intelligence. His new understanding was, “I think that you don’t necessarily have to use it to see it increase but it’s whether or not you’re conscious of it and I think that provides some of that increase as well.” Antonio stated that though he already knew about mindset because his campus conducts professional learning sessions on this topic, “you never really pay attention… (in this study) we’re actually focused on it, so I think it did help change my view.” Johnathan adds “I think I’ve almost gotten to the point where I haven’t always thought it through all the way until you kind of made me think about it or rethink it.” Sandy also reflected on her thinking:

> So, you know you can, as a teacher, you can assume a lot and based on what you've been doing, especially with my years of teaching you understand mindset. You kind of get it, but sometimes we get too relaxed thinking that we're good. But we should self-assess at least every couple of years to make sure we're still on the right track, because the kids change (due to Covid)… They do things instinctively different. So, I had to… I thought …I had it right that a couple of my kids did it differently. You know I assumed a lot so that's where I'm glad you made… I'm glad I got with you on this, because now, I know that that 80% of what I was thinking was right, but Covid kids made me think differently and how I need to approach it a little bit better.

Especially, in the case of “Hector,” as noted above. Hector thought about his beliefs around the domain of intelligence. Initially, Hector indicated that intelligence was likely a fixed attribute. After giving it much consideration, however, Hector revised his initial statement, indicating he had changed his belief about this domain.

Theme Five: Teacher Knowledge of Mindset

Teacher knowledge of the construct of mindset was a theme that was not derived from document analysis. Instead, similar to teacher beliefs, this knowledge was only provided by currently practicing teachers, through interview responses. Appendix J summarizes those responses. Teacher knowledge of mindset was discovered as teachers were asked what they know about this concept. When initially asked about their understanding of the concept of mindset, the high school engineering teachers had varied responses. Hector and Sandy were able to describe the construct. Hector defined mindset as, "the mental fortitude to complete whatever it is that you're doing." He describes a person with a growth mindset and then contrasts with a description of a person with a fixed mindset. "If you have the mindset that it may be hard but (then think), 'I'm gonna do it', then that person is generally going to be successful. If you have a mindset that says, 'Oh well. It's hard so I'm just going to not do it and find something else." Hector understands that mindset is about mental strength because a person with a growth mindset will continue in a task even if it is difficult and he may fail. Sandy described mindset as "I want to improve myself, so I go and educate myself on things I don't know or I'll keep doing trial and error until I figure it out or come up with a different way of getting things done." With this statement, Sandy understands that a growth mindset involves believing that growth is possible and pursuing knowledge despite difficulty that may be encountered. The other teachers hedged at a definition or stated that they did not know how to define mindset.

As the study continued, the teachers grew in their understanding of the concept of mindset. Hector stated, "…mindset is important because they first have to believe that it's something that can get done. The kids are so easily defeated, you know, that they pretty much take themselves out of it before they even get a chance to think about the problem and whether or not they can to it." With this statement, he is demonstrating an understanding that students need to believe in their won ability to grow. Sandy added, “You definitely don’t know what the kids are bringing to the table so you got to figure that out.” Sandy demonstrates understanding that a teacher cannot make assumptions about student knowledge. Johnathan adds that, “as educators, they have to have faith in us and we have to support them. …absolutely they have to try.” Johnathan describes teacher belief in student ability to achieve and student persistence in attempts in learning.

Summary of Findings: Mindset

Five major themes were identified from documents and interviews. Table 12 summarizes the identified themes, subthemes, and sources of themes for research question one.

Table 12

Summary of Major Themes, Subthemes and Sources of Identified Themes for Research Question One: Mindset

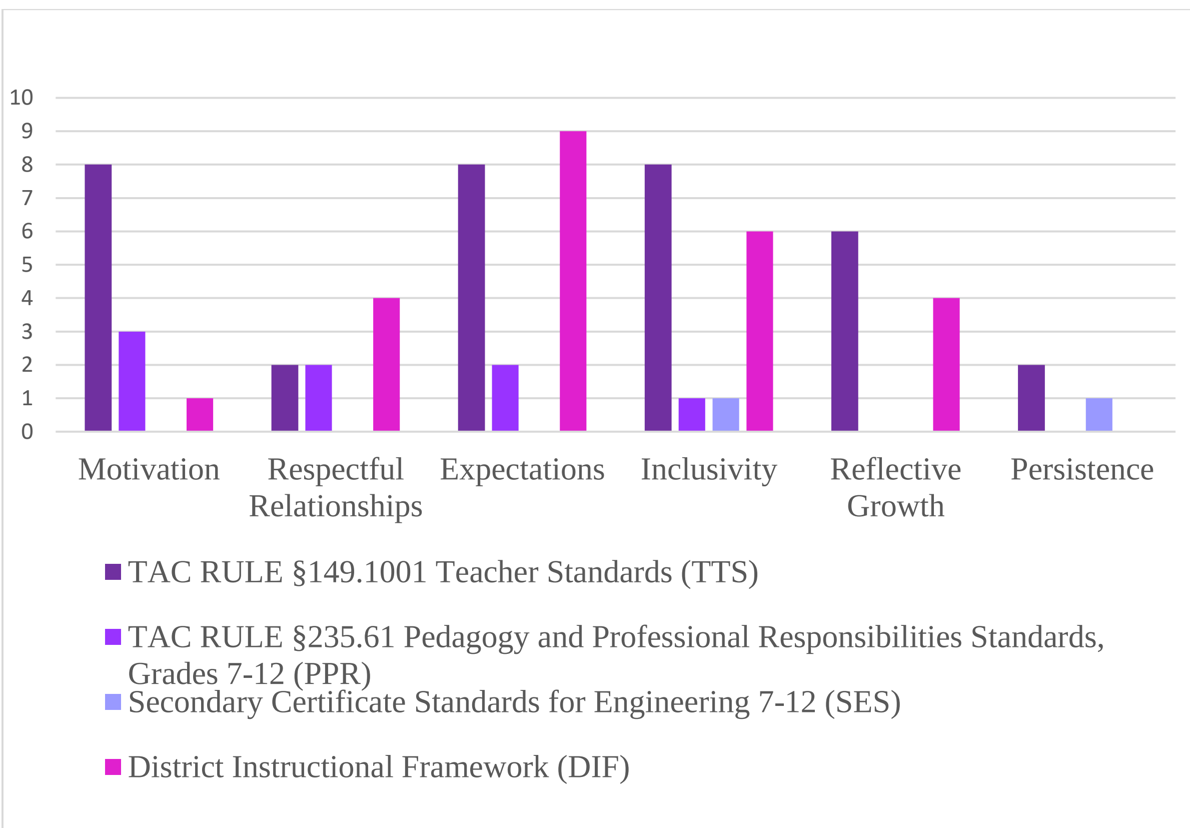
Major Themes	***Subtheme***	***Source of Identified Themes***
One: Teacher-Student Interactions	Motivation	Documents and Interviews
	Respectful Relationships	Documents and Interviews
Two: Classroom Climate	Expectations	Documents and Interviews
	Inclusivity	Documents and Interviews
	Reflective Growth	Documents and Interviews
	Persistence	Documents and Interviews
Three: Attitude Toward Engineering	None	Documents and Interviews
Four: Teacher Beliefs	None	Interviews
Five: Teacher Knowledge of Mindset	None	Interviews

Within the documents codes were identified for themes and subthemes of mindset. Appendix K provides a summary of the frequencies of statements in document analysis. Figure 3 represents the frequency of statements and phrases, from state and district documents, within the themes of Student-Teacher Interactions (subthemes: motivation and respectful relationships) and Classroom Climate (subthemes: expectations, inclusivity, reflective growth, and persistence).

The four subthemes that have the most support within the documents are as follows: expectations for students, inclusivity, motivation, and reflective growth (Figure 3). From the prevalence of the identified subthemes, teachers are expected to know how to create a climate for student growth mindset and teachers should know how to have interactions that enable student growth mindset. The two subthemes that had the least support within the documents are persistence and attitude toward engineering. In each case of theme and subtheme identified within the documents, a corresponding teacher response was identified from interview text. These interview responses supported teacher possession of knowledge for each theme and subtheme and provided context to teacher understandings of the concepts.

Figure 3

Comparison of Documents for Domains of Mindset Understandings in Themes: Teacher Interactions and Classroom Climate



The theme of teacher beliefs, which was only identified in interview data, revealed that teachers believe in potential student growth in the following student attributes: problem solving, motivation, effort, ability, and self-control. For the characteristic of student intelligence, each teacher responded in an inconclusive manner, indicating reticence in belief in student growth in that domain. The final theme discovered for the first research question was teacher knowledge of mindset. This theme was also only identified in interview data and I discovered from the teacher responses that teachers do not have a clear understanding of this concept. One teacher did not attempt a definition for the concept. Two of the teachers correctly related the concept to personal motivation and another more specifically related mindset to persistence in the face of potential failure on an attempt. This fourth response also correctly related mindset to potential limitations on personal attributes.

Research Question Two: Feedback in Context of Problem Solving

Textual data were analyzed for expectation of teacher knowledge (found in documents) and possession of teacher knowledge (found in interviews) of feedback in the context of problem solving. Three major themes were identified with subthemes discovered within two of these. Feedback was the first major theme with the subthemes: solving a problem or improving design, feedback for student growth, and effective feedback. The second major theme was problem solving with the subthemes: thinking skills and entering the problem space. The third major theme was set apart because the intention of Research Question Two was to discern teacher understandings of feedback practices in the context of problem solving. Therefore, the third theme was a special category created for this specific intersection of ideas. Table 13 summarizes the identified themes, subthemes and sources of themes for research question one.

Table 13

Summary of Major Themes, Subthemes and Sources of Identified Themes for Research Question Two: Feedback in the Context of Problem Solving

Major Themes	***Subtheme***	***Source of Identified Themes***
One: Feedback	Solve a Problem or Improve Design	Documents and Interviews
	Feedback for Student Growth	Documents and Interviews
	Effective Feedback	Documents and Interviews
Two: Problem Solving	Thinking Skills	Documents and Interviews
	Content	Documents and Interviews
	Process	Documents and Interviews
	General	Documents and Interviews
	Entering the Problem Space	Documents and Interviews
Three: Feedback in the Context of Problem Solving	None	Documents and Interviews

Theme One: Feedback

Feedback was discovered as an element of teacher knowledge expectations (within the documents) and practices (within the interview responses). Statements and phrases identified for coding as feedback in the document analysis may have been identified and coded in more than one subtheme, enabling full understanding of how the character of feedback related to the conceptual framework of this study.

Solve a Problem or Improve the Design. The subtheme solve a problem or improve the design of a problem represents instructional feedback directed toward improving a student product and relates to this study because product improvement is part of the process of solving problems, specifically design problems (Cross, 2021). Statements were identified that represented an expectation of knowledge in prompting students to use information or find information and apply that information to a potential solution. See Table 14 for example statements and phrases identified in the documents to create this subtheme.

Table 14

Theme: Feedback

Statements and Phrases Identified in Documents for the Subtheme: Solving a Problem or Improving Design

Document	***Reference (Statement/Phrase)***
PPR	use carefully framed questions to enable students to reflect on their understanding of content and to consider new possibilities
SES	the iterative engineering design process (e.g., identification and formulation of problems, conceptualization of possible solutions, analysis of solutions to find an optimal solution based on practical and realistic constraints, implementation of the chosen solution, validation of the chosen solution, and solution redesign if necessary
DIF	think critically and synthesize information from multiple sources to develop and apply skills for real world applications

Teachers interviewed also demonstrated knowledge of this type of instructional feedback. Hector describes an assignment wherein students discover potential market feedback to help them ideate their future design:

> I just had them figure out… what they could do to improve upon the cell phones that they have… Every year there's a new phone (that) comes out for all of these different companies. So I basically ran them through the same process… seeing what they like about the phone, asking other people what they like and dislike and then compiling all of their data into a spreadsheet so that they can sort through the information. … and then the things that were… popular amongst the people that they were able to reach out to… Those were the things that they were adding to the designs for the new phones.

Sandy describes her use of questioning to push students toward design improvement and solutions. "You can show them how to problem solve by giving them a set of questions that will give them a better idea of how to solve the problem…" If a student is struggling, she stated, “I would ask them what have they done so far? What has been the result? …and then I would make suggestions… Have you tried this? What do you think of that?” Johnathan carefully monitored his students as they are solving problems. When they seem to struggle, like Sandy, Johnathan will prompt them with questioning. “How are we doing what? What do you think about this?” With these questions, he tried to “steer them to let them derive their own pathway to keep going.”

Feedback for Student Growth. Feedback for student growth is a more general type because it is not targeted to improving a product but rather improving student learning. Within the documents, there were 12 identified statements or phrases of feedback for student growth (Table 15).

Table 15

Theme: Feedback

Statements and Phrases Identified in Documents for the Subtheme: Feedback for Student Growth

Document	***Reference (Statement/Phrase)***
PPR	promote students' use of self-monitoring and self-assessment
	base feedback on high expectations for student learning
DIF	teachers provide timely feedback to students
	assessment items and performance tasks are reviewed to refine what students need to know and be able to do
	formative assessments are aligned to the skill and rigor of the standard(s) and created prior to designing the lesson
	student to student and teacher to student discourse reflects substantive thinking in relation to the learning objective(s)
	purposeful questioning techniques are used to promote critical thinking
	students self-monitor their own learning in relation to the learning objectives
	growth data are used to identify individual student needs for intervention and to create growth targets for students
	student receive clear and specific feedback that informs their progression toward the learning objectives
	teacher observes, provides individual support, and elicits feedback to inform next steps
	teacher gives information with which a learner can confirm, add to, overwrite, fine-tune, or restructure information in memory

Hector adds to understandings of providing feedback for student growth as he describes his feedback support to students who are struggling with a problem.

Effective Feedback. Within the documents, there were many identified statements or phrases for effective feedback. Statements and phrases were coded for this subtheme when the statement characterized the feedback in some way or implied that a teacher should use effective feedback methods (see Appendix M for full text). Table 16 summarizes characterizations of feedback derived from references discovered in document analysis.

Table 16

Summary of Feedback Characterizations Identified in Documents

Document	***Feedback Descriptors***
TTS	Consistent, immediate, lesson adjusts as a result
	Immediate, reinforces learning
	Detailed, constructive, aligned with goals
	Based on data, aligned with goals
	Timely, comprehensible, based on data, aligned with goals
PPR	Timely
	Constructive, guides student learning
	Use appropriate language, timely, accurate, constructive, substantive, and specific
	Based on high expectations for student learning
	Carefully framed questions, enable student to reflection
DIF	Clear, specific, informs progression toward the learning objective(s)
	Information with which a learner can confirm, add to, overwrite, fine-tune, or restructure in memory

Interview analysis added much insight to understandings of effective feedback. Appendix N provides detail of how the responding teachers characterized their feedback when answering various questions during the interviews. High school engineering teachers described feedback that promotes student growth mindset. For example, they reported that they make students aware of their processes, aligning with the FP type from Hattie and Temperley (2007). Johnathan provides an example of FP feedback when he, "… ask(s), 'How are we doing? What do you think about this?'... I don't want to give them answers, but I tried to steer them and let them derive their own pathway to keep going." They also reported feedback in the FR type. For example, Hector states he "keep(s) them as even-keeled as possible… this is what we're supposed to be doing so let's not get excited about that." Antonio says that "feedback has to do a lot with making sure that the student is aware of what they're doing." The examples from Hector and Antonio feedback-regulatory (FR) because the teachers are providing information that confirms student confidence in moving forward in their task. Hector describes his feedback to students struggling with a problem:

> I always tell them that it is never as complicated as they make it because a lot of the things are mental and… they tend to get in their own way. So, I try to break down whatever the issue is, in terms of things that they already understand and make those correlations… continue to ask them questions that build upon… the previous question, which again is tied to things that they're already familiar with and try to push them to see how those relationships carry over.

Hector is describing a process-level feedback (FP) and regulatory-level feedback (FR). This scenario qualifies as FP because Hector is addressing the students' understandings as they make correlations between what they know and what they need to know. The feedback also qualifies as regulatory, encouraging students to overcome their complicating of the problem at hand. These levels (FP and FR) were identified by Hattie and Temperley (2007) as effective in promoting student mastery and they align with findings regarding effective feedback for promoting student growth mindset (Haimovitz & Dweck, 2017; Sun, 2015).

Theme Two: Problem Solving

The theme of problem solving was represented in the documents with references that were identified with the following subthemes: thinking skills (content, process, or general) and entering the problem space.

Thinking Skills. Thinking skills related to problem solving were identified in the documents in three categories: content, process, and general. There was only one statement that did not indicate a context of content or process and was, therefore, identified within the general thinking skills subtheme. Table 17 includes all statements and phrases within the subthemes of thinking skills identified in the documents.

Table 17

Theme: Problem Solving

Statements and Phrases Identified in Documents for the Subtheme: Thinking Skills

Subtheme	*Document*	*Statement/Phrase*
Thinking Skills (Content)	***TTS***	teachers set high expectations and create challenging learning experiences for students, encouraging them to apply disciplinary and cross-disciplinary knowledge to real-world problems
	SES	use engineering, mathematics, physics, and chemistry concepts to design solutions to engineering problems use problem-solving techniques from mathematics, the physical sciences
Thinking Skills (Process)	***SES***	the iterative engineering design process (e.g., identification and formulation of problems, conceptualization of possible solutions, analysis of solutions to find an optimal solution based on practical and realistic constraints, implementation of the chosen solution, and solution redesign if necessary implement and completely test a design solution using appropriate technology use problem-solving techniques from mathematics, the physical sciences use various strategies to determine the risks and benefits of designed solutions to a variety of problems solve problems and communicate information using a variety of computer applications (e.g., spreadsheets, word processors, mathematics packages, graphics programs)

	DIF	Thinks critically (analyses, synthesis, problem solves) opportunities to… problem solve and collaborate occur daily
Thinking Skills (General)	***PPR***	instruction that maximizes students' thinking skills

Teacher interview responses supported the idea of content knowledge in student problem solving. For example, Hector describes qualities that characterize students who are good problem solvers in the context of a classroom problem solving activity related to cell phones.

> It was more about who was more in tune with their phone. Because, of course, they all are on them and they don't go anywhere without them and that's all they do all day long is mess around on the phones. But the ones that are knowledgeable about some of the hardware that goes into the phone and some of the different ways you can use the different applications, those were the ones that were jumping in, you know, with both feet and trying to figure it out.

Johnathan characterizes his students as good problem solvers when they have content knowledge in mathematics:

> …we have three females. All three of those are good mathematically, and I say three quarters of my males are very good, with a mathematical background. Many of them have taken additional sciences and they're usually taking even AP or honors courses as well, like English and history so they're very well-rounded students.

Entering the Problem Space. Another subtheme identified within the theme of problem solving was that of entering the problem space. In document analysis, statements or phrases that included expected teacher knowledge in concepts such as motivation, persistence, and self-regulation were included for this theme. Fourteen statements or phrases were identified (Table 18).

Table 18

Theme: Problem Solving

Statements and Phrases Identified in Documents for the Subtheme: Entering the Problem Space

Document	***Statement/Phrase***
TTS	encourage all students to overcome obstacles and remain persistent in the face of challenges, providing them with support in achieving their goals
	teachers set high expectations and create challenging learning experiences for students, encouraging them to apply disciplinary and cross-disciplinary knowledge to real-world problems
	teachers provide opportunities for students to engage in individual and collaborative critical thinking and problem solving
	teachers lead and maintain classrooms where students are actively engaged in learning as indicated by their level of motivation and on-task behavior
PPR	promote students' use of self-monitoring and self-assessment
	use effective communication techniques, including questioning and discussion techniques, to foster active student inquiry, higher-order thinking, problem solving, and productive, supportive interactions
	encourage students' self-motivation and active engagement in learning
SES	the role of individual and group projects in promoting learning and creating a learning environment that actively engages students in learning and encourages self-motivation
	motivate students and actively engage them in the learning process by using a variety of interesting, challenging, and worthwhile engineering design tasks in individual, small-group, and large-group settings
DIF	Perseveres (inquires, learns, seeks knowledge)
	Support for dependent learners to become independent thinkers
	Problem solves (plans, self-motivates, monitors, sets goals)
	students self-monitor their own learning in relation to the learning objectives
	student self-monitoring toward the learning target occurs daily

Responses to interview questions demonstrated that teachers possess knowledge of student motivation to enter the problem space. For example, Hector describes his students:

> The biggest thing for most of my students right now is they're curious. And so that leads to… asking questions and trying to find the answers… when those answers aren't readily available, then it pushes them to go and try to figure out what they can do on their own.

Johnathan describes curiosity in his classroom, "…many of them will explore… if they don't know it… on their own." Sandy, when explaining qualities that make her students good problem solvers relates the same sentiment, "… curiosity and the ability to try something more than one way… They want to know how things work and why they work the way they do." In each case of interview response, teachers attribute student motivation to an intrinsic curiosity that drives students into the problem space.

Theme Three: Feedback in the Context of Problem Solving

The final theme identified as relevant to research question two was feedback in the context of problem solving. This theme was pulled out as a separate idea because statements and phrases contextualized the feedback given to students so that it intersected with the classroom work occurring. Because of this intersection, statements identified in the documents were double-coded as feedback in a different subtheme (Table 19).

Table 19

Statements and Phrases Identified as Theme Three: Feedback in the Context of Problem Solving

Document	***Statement/Phrase***
TTS	teachers communicate with students and families regularly about the importance of collecting data and monitoring progress of student outcomes, sharing timely and comprehensible feedback so they understand students' goals and progress
PPR	use carefully framed questions to enable students to reflect on their understanding of content and to consider new possibilities promote students' ability to use feedback to guide and enhance their learning
SES	the iterative engineering design process (e.g., identification and formulation of problems, conceptualization of possible solutions, analysis of solutions to find an optimal solution based on practical and realistic constraints, implementation of the chosen solutions, validation of the chosen solution, and solution redesign if necessary
DIF	think critically and synthesize information from multiple sources to develop and apply skills for real world applications

The engineering teachers interviewed described feedback they provided as students solve problems in the classroom. Antonio breaks down the problem for his students as he leads students to "work things through in baby steps all the way up through." Hector describes a similar process as his students are working through problems. "I try to give feedback for each step because I would hate for them to get too far and end up doing something that is not necessarily correct and then have to stop and go too far back to try to correct it." He tries to do it in "small bits" from beginning to end to avoid "having to scour the whole process…" Sandy's description of feedback aligns with these statements. She provides feedback "after every step because feedback is needed so they know what direction they're going… If I let them do their thing until they get halfway through… sometimes they're on the wrong path and don't realize it or they may go in a direction that's not good…"

Summary of Findings: Feedback in the Context of Student Problem Solving

As with question one, some of the statements and phrases coded had two or more codes applied when they were identified as fitting into multiple themes or subthemes. For theme one, feedback, the high frequency of statements or phrases coded indicated an expectation of teacher knowledge of the instructional practice of providing feedback to students. Interview responses supported the findings from document analysis in each subtheme of feedback, indicating robust practice in applying feedback within the engineering classroom. Appendix L shows frequencies for each theme and subtheme discovered in the documents for question two.

For theme two (problem solving), in the subtheme of thinking skills, there were eight incidences mentioned in the documents. Content related thinking skills in relations to problem solving were identified three times. Teacher interviews aligned with the concept that student content knowledge supports the activity of problem solving. Process related thinking skills were more robustly supported with seven mentions. Again, teacher interviews indicated that they instruct on engineering design process. One statement from the documents was identified for general thinking skills.

Fourteen statements in the documents aligned with the concept of entering the problem space indicating that there is an expectation that teachers create an environment wherein students can effectively enter a problem space within the classroom. Teacher interviews added clarification to this idea as three teachers mentioned student curiosity as a specific factor that adds motivation for student problem solving activity.

There were five incidences of statements or phrases coded within the documents that were specific to providing feedback in the context of problem solving. Teacher interviews provided more specific understanding to this type of feedback with three teachers stating that they provide feedback at each stage of the problem-solving process so they can support students in moving toward a solution.

CHAPTER V

Discussion and Conclusion

High school engineering teachers work in a system that values student achievement. This same system endeavors to prepare students for future employment in the technical workforce. This study examined how the system of education and teachers therein understand mindset and feedback practices for this unique set of teachers. Although the findings do not provide generalized statements regarding high school engineering teachers, the findings do provide important insight into how the state, school district and four engineering teachers view mindset and feedback.

Research Question One: Mindset

Mindset, a belief about degree of malleability of personal qualities, has been characterized as ‘growth mindset’ or ‘fixed mindset.’ A growth mindset is a belief that personal qualities can change, or grow. Alternately, a fixed mindset is a belief that personal qualities cannot change (Mrazak et al., 2018). In examining state and district documents, this study confirms that the authors of these documents expect all teachers know how to create a classroom climate wherein students believe in their ability to grow in their learning. In addition, high school engineering teachers interviewed for this study confirmed that they know how to create this classroom climate. Both sources of information (documents and interviews) supported high school engineering teachers enacting this knowledge through the following modalities: teacher-student interactions, respectful relationships, holding high expectations for student achievement, creating an inclusive environment wherein all students engage in the learning, reflecting on work with the intention of growth, and persisting through obstacles that occur in the learning process. Though, in the context of creating this classroom climate, teachers understand the concept of mindset, this study revealed that high school engineering teachers cannot accurately define the construct of mindset. When initially asked to describe mindset, all high school engineering teachers clearly demonstrate a low level of understanding, indicating that they may benefit from instruction on mindset theory as knowledge of the theory may help high school engineering teachers understand why this classroom climate helps engineering students to grow in their problem-solving abilities.

A finding around teacher beliefs may relate to the findings around teacher understanding of mindset. In this study, teacher beliefs were categorized as either growth or inconclusive. Initially, teachers indicated they believed students have a potential for growth in each of the following domains: problem solving, effort, motivation, ability and self-control. However, for the characteristic of intelligence, all high school engineering teachers initially indicated a lack of confidence for student ability to improve. This finding is interesting because intelligence has historically been used as a measure of student potential in learning and achievement, and intelligence has been shown to improve when people exercise executive functions such as those required in problem-solving activities (Buschkuehl & Jaeggi, 2010). Intelligence is also thought to be inherited and assumptions around the fixedness of intelligence are used to determine a person's mindset, fixed or growth (Dweck, 1999, 2006). Therefore, teachers may see this characteristic as difficult to change and they may not know factors that influence changes in student intelligence. This finding further supports the need for teacher understandings of mindset because, through providing problems for students to solve and creating a classroom climate of student growth, teachers should believe in student growth in the domain of intelligence.

In follow-up interviews, teachers added more context to their understanding of the characteristic of intelligence, describing it as connected to a skill such as problem solving. One of the high school engineering teachers even reported change in his belief about intelligence. This finding is interesting because it shows the high school engineering teachers experienced growth in their understanding as a result of involvement in this study. At the beginning of the study, the high school engineering teachers were not informed of the construct of mindset, other than information they may have acquired through their own professional learning. Through involvement however, they reflected on their own thinking and they reported that their beliefs changed. This finding has two important implications. First, teacher mindset around student potential growth in intelligence may change as a result of understanding the construct of mindset. Second, teacher growth may be a result of prolonged reflective activity, such as was required for involvement in this study. This study confirms the importance of reflective practice in teacher growth.

Information regarding teacher knowledge of mindset was only directly analyzed from interview data. An interesting finding regarding expectation of teacher knowledge of mindset indirectly arose from document analysis, however. Across all analyzed documents, TTS and DIF were found to have the most consistent representation of ideas related to teacher knowledge of mindset. This finding is interesting because both of these documents are standards of practice for currently practicing teachers. However, the PPR is a standard of practice for teachers entering the field and this document contained fewer statements or phrases relating to growth mindset. The difference in representation between these documents may indicate that expectation of knowledge of creating a classroom of student growth mindset (as demonstrated in state documents) is a task that requires a deep level of understanding of student learning, only gained through experience.

High school engineering students are expected to fully engage in the problem space. An important feature of this space is failure. The engineering design process, an integral part of high school engineering curriculum, takes into account that potential solutions will go through many stages of proposal, trial and error, and re-design (Cross, 2021). Persistence is required of students as they solve problems and a classroom climate of persistence implies that teachers understand that failure, or potential failure, is a part of this process. Thus, learning is not easy and facing obstacles, and sometimes failure, is an important part of the learning process (Hattie & Yates, 2014). The importance of persistence is missed in the state and district documents, however. This under-representation is evidenced by the imbalance of statements regarding support and knowledge of student persistence. For example, there are many, varied statements regarding expectations for achievement in student outcomes but only two statements regarding student persistence. Nevertheless, all high school engineering teachers interviewed for this study acknowledged the importance of failure in the learning process and described how they supported students as they encountered failure. The under-representation of expectation of teacher knowledge in persistence indicates there may be a need for more acknowledgement from state and district policy-makers regarding student persistence and teachers may need professional learning support in understanding of the importance of student persistence.

A final interesting finding for research question one related to student attitude toward engineering. The documents contained only one reference that characterized student prior knowledge of the field of engineering and student attitude as affecting learning. Teacher interviews, however, identified a problem in student understanding of the field of engineering. The high school engineering teachers reported that their students did not understand the context of their coursework when they selected to take the engineering class. The teachers indicated that student attitude improved as students began to understand the field, however. The implication of this finding is that students' attitudes change with their experiences in the engineering classroom and their initial attitude may be determined by lack of understanding. Attitude toward engineering is important and relates to the literature on student and teacher beliefs which impact mindset (Jones et al., 2000; Watt, 2004). Students may hold assumptions about personal potential within the field and may not pursue engineering. Thus, aligning with current national trends in science education reform, students may benefit from early instruction in engineering practices and early instruction in potential career pathways such as engineering.

Research Question Two: Feedback in the Context of Problem Solving

The findings around feedback in the context of problem-solving activities confirmed teacher understanding of this instructional practice. In analyzing both documents and interviews, three major themes were discovered: feedback, problem solving, and feedback in the context of problem solving. Exploration of these themes confirmed that teachers understand the importance of providing feedback and they provide various types of feedback to their students as students are solving problems.

Particularly interesting findings arose within the subtheme of effective feedback. For example, documents call for feedback to be “immediate” or “timely.” This characterization may not align with findings in the literature for supporting student problem solving or student reflective processes. Kulhavy and Anderson (1972) found that feedback may be more effective if it is not immediate. Allowing time between the completed student product and feedback may enable greater student reflection on the work (Kulhavy & Anderson, 1972; Mory, 2004; Shute, 2008). Refraining from offering feedback during problem-solving processes outside of brainstorming was also reported in the literature to be effective because the delay allows students to focus on their problem-solving process (Corno & Snow, 1986). Thus, the statement of “timely” feedback is more appropriate because this phrasing would support either immediate or delayed feedback. Another consideration of effective feedback offered during problem solving, specifically during brainstorming sessions, is the suggestion that there should not be criticism of student ideations (Cross, 2021). Critical feedback during creative work may prohibit this important part of design work. However, teachers reported providing both positive and negative feedback to students so students are aware when they are progressing correctly or incorrectly in their work. The teachers did not specifically say if this feedback is during brainstorming. Thus, there may be need for greater contextualization of providing effective feedback during problem solving.

An interesting finding regarding feedback practices was discovered as the teachers described how they, at times, withdraw from a student group as the student group discusses potential problem solutions. The engineering teachers found, through experience, that it was better for students to explain the problem situation to each other and to argue about potential solutions. The group discussions between students were more productive in making meaning of the problem than teacher explanations. The teachers felt that their own interventions may interfere with student progress because students used language that could be readily understood by each other and were therefore productive in constructing explanations within the problem space. Teachers noted that student arguments over potential solutions to a problem seemed to move the problem-solving process forward. This finding is interesting because teachers indicated that this social construction of understanding of the problem and potential solutions may serve the students as a feedback mechanism on their own thinking about the problem.

Teachers also added contextual understanding of the concept of using data as a form of feedback. The cell phone problem presented by Hector is an example of instructional practice where students are taught how to use feedback gathered from potential stakeholders of design as a tool for ideation or innovation in the engineering design process. This concept is interesting because this type of feedback is provided from a source other than the teacher and it directs student learning on a potential new design, thus confirming the use of feedback for reflective growth and the use of feedback to improve a design. Teachers also confirmed the use of questioning as a form of feedback to students. According to the documents, teachers are expected to use “purposeful questioning techniques” to “promote critical thinking (DIF).” The high school engineering teachers recalled several instances of using questioning to guide students through the problem-solving processes of engineering design.

Both documents and teacher interviews confirmed the importance of content and process knowledge as enhancing the instruction on the thinking skills required for problem solving. The literature indicated that content knowledge enables facility in problem representation, an important skill for solving a problem (Mayer & Wittrock, 2006). Several statements from the documents emphasized the importance of applying content knowledge in the development of student thinking skills. Teacher interviews supported this finding as they described student motivation and facility in problem solving improvement when students have subject domain knowledge related to the problem (such as mathematics or physics). Several statements were identified in the documents that emphasized the importance of instructing on the thinking skill of problem solving. As with domain knowledge, high school engineering teacher responses confirmed that that they provide instruction in processes related to problem solving.

The subtheme of entering the problem space revealed interesting findings. In order to enter a problem space and successfully solve a problem, a student requires qualities such as motivation and self-regulation. (Mayer & Wittrock, 2006). This idea was confirmed in document analysis. High school engineering teachers’ responses indicated that they possess knowledge of student motivation to enter the problem space as they described student motivation. Of particular interest was that three of the four engineering teachers interviewed independently described the student motivation as prompted by student curiosity. These teachers indicated that their efforts in motivating students related to their ability to cause or prompt student curiosity. The teachers are able to create this curiosity, and thus motivation, when they provided problems that piqued student interest either through relevance to prior knowledge (such as a problem with improvements to cell phones) or through providing a novel experience that students found interesting (such as a problem with programming a robot). The relationship of curiosity and motivation adds greater understanding to the classroom situations that improve student motivation and thus enable a student to enter the problem space.

The final theme identified in document analysis, that was relevant to research question two, was feedback in the context of problem solving and the engineering teachers interviewed added contextual description to the practice of this feedback. The teachers emphasized that they respond to student work at progressive intervals so students can make corrections as they progress through the problem. They provide feedback at the beginning, throughout and at the end of a problem-solving activity. The feedback has the purpose of prompting student thought and progress through the activity. Feedback types include: questioning, redirecting, offering ideas or suggestions and explanations of concepts. The teachers emphasized that effective feedback in the context of student problem solving must be accompanied by teacher actions such as: listening, awareness of student activity and progress, and sometimes restraint in offering feedback as students work through the problem collectively. An interesting idea that was offered by the engineering teachers was the suggestion that students provide feedback to each other in this context as they argue over ideas and solutions and as they explain problem and solution features to each other. In this manner, students are socially constructing the character of both the problem and potential solution.

Conclusion

Based on the findings in this study, I am proposing a model for optimizing student problem-solving in the high school engineering classroom (Figure 4). The classroom climate that may improve student solution-finding will be an inclusive environment that promotes high expectations for student achievement, in general and not specific to problem-solving activities.

Teachers will balance this climate with support in both reflective growth and student persistence in solution-finding. This last statement suggests that teachers will help students to understand the process of reflection and inculcate understanding of the importance of failure, as a necessary part of learning. In this model classroom, high school engineering teachers will support students through the reflective process and help their students understand how to overcome obstacles that they may encounter in learning and finding solutions.

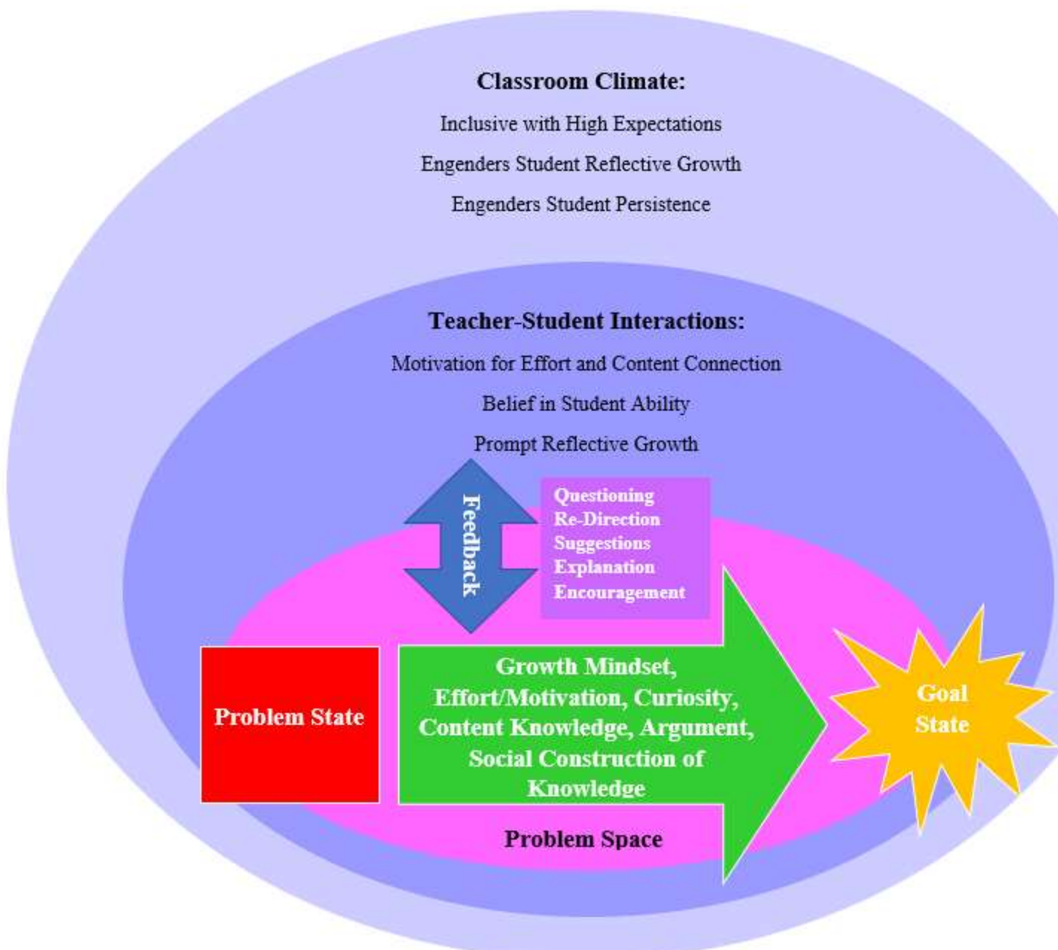
According to the proposed model, teacher-student interactions should include motivation that elicits student curiosity. This statement indicates that teachers and curriculum developers should attempt to discover types of problems that would interest students based on student experiences and prior knowledge.

I am also proposing that teachers reflect often upon their own beliefs around student ability and the potential for student growth. This reflection will serve to improve teacher-student interactions and communicate confidence in student growth. Teachers should guide students through the reflective growth process, communicating why it is necessary. Teachers should support student reflection on both successes and failures and teachers should adopt a personal attitude of reflective growth in their own instructional practices so they can model this behavior for their students.

As students engage in problem-solving activities, high school engineering teachers should monitor these activities closely and engage in effective feedback practices such as: questioning students on their thinking, making suggestions and explanations, re-directing misconceptions or possible wrong solution paths, and encouraging student work that is effective in solution-finding. Teachers should remain aware of the positive solution-finding impact of student argument and social construction of knowledge about the problem and potential solution. Teacher awareness of these aspects of collaborative problem-solving processes may be effective feedback mechanisms within the problem space. Since content knowledge is essential to problem representation, teachers should be careful to instruct on relevant content before students begin a problem-solving activity.

Figure 4

Model for Optimizing Student Problem-Solving Outcomes in the High School Engineering Classroom



Students may also benefit from awareness of and reflection on their own mindsets due to the impact of mindset on self-regulation and motivation within the problem space. Therefore, teachers and curriculum developers should incorporate mindset instruction into their lessons as an essential thinking skill for entering the problem space and finding success in solution development.

Recommendations for Future Research

This study brought forward some areas of interest that should be explored in future research. Because problem solving necessarily involves failure, elements of a classroom climate that create a safe place for student failure as students proceed in the problem space should be studied. This exploration would include describing instructional interventions that encourage student persistence, especially in an engineering classroom. In this study, I found that state and district policy-makers and high school engineering teachers hold high expectations for student achievement and they create an inclusive classroom wherein all students are expected to take part in the learning. The classroom environment is a positive, nurturing space with high expectations for growth. Though the high school engineering teachers seem to know how to create situations for student reflective growth and persistence, these characteristics of the classroom may need more emphasis. These two aspects of the classroom climate (reflective growth and persistence) are important because they cause students to look at their own need for growth. Taking the reflective classroom climate into account alongside the positive climate creates a more complete picture of supporting student growth in the problem space. Learning is not easy. There is failure along the way and thus, some failure should be expected in the process. It seems that there is too much emphasis on the positive climate of learning and less emphasis on the challenging aspects of learning. This type of classroom may be created if teachers structured feedback explicitly around the concept of failure, creating a meaning system analysis as suggested by Yeager and Dweck (2020). Thus, the current trend in classroom climate may be imbalanced for promoting growth mindset as there may not be adequate knowledge of the importance of failure and knowledge of how to support failure.

Another area of recommended research is an exploration of the nature and impact of grades and accountability measures given to students during problem-solving activities. During teacher interviews, a discussion of deadlines and grades arose. The engineering teachers had different philosophies of deadlines and grading protocols. Classroom grading procedures may complicate the development of growth mindset in contexts where achievement outcomes are associated with high stakes such as future cumulative grade reports that determine college acceptance or even attainment of scholarship funding of higher education. Thus, grades and deadlines may create a confounding effect, depending on the perspective of the student. More understandings around mitigating these classroom accountability factors should be explored.

A question that remained unanswered from the findings of this study is the importance of teacher mindset in moving a student into the problem space. The literature reviewed indicated that a parent can have a fixed mindset and the child can develop a growth mindset regardless of the mindset of the parent (Haimovitz & Dweck, 2016). The question of teacher mindset, however, should be explored further because qualities of teacher-student interactions that support students moving into the problem space seem to indicate teacher should have growth mindset. In particular, creating a classroom that values and models reflective growth would require a teacher that believes he or she can change and students can change. Teacher mindset also impacts instructional practices such as feedback (Bryan & Abell, 1999; Howard-Jones, 2014; Loucks-Horsley et al., 2009) and feedback influences student mindset (Haimovitz & Dweck, 2017). Therefore, more understanding about the influence of teacher mindset may help school administrators make effective selection of future engineering faculty members.

A final area of potential future investigation that I uncovered was the professional learning experience of the participating teachers. The process of being progressively interviewed and journaling about their instructional practices had an instructional impact. The engineering teachers reported deep reflection and even change in belief around their understandings. This study caused thought and reflection on practice which is a desired outcome in professional growth. The protocol used in this study (interviewing, focus group discussion and journaling) should be explored for intersections with current models and potential for a novel model for teacher understanding of mindset through professional learning.

Recommendations for Future Practice

This study has implications for professional practice in the areas of initial teacher preparation and continuing learning for educators (teacher professional development). Current and future teachers should learn the elements of the problem space in order to understand their problem-solving activities provided to students in engineering classrooms. Current and future teachers should also understand how to support student success in problem-solving activities through creating a classroom climate and having effecting interactions (including effective feedback) with their students.

Future policy-makers should expand teacher knowledge expectations to include knowledge of supporting student failure and persistence in problem situations and expand expectations to include knowledge of promoting student self-motivation and self-regulation. These policy changes should be reflected in state-created documents that drive teacher development.

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APPENDICES

APPENDIX A

TCU-RECRUITMENT EMAIL

Subject Line: Flex Opportunity - Request for Participation in High School Engineering Study

Dear [Name]:

My name is Monica Amyett and I am a research assistant working with Dr. Molly Weinburgh at Texas Christian University (TCU).

I am contacting you today to determine your interest in participating in my current research project. This project is being conducted in fulfillment of the requirements of my doctoral dissertation. If selected to participate, you will gain insight into your instructional practice in the areas of mindset, feedback and student problem solving. Also, if you are selected to participate in this study, you will be awarded 6 hours of professional development flex credit through the Fort Worth ISD CTE Department. Your participation in this study will occur for approximately 12 weeks (September 13, 2021 – November 15, 2021). During the 12 weeks, you will dedicate approximately 7 hours and 20 minutes of time to participate. The timeline for data collection is provided below. All tasks must be completed off of your contracted time of work with Fort Worth ISD.

Date Range	Task	Time Required
9/13-9/17	Scheduling Interviews & Planning Times for Journaling	60
9/20-9/30	First Interview	60
9/30-10/10	Focus Group Interview	120
10/30-11/15	Second Interview	60
10/11-10/30	Journal Entry One	20
10/11-10/30	Journal Entry Two	20
10/11-10/30	Journal Entry Three	20
10/11-10/30	Journal Entry Four	20
11/15-11/30	Manuscript Review	60

Participation is voluntary. Please complete this survey so I can determine if you meet the participant selection criteria. If selected, all data provided by you will be electronically secured. Also, if you are selected to participate, you will be required to conduct a problem-solving activity (that you select from your lessons) in your engineering classroom during the time of the study. No student data will be taken in this study but you will be asked about your mindset and feedback to students during your participation.

If you are willing to be a part of this study, please respond to this communication and complete the selection survey by September 10, 2021. From those candidates who indicate they are willing to participate, five engineering teachers will be selected. If selected, you will be notified and provided a Participant Consent Form and you will be given more information regarding the data collection timeline, and participation tasks.

If you have any questions, please do not hesitate to contact me at m.amyett@tcu.edu or Dr. Weinburgh at m.weinburgh@tcu.edu.

Thank you for considering participation in my study.

Sincerely,
Monica K. Amyett, Ph.D. Candidate
Texas Christian University

APPENDIX B

Participant Survey

Your answers to the following questions will help me determine if you will make a suitable candidate for participation in this study. Please answer all questions to the best of your knowledge.

How many years have you been a teacher?

Did you receive a summary score of “proficient” or higher on your last TTESS evaluation?
Yes
No

Please briefly describe your work experience before you became a teacher. What type of work did you do? For how many years?

APPENDIX C

TCU-SELECTION EMAIL

Subject Line: Selection for Participation in Engineering Research Study

Good Morning/Afternoon:

Congratulations! You have been selected to participate in my research project. Through your participation, you will gain insight into your instructional practice in the areas of mindset, feedback and student problem solving. You will also be awarded 6 hours of professional development flex credit through the Fort Worth ISD CTE Department. Data collection for this study will begin on September 13, 2021 and end on November 15, 2021. The schedule for data collection is outlined below. All tasks must be completed off of your contracted time of work with Fort Worth ISD

Date Range	Task	Time Required
9/13-9/17	Scheduling Interviews & Planning Times for Journaling	60
9/20-9/30	First Interview	60
9/30-10/10	Focus Group Interview	120
10/30-11/15	Second Interview	60
10/11-10/30	Journal Entry One	20
10/11-10/30	Journal Entry Two	20
10/11-10/30	Journal Entry Three	20
10/11-10/30	Journal Entry Four	20
11/15-11/30	Manuscript Review	60

Please use this link to read and acknowledge the required consent for participation. To prepare for participation, plan your engineering lessons so that your students will engage in a problem-solving activity during the reflective journaling time of the study. At our first meeting we will schedule your interviews and journal entries. If you have questions about the tasks listed above, please do not hesitate to reach out by replying to this e-mail. I will provide further explanation as requested.

I am sincerely grateful for your willingness to be a part of this study.

Again, thank you for your participation.

Sincerely,

Monica K. Amyett, PhD Candidate
Doctoral Student, Science Education
Texas Christian University

APPENDIX D

Informed Consent to Participate in Research
(This form will be administered through Qualtrics and provided via a link in the Selection E-Mail)

Title of Research: High School Engineering Teacher Understandings of Mindset and Feedback during Classroom Problem-Solving Activities, A Case Study

Principal Investigator: Molly Weinburgh, Ph. D.
Co-investigator: Monica K. Amyett, Ph. D. Candidate

Overview: You are invited to participate in a research study. In order to participate, you must be a high school engineering teacher.

Study Details: This study is being conducted with teachers employed by Fort Worth Independent School District. All contact will be conducted off district time via the following online applications: Zoom and Qualtrics.

The purpose of this study is to discover high school engineering teachers' understandings of the concept of mindset. This study will also discover high school engineering teachers' knowledge of the instructional practice of feedback to students as their students are solving problems in the classroom. This study will require no more than eight consecutive weeks of participation. At the completion of the data collection, you will be awarded 6 hours of Flex time.

Participants: You are being asked to take part because you are a high school engineering teacher and we want to explore how you understand mindset and instructional feedback to students as students are engage in problem solving. If you decide to be in this study, you will be one of five participants in this research study.

Voluntary Participation: Your participation is voluntary. You do not have to participate and may stop your participation at any time.

Confidentiality: Even if we publish the findings from this study, we will keep your information private and confidential. Anyone with authority to look at your records must keep them confidential.

What is the purpose of the research?
The purpose of this study is to discover high school engineering teachers' understandings of the concept of mindset. Through analysis of teacher understandings of their own possible biases and practices, this study will explore (a) teacher understandings of the concept of mindset and (b) teacher perceptions of their feedback as students engage in problem-solving activities.
This study will answer the following questions:

1. How do high school engineering teachers understand the construct of mindset?
2. How do high school engineering teachers understand the role of feedback as their students are engaging in problem-solving activities?

What is my involvement for participating in this study?
This study will require no more than 12 consecutive weeks of participation. The research includes two one-hour interviews, one two-hour focus group interview, four 20-minute journal entries and a review of findings. The total time for participation is estimated to be seven hours and 20 minutes. The table below summarizes all interactions required to complete this study and the time required for each interaction:

Date Range	Task	Time Required
9/13-9/17	Scheduling Interviews & Planning Times for Journaling	60
9/20-9/30	First Interview	60
9/30-10/10	Focus Group Interview	120
10/30-11/15	Second Interview	60
10/11-10/30	Journal Entry One	20
10/11-10/30	Journal Entry Two	20
10/11-10/30	Journal Entry Three	20
10/11-10/30	Journal Entry Four	20
11/15-11/30	Manuscript Review	60

All tasks will occur electronically, through Zoom and through the Qualtrics survey tool. Zoom meetings will be recorded using the embedded Zoom recording feature. The Principal Investigator and Co-Investigator will be the only people with access to these recordings. On these recordings, your information will be identifiable. These recordings will be maintained on the hard drive of the Co-Investigator's laptop after the Final Report of this study is submitted to the Texas Christian University (TCU) IRB.

Can I withdraw?
You do not have to participate in this research study. You should only take part in this study if you want to volunteer. You should not feel that there is any pressure to take part in the study. You are free to participate in this research or withdraw at any time. Decision to participate or not to participate will not affect your job status. You can withdraw by contacting me at m.amyett@tcu.edu and informing me of your request to withdraw.

What are the risks for participating in this study and how will they be minimized?
Risk is minimal. We don't believe there are any risks from participating in this research that are different from risk that you encounter in everyday life. The reflection on your teaching and feedback may produce slight unease. If so, you may withdraw.

What are the benefits of participating in this study?
Although you will not directly benefit from being in this study, other peoples might benefit because the information gathered and reported in this study will add to understandings of instructional practices in high school engineering classrooms.

A secondary purpose of this study will be to inform teachers of their own potential biases embedded within their beliefs, specifically their mindset. Understanding mindset may help teachers realize a potential need for change in their instructional practice or it may help teachers notice the features of the support they provide or do not provide to students. Through this study, teachers will also understand the importance of the types of feedback they give to their students as feedback impacts student motivation, engagement and pursuit of solutions to difficult problems. Mindset theory has potential implications in student learning of problem-solving behavior and student persistence through a problem. Therefore, engineering teacher mindset may matter in creating an optimal instructional climate where problem solving can occur.

Will I be compensated for participating in this study?
You will be awarded 7 hours of professional learning "flex" credit from the Fort Worth ISD CTE Department.

Is there any conflict of interest?
There is no conflict of interest in this study.

What are my costs to participate in the study?
To participate in the research, you will not need to pay anything.

How will my confidentiality be protected?
We may publish what we learn from this study. If we do, we will not include your name. We will not publish anything that would let people know who you are.

Your personal information collected for this research will be kept as long as it is needed to conduct this research. Once your participation in the research is over, your information will be stored in accordance with applicable policies and regulations.

While we are conducting the research study, we cannot let you see or copy the research information we have about you. After the research is completed, you have a right to see the information about you, as allowed by TCU policies.

If you have concerns about the use or storage of your personal information, you have a right to lodge a complaint with the data supervisory authority in your country.

Unless otherwise described elsewhere in this consent form, there is no limit on the length of time we will keep Your Data Record for this research because it may be analyzed for many years. We will also retain Your Data Record to comply with our legal and regulatory requirements. We will keep it as long as it is useful, unless you decide you no longer want to take part. You are allowing access to this information indefinitely as long as you do not withdraw your consent.

What will happen to the information collected about me after the study is over?
Your name and other information that can directly identify you will be deleted from the research data collected as part of the project.

Who should I contact if I have questions regarding the study or concerns regarding my rights as a study participant?
You can contact [insert name of Investigator or designated research staff member] at [insert email and phone number] with any questions that you have about the study.

Dr. Dru Riddle, Chair, TCU Institutional Review Board, (817) 257-6811, d.riddle@tcu.edu; or Dr. Floyd Wormley, Associate Provost of Research, research@tcu.edu

By selecting "Agree to participate" below, you are agreeing to be in this study. Make sure you understand what the study is about before you agree. You will be given a copy of this document for your records upon request. If you have any questions about the study after you agree to participate, you can contact the study team using the information provided above.

By selecting “Consent to be audio/video recorded” below, you are agreeing to be audio and video recorded. You will be given a copy of this document addendum for your records upon request.

APPENDIX E

Interview Guide – Initial Teacher Interview

Construct	**Main Question**	**Subtopics**
Q1 Mindset	Tell me about your philosophy of teaching engineering.	1. What do you think about your engineering students? 2. What traits do your engineering students have that make them good problem solvers? Which students have these traits? 3. Can a student get better at solving problems? … effort? motivation? intelligence? ability? self-control? 4. If a student does not have good problem-solving skills, how could they get better 5. What is the role of effort in solving problems? motivation? 6. What do you know about the concept of mindset?
Q2 Feedback	What do you say when your students are solving problems?	1. If a student is struggling with a problem, what would you say? 2. If a student is succeeding? 3. When a student receives feedback from a teacher, how does that feedback impact the student? 4. What type of feedback do you provide to students in problem solving situations? 5. When, throughout the problem-solving situation, do you provide feedback?

APPENDIX F

Interview Guide – Final Teacher Interview

Construct	**Main Questions**	**Subtopics**
Q1 Mindset	After working with me in this study, tell me about your current or new understandings of the concept of mindset.	1. How has this study changed your understanding of the concept of mindset?
		2. What is your current understanding of how a teacher or parent impacts student mindset?
Q2 Feedback	After working with me throughout this study, tell me your current or new understandings of providing feedback to students.	1. Has this study changed your understanding or practices around providing feedback to students?
		2. What have you learned about yourself or your students after taking part in this study?
Q2 Problem Solving	Tell me how you provide feedback to students as they are solving problems in your class.	1. What have you learned about problem solving after taking part in this study?

APPENDIX G

Topic Guide – Focus Group Interview

Preliminary Activity:
Before the interview questions are posed, participating teachers will be asked to respond to the following statements:

> "You have a certain amount of intelligence, and you really can't do much to change it.
> Your intelligence is something about you that you can't change very much.
> Being a "math person" or not is something that you really cannot change. Some people are good at math and other people aren't."
> (Yeager, 2016).

Teachers will be asked to respond on a six-point scale, indicating their agreement (high value) or disagreement (low value) with a lower average value indicating a growth mindset. Following the teachers' personal mindset assessment, we will discuss the concept of mindset and clarify misconceptions around what mindset is. The teachers will also be introduced to other domains of mindset such as effort, motivation, self-control and creativity. A discussion around this topic will be encouraged.

Interview Questions:
Following the preliminary activity, the following types of questions will be asked of the teacher group.

Topic	Example Questions
Q1Mindset	Why is student mindset important in student problem solving? How does your mindset effect students as they are solving problems? What can you do to effect student mindset?
Q2Feedback	What types of feedback to you provide to students as they are solving problems? Why is feedback important for students as they are solving problems? When do you give students feedback in a problem-solving context?

APPENDIX H

Reflective Journal Prompts

Journal Prompt #1 – Before the Problem-Solving Activity Begins

- Describe the problem-solving activity that your students will engage in.
- For approximately how many class days will this activity occur?
- What do you notice about your mindset before students begin a problem-solving activity?
- What do you notice about student mindset before students begin a problem-solving activity?
- Describe the feedback you provided to your students before this activity began.

Journal Prompt #2 – Beginning of the Problem-Solving Activity

- What do you notice about your mindset as students begin a problem-solving activity?
- What do you notice about student mindset as students begin a problem-solving activity?
- Describe the feedback you provide to your students as they are beginning a problem-solving activity.

Journal Prompt #3 – Mid-Term of the Problem-Solving Activity

- What do you notice about your mindset as students engage in a problem-solving activity?
- What do you notice about student mindset as students engage in a problem-solving activity?
- Describe the feedback you provide to your students as they are engaging in a problem-solving activity.

Journal Prompt #4 – After the Problem-Solving Activity Ends

- What do you notice about your mindset as students finish a problem-solving activity?
- What do you notice about student mindset as students finish a problem-solving activity?
- Describe the feedback you provide to your students as they are finishing a problem-solving activity.

APPENDIX I

Question One: Mindset

Teacher beliefs about malleability of student characteristics

Interviewee	***Response***	***Growth or Inconclusive***
	Domain: Problem Solving	
Antonio	"Always, of course. They always get better, as far as the study skills, the problem, the resources… They start finding other ways on how to find the answer…"	Growth
Hector	"Yes, I believe all students can get better. It's just a matter of desire. Do they want to get better?"	Growth
Johnathan	"I absolutely think so. I think most of them have the capability. Either they haven't been presented the chance to or they just have not been pushed to try to do so. I believe everyone is capable of getting better at solving problems."	Growth
Sandy	"Yes, I do believe so."	Growth
	Domain: Effort	
Antonio	"…the effort is always there and it can always improve."	Growth
Hector	"…I believe they can. …it's just the effort is just about motivation. If they're not motivated to do it then they're not going to put effort into it. So can they get better? Yeah, they can. We just got to figure out how to push the buttons."	
Johnathan	"I have no doubt about that, yes. I completely believe they can."	Growth
Sandy	"Yes, because if they've got the mindset that they want to learn, and they want to figure things out and problem solve, yes."	Growth
	Domain: Motivation	
Antonio	"Oh yeah, definitely. You know, motivation comes from within."	Growth
Hector	"…I believe they can. …it's just the effort is just about motivation. If they're not motivated to do it then they're not going to put effort into it. So can they get better? Yeah, they can. We just got to figure out how to push the buttons."	Growth
Johnathan	"Yes, I think motivation… I think they have to feel comfortable… the teacher and the rest of the students aren't going to maybe laugh at them when they throw out some ideas…"	Growth
Sandy	"Most definitely. If you can find the right motivation that triggers them."	Growth

Domain: Intelligence

Antonio	"Intelligence I don't know that one can become more intelligent because, obviously, I think they're either born with intelligence or not."	Inconclusive
Hector	"…I'm not certain that it's something that one can gain or lose. Of course, you can always gain knowledge. But the way I think about intelligence is kind of like what you do with it…. I don't necessarily believe you can gain intelligence."	Inconclusive
Johnathan	"I don't… I will say they get better at expressing themselves and many times they get more confident in their abilities. It'll seem perhaps like maybe their intelligence but I think they can get better in terms of just their confidence building up and being able to express themselves."	Inconclusive
Sandy	"That's a trick question… I think they can become smarter… I don't know if they get more intelligent. I just think they get better at what they're doing."	Inconclusive

Domain: Ability

Antonio	"Yes, ability is always something that you can be taught. Like a trait."	Growth
Hector	"Yeah, I believe you can gain in ability. It just takes a lot of practice and understanding of what it is that you're trying to do. Then you can gain that ability.	
Johnathan	"Completely believe that goes along with effort in terms of applying themselves and they learn more just applying it."	Growth
Sandy	"Most definitely."	Growth

Domain: Self-Control

Antonio	"Oh definitely. Even all the way up to your adult life. You always make mistakes and you always learn from your mistakes. … I think that definitely students learn as they go, at self-control, how to control their instincts and how to control their urges."	Growth
Hector	"I believe so. Again, it just takes a while to… and practice."	Growth
Johnathan	"Probably we all could have better self-control including myself, but I believe students could get better at that as well."	Growth
Sandy	"Oh yes. To me, that's sort of learned. So, as they do the trial and error, their self-control gets better because they don't get as angry or frustrated because they know there's a method."	Growth

APPENDIX J

Teacher knowledge of mindset

Interviewee	***Response***
Antonio	"The mindset… I don't really know mindset. I've heard it. I know that we've gone through some trainings. …I really don't know much about it."
Hector	"We've read some studies about mindset in growth and things like that. For me, it's about, do you have the mental fortitude to complete whatever it is that you're doing? For example, math is a big issue for a lot of the kids. Again, everybody is not good at math but if you have the mindset that it may be hard but I'm gonna do it, then that person is generally going to be successful. If you have a mindset that says, 'Oh well. It's hard so I'm just going to not do it and find something else. Then you know that's pretty much what's going to happen on that… So it's pretty much like I said. Mental fortitude."
Johnathan	"… a mindset, to me, is just my first perception of … a certain task or anything presented to me… Like, how do I get there from here? What do I need to do?"
Sandy	"… people can change their mindset, based on what motivates them or what makes them feel good about themselves. It's mostly about self-esteem. It's mostly about growing as a person. That's pretty much what I consider mindset… In my mind it's growing, being positive, figuring out motivation… Like I want to improve myself, so I go and educate myself on things I don't know or I'll keep doing trial and error until I figure it out or come up with a different way of getting things done."

APPENDIX K

Question One: Mindset

Frequencies of Phrases Referencing Major Themes and Subthemes Identified in Documents

	Major Themes	Teacher-Student Interactions		Classroom Climate				Attitude toward Engineering	Total
	Subthemes	Motivation	Respectful Relationship	Expectations	Inclusivity	Reflective Growth	Persistence	None	
Document Analyzed	TTS	8	2	8	8	6	2	0	34
	PPR	3	2	2	1	0	0	0	8
	SES	0	0	0	1	0	0	1	2
	DIF	1	4	9	6	4	0	0	24
	Total	12	8	19	16	10	2	1	68

APPENDIX L

Question Two: Feedback in the Context of Problem Solving

Theme: Feedback

Statements and Phrases Identified in Documents for the Subtheme: Effective Feedback

Document	***Reference (Statement/Phrase)***
TTS	consistently check for understanding, give immediate feedback, and make lesson adjustments as necessary
	provide immediate feedback to students in order to reinforce their learning and ensure that they understand key concepts
	providing detailed and constructive feedback and partnering with families in furthering their students' achievement goals
	set individual and group learning goals for students by using preliminary data and communicate these goals with students and families to ensure mutual understanding of expectations
	communicate with students and families regularly about the importance of collecting data and monitoring progress of student outcomes, sharing timely and comprehensible feedback so they understand students' goals and progress
PPR	characteristics of effective feedback
	role of timely feedback in the learning process
	use constructive feedback to guide each student's learning
	use appropriate language and formats to provide each student with timely feedback that is accurate, constructive, substantive, and specific
	base feedback on high expectations for student learning
	use carefully framed questions to enable students to reflect on their understanding of content and to consider new possibilities
DIF	students receive clear and specific feedback that informs their progression toward the learning objective(s)
	teacher gives information with which a learner can confirm, add to, overwrite, fine-tune, or restructure information in memory

APPENDIX M

Question Two: Feedback in the Context of Problem Solving

Theme: Feedback

Teacher characterizations of their feedback practices

Interviewee	***Response***
Antonio	“always try to praise 100%” “have them go help other groups… so that they can feel successful” “make sure that the student is aware of what they’re doing bad, but… hear more of what they’re doing…” “if your kids are successful, … have a good feedback right there…” “both positive and negative feedback. It’s always good to let them know one way or the other.” “create a relationship with students and the feedback has to do a lot with making sure that the student is aware of what they’re doing…”
Hector	“If they’re already succeeding, I’ll tell them good job, that’s what you’re supposed to be doing.” “I try to keep them as even keeled as possible and so I congratulate them on doing well…I also let them know…this is what we’re supposed to be doing so let’s not get excited for that. Let’s get excited for the things that we do that we’re not supposed to be doing. I try to keep them in the middle of the road.” “…I won’t immediately give them feedback because I’m going to push them back towards the information that they should already have so that they can find it. If it’s something that I haven’t covered or… comes out of nowhere then I’ll bring the whole group in because it’s something that… we haven’t discussed.”
Johnathan	“… ask, ‘How are we doing? What do you think about this?’... I don’t want to give them answers, but I tried to steer them and let them derive their own pathway to keep going.” “I don’t actually tell them, ‘Great job. You’re doing fabulous.’” “I’ll give them a few minutes before I’m really kinda … looking over their shoulders. “ “Pretty constant feedback. I think that’s part of my role.”
Sandy	“I basically show them… let them mimic after me to give them some idea or I will show them different methods and try to find one that works best for them and get them to use that method to see if they can improve.” “I would ask them what have they done so far? What has been the result? I would make suggestions as to have they tried this? What do they think of that? I wouldn’t let them sit there and feel like they’ve struggled.” I would try to point them in a direction that might work or get them to start listing things that might help them look at it in a different perspective.”

	"…ask them cold they think of another way. Typically, I ask questions to their questions. I won't give a direct answer because not everybody thinks the same way. …if you were to present to this group of people, what would you tell them?... and see where it goes from there. I get them to try and think beyond themselves."

APPENDIX N

Question Two: Feedback in the Context of Problem Solving

Frequencies of Phrases Referencing Major Themes and Subthemes Identified in Documents

Major Themes	Feedback			Problem Solving				Feedback in the Context of Problem Solving
Subthemes	Solve or Improve Design	Student Growth	Effective	Thinking Skills (Content)	Thinking Skills (Process)	Thinking Skills (General)	Entering Problem Space	
TTS	0	0	5	1	0	0	4	1
PPR	1	2	6	0	0	1	3	2
SES	1	0	0	2	5	0	2	1
DIF	1	10	2	0	2	0	5	1
Total	3	12	13	3	7	1	14	5

VITA

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Texas Christian University
Doctor of Science Education
University of North Texas (2004)
Master of Education (Secondary Education, Science)
University of North Texas (2000)
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Certifications

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Employment

Fort Worth ISD – CTE Instructional Specialist - (August 2017 – Present)
Tarleton State University (FTW) – Adjunct Professor – (Fall 2021)
Project Lead the Way – Master Teacher - (July 2015 – July 2019)
Tarrant County College – Dual Credit Instructor - (August 2008 – May 2017)
Azle ISD – High School Science Teacher - (August 2006 – August 2017)
Bethesda Christian School – Teacher/Science Department Chair - (August 2001 – July 2006)

Publications

Price, C., Biffi, D., Weinburgh, M. H., Smith, K. H., Silva, C., Amyett, M., & Domino, A. (Accepted 2022). Emergent multilingual learners use of multimodal discursive practices in science journals to communicate 'doing' and 'learning' on erosion. *Electronic Journal of Science and Mathematics Education.*

Amyett, M. K., & Gallavan, N. P. (2021). Epilogue. In L. Fulton, J. Yoshioka, & N. P. Gallavan, (Eds.), *Online teaching and learning for teacher educators*. Rowman & Littlefield.

Amyett, M. (2019). Instructional: COACHING & its role in career development for CTE teachers. *Techniques, 95*(5), 24-28.

Awards and Recognitions

- ATE Clinical Fellow
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Grants

- Azle Educational Foundation Grant
- Northrop Grumman Science Grant (for Bethesda Christian School)