Examining Teacher Beliefs and Agency Upon Implementation of Culturally Responsive Pedagogy and the Engineering Design Process

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ABSTRACT

The instructional practices of the engineering design process and culturally responsive pedagogy have each garnered national attention through multiple decades of research. The findings from the literature associated with each field urge educators and policy-makers to integrate the pedagogical constructs in K-12 instruction. There is a significant amount of research that supports the positive student outcomes associated with each approach. Moreover, scholars have argued that the implications of immersion for each construct within science and mathematics content include heightened student engagement and improved academic achievement. Still, there remains a lack of literature that addresses the beliefs and agency of teachers upon enactment of these critical practices in their content areas.

The movement around educational reform is rooted in teachers serving as learners. However, understanding how teachers learn and respond to reform is largely overlooked. Accordingly, this dissertation study is grounded under the assertion that it is of great significance to examine the way in which teachers perceive and define new pedagogical approaches upon implementation. The author explores how, and in what ways, are secondary mathematics and science teacher pedagogical beliefs and sense of agency related to the integration of the engineering design process and culturally responsive pedagogy within their content curricula. The core properties of agentic behaviors, rooted in social cognitive theory, include: intentionality, forethought, self-reactiveness, and self-reflection. The author utilized a comparative multiple case study design using an embedded mixed methods approach, allowing for the qualitative and quantitative data to be collected and analyzed concurrently. The data collected allowed

for case analysis for each teacher along with cross-case analysis between the teachers. These cases represent experiences of the select secondary math and science teachers enrolled an NSF funded five-year, fellowship program inclusive of a master's degree in STEM education and professional development.

The findings from this study add to the significant gap in literature surrounding how teachers perceive the engineering design process and culturally responsive pedagogy. The self-reported pedagogical beliefs suggest a synergistic relationship between the two constructs. The participating teachers expressed a strong preference towards the enactment of a culturally responsive engineering design process. Furthermore, the agentic behaviors examined contribute to the literature on the defining categories and assertions about teachers theorized as change agents. The research also suggests that teacher agency is driven primarily by the pursuit of positive student outcomes. Overall, the findings documented offer valuable recommendations for teacher educators, professional development providers, policy-makers, and researchers. The results from this research underscore the importance of empowering teachers with professional development that is shaped and informed by their beliefs and experiences.

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CHAPTER I

INTRODUCTION

The 21st Century workforce must possess not only mathematical and scientific content knowledge, but, also, the skills needed to effectively utilize technological advancements that will solve the multidisciplinary problems of tomorrow (Crotty, Guzey, Roehrig, Glancy, & Ring-Whalen, 2017). Accordingly, how students are prepared has the power to yield the prosperity and progress needed for a nation's economic growth (Stevens & Weale, 2003). The realization that students need adequate support during K-12 years in order to grow the future workforce has led many countries to invest resources in science, technology, engineering, and mathematics (STEM) education (Rogers, Wendell, & Foster, 2010). Moreover, several national reports (National Research Council, 2007a, 2007b; National Science Board, 2010; President's Council of Advisors on Science and Technology, 2010) have urged educators and policymakers to adopt efforts that improve student achievement and heighten student interest in the critical areas of STEM (Crotty et al., 2017).

Today's student must be prepared to serve as the innovator needed for the 21st Century workforce, capable of utilizing STEM to solve complex problems (Partnership for 21st Century Skills, 2009; Zhao, 2012). According to the NRC (2012), K-12 STEM education is critical to cultivating the necessary skills for students to serve as contributing and informed members of an increasingly technological society (Honey, Pearson, & Schweingruber, 2014). Although scholars and researchers agree on the importance of strengthening STEM education in K-12 classrooms, many continue to engage in discourse over the best approach towards ensuring that students receive experience in all areas of STEM (Wang, Moore, Gillian, Roehring, & Park, 2011). In 2014, the Committee on Integrated STEM Education (Honey et al., 2014) published a report stating that while the committee members were unable to reach a consensus on the definition of integrated STEM, they recognized that engineering is the least developed domain within K-12 STEM education curricula. Consequently, inclusion of engineering as a discipline, and, integration of the engineering design cycle in science and mathematics instruction has entered the national platform (NRC, 2012). It is important to note here that many of these efforts and professional development programs envision engineering through the lens of a design process (Wang et al., 2011). The utilization of an engineering design process is further supported by the Accreditation Board for Engineering and Technology (ABET) wherein engineering design is defined as a "decision making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs'' (ABET, 2015, p. 2). Engineering design is an active process that creatively seeks solutions through scientific reasoning and mathematical problem solving. Therefore, the enactment of the engineering design cycle is the distinctive characteristic of the engineering profession (Dym, 1999).

In a report published by the National Academy of Engineering and National Research Council (NAE and NRC) (2009) the authors delineated multiple reasons for the inclusion of the engineering design cycle in K-12 education. The proposed benefits included improved student achievement in mathematics and science courses, increased awareness regarding the work of engineers, engagement in engineering design, interest in pursuing careers related to engineering, and, increased technological literacy (Katehi, Pearson, & Feder, 2009). The authors argued that teaching mathematics and science concepts while solving real-world or relatable problems through engineering design can ease the students' grasp and understanding of challenging material. Accordingly, teaching through engineering design has the potential to positively impact students' achievement in math and science coursework (Katehi et al., 2009). Moreover, the heightened student engagement and improvement in academic learning outcomes is of great significance for students of color who are historically outperformed by their Caucasian counterparts in mathematics and science content areas (Estrada et al., 2016).

A study conducted with Project Lead the Way (PLTW) curricula supports the positive learning outcomes achieved through engineering design challenges (Bottoms and Uhn, 2007). Students enrolled in the PLTW coursework scored significantly higher on their math and science achievement in the National Assessment of Educational Progress (NAEP) in comparison to students in a random, stratified group (Bottoms and Uhn, 2007). Moreover, students participating in the Engineering is Elementary program, developed by the Museum of Science in Boston, which infuses engineering design within science content, reported a significant improvement on post-test scores evaluating students' science and engineering knowledge (Lachapelle & Cunningham, 2007). Similarly, Akins and Burghardt (2006) asserted that experience with engineering design encourages mathematical reasoning in students. The authors, through use of pre- and post- data, found that students with the lowest initial scores experienced the highest achievement gains. The findings suggested that engineering design is capable of narrowing achievement gaps in mathematics instruction (Akins & Burghardt, 2006).

The National Research Council (NRC, 2009) has argued that providing students with learning experiences inclusive of engineering design skills in secondary math and science classrooms can help clarify abstract and challenging topics through use of real-world context. Recent studies have also shown that experience with engineering design projects can yield significant improvement in student academic achievement specifically in the areas of mathematics and science (Akingolu & Tandogan, 2007). The engineering design process, when integrated in content, is capable of improving students' understanding of scientific knowledge and help connect the fields of science and engineering (Kimmel & Rockland, 2002). Thus, through the combined curricular efforts of science and engineering, students are able to grasp the impact scientific concepts have on solving societal problems that have an engineering context (Bamberger & Cahill, 2013).

The utilization of the engineering design process is often associated with, and commended for, situating content in real-world scenarios. However, Householder (2012) emphasized the need for contextualizing design problems in a manner that connects with the lives and background of students in an effort to be inclusive of diverse learners (Householder & Hailey, 2012). While the engineering design holds promise for improved achievement and student interest, there remains underrepresentation of Hispanic and African American populations in STEM fields (Estrada et al., 2016). This disparity has led to scholars to advocate for educators to utilize the cultural and linguistic background of students and provide for instruction that is, therefore, culturally responsive or relevant (Gay, 2000; Siwatu, 2011).

Science and mathematics teacher preparation has made separate, albeit, significant, strides in preparing educators to infuse engineering design skills (Daugherty & Custer, 2012; Katehi et al., 2009; NAE, 2008; Wang et al., 2011), and culturally responsive pedagogy (Cochran-Smith, Davis, & Fries, 2004; Gay, 2000; Ladson-Billings, 2009; Siwatu & Starker, 2010). Still, there remains a gap in the literature on the beliefs and agentic behaviors derived from the integration of the engineering design process (EDP) and culturally responsive pedagogy (CRP). Such research would help inform scholars and teacher education programs on the factors that contribute to the intentionality and forethought of teachers who are willing to enact instruction inclusive of EDP and CRP. Furthermore, examining the experiences of these teachers can provide insights on the barriers and catalysts encountered along the way.

Problem Statement

The nation's leaders in STEM education and research have emphasized the importance of utilizing the engineering design process (EDP) in mathematics and science instruction (NRC, 2012). This notion is emphasized in the National Academy of Engineering report, "Engineering in K-12 Education: Understanding the Status and Improving the Prospects" (2009). The authors urged educators to integrate the engineering design process (EDP) in the critical areas of mathematics and science as the inclusion heightens students' academic achievement, and motivation to persist through coursework (Katehi et al., 2009). Moreover, the use of EDP in secondary mathematics and science coursework allows students the opportunity to be challenged in a way that is different from the routine classroom activities (Goeser et al., 2009). Thus, EDP serves as "a vehicle to use all of the science and math material they have been taught throughout their education" (Hynes et al., 2011, p.8). Hence, the interdisciplinary nature of engineering design allows for scientific reasoning and mathematical problem solving that is also grounded in real-world occurrences (Lachapelle & Cunningham, 2014).

However, this concept of “real-world” in EDP can be further contextualized to purposefully integrate the culture of students (Householder, 2012). Building upon the culture and background of students is especially beneficial to schools situated in urban areas that serve underrepresented and marginalized student populations (Gay, 2000). Culturally Responsive Pedagogy (CRP) is defined as the utilization of “the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively” (Gay, 2002, p. 106). This philosophy of teaching urges for the design and embodiment of instruction that is sensitive towards, and informed by, students’ cultural and linguistic characteristics. (Gay, 2002; Irvine, 2010; Ladson-Billings, 1995, 2009). CRP entails a student-centered approach to teaching that connects content topics with the life experiences of the students being taught (Castaneda & Mejia, 2018). CRP is grounded in the belief that all students can be successful and encourages teachers to adopt an asset-based mindset when interacting with students (Ladson-Billings, 1994). Accordingly, schools and teachers are advised against using terms such as ‘at risk’ or ‘disadvantaged’ when referencing diverse students (Hilliard, 2000, 2006). Instead, teachers should recognize and appreciate the cultural experiences that students from diverse background are able to contribute to the instruction (Paris, 2012).

The constructs of engineering design and culturally responsive pedagogy have each garnered national attention (Katehi et al., 2009; NAE, 2008) and multiple decades worth of literature (Gay, 2000, 2010; Katehi et al., 2009; Ladson-Billings, 2009; Lee & Fradd, 1998; NAE, 2009; NRC, 2007a, 2007b; Wulf, 1998). The findings from each body of research urge educators and policy-makers to integrate the pedagogical constructs in

K-12 instruction. Moreover, both philosophies of teaching are rooted in research-driven support for inclusion in science and mathematics curriculum (Crismond, 2001; Kolodner et al., 2003; Mehalik, Doppelt, & Schunn, 2008; Wendell & Lee, 2010). Scholars in each field argue that the implications of immersion with science and mathematics content include heightened student interest and improved academic achievement (Aguirre, 2009; Aguirre & Zavala, 2013; Katehi et al., 2009; Lachapelle & Cunningham, 2007). Consequently, recent efforts in teacher development have been conducted to encourage the use of each approach in K-12 instruction (Estapa & Tank, 2017; Jackson & Bouttee, 2018; Nash, 2018; Nugent et al., 2010; Siwatu, 2007).

Projects such as the What Works Clearinghouse (WWC), and, the Core Practice Consortium (CPC) are just two of the more prominent efforts in a growing list of resources designed to promote evidence-based instructional practices recommended for teachers (Core Practice Consortium, n.d.; What Works Clearinghouse, n.d.). However, absent in the conversations surrounding teacher intervention are the teacher beliefs about said approaches. The concept of teacher beliefs guiding instructional practices is a widely agreed upon and documented notion in educational reform (Cochran-Smith & Fries, 2005; Nieto, 2009; Pajares, 1992, 2002). Still, there is limited research regarding how teachers perceive, interpret, and shape their agency as they implement new pedagogical approaches into their existing practice (James S McDonnell Foundation, 2019).

Although both CRP and EDP have been advocated for by experts and researchers, there is a lack of literature that addresses the beliefs and agency of teachers upon integration of these critical practices in their content areas. The movement around educational reform is rooted in teachers serving as learners; however, understanding how teachers learn and respond to reform is largely overlooked (De Floria, 2016). In a recent publication titled, *Effective Teaching and Successful Learning, Bridging the Gap between Research and Practice*, the author explains that there is an abundance of material that advocates for various teaching strategies without giving proper consideration to how teachers understand, respond, and utilize these techniques (De Floria, 2016). As such, the crux of this dissertation research lies in the value of understanding secondary mathematics and science teachers' beliefs regarding the pedagogical constructs of EDP and CRP upon integration within their existing practices and content curricula. Furthermore, the author examined how implementation and experience with the pedagogical approaches shapes the teachers' agentic behaviors involved in instructional planning and enactment.

Theoretical Foundation

The theoretical framework for this study was guided by Bandura's (1986) social cognitive theory (SCT). Over the past decades, SCT has further informed educational research regarding the impact of teacher beliefs and agency towards the enactment of pedagogical practices and instructional decisions. Specifically, teacher beliefs and agentic behaviors as they relate to the engineering design process and culturally responsive pedagogy are operationalized within the framework of this research and discussed in detail in the presentation of the literature review.

Social Cognitive Theory and Self-Beliefs

Upon publishing "Self-efficacy: Toward a Unifying Theory of Behavioral Change," Bandura (1977) began theorizing the translation of self-beliefs to action, an element he acknowledged was missing from his previously published work on social learning theory. Later, with the publication of "Social Foundations of Thought and Action: A Social Cognitive Theory," Bandura (1986) evolved his theory of social learning into social cognitive theory. Through this work he delved deeper into the critical role cognition plays on human actions and behaviors. This was also the conception of Bandura's (1986) triadic reciprocal determinism, which is defined as a view that connects behaviors, environmental influences, and personal cognitive factors. According to Bandura (1986), all three constructs interact in an iterative manner to yield human functioning (Pajares, 2002).

Bandura (1997) continued to emphasize that the most prevalent element surrounding human functioning is that of self-beliefs, including self-efficacy and outcome expectancy. Bandura (1997) argued that to have the incentive to pursue and deliver change, an individual must first believe that an action is capable of producing said desired change or outcome. Bandura (1997) specified this claim by stating that through human functionality "people's level of motivation, affective states, and actions are based more on what they believe than on what is objectively true" (p. 2). Consequently, teacher beliefs have served an integral role in research that investigates implementation of practices in the classroom and curricular planning (Gay, 2010; Pajares, 1992; Rimm-Kaufman & Sawyer, 2004; Siwatu, 2007). These set of beliefs, often referred to as pedagogical beliefs, constitute the factors that teachers determine to be effective strategies for instruction (Polat, 2010; Vartuli,1999).

Self- Beliefs and Human Agency

Through furthering the development of SCT, Bandura (2001) was able to provide an understanding of human agency. The concept of agency asserts that each individual is capable of serving as an agent who is actively engaged in their own growth and has the ability to make things happen by actions (Pajares, 2002). According to Pajares (2002) at the core of human agency is the idea that "individuals possess self-beliefs that enable them to exercise a measure of control over their thoughts, feelings, and actions…" (p.1). As such, agency entails one's intentional influence over their functioning, actions, and life's circumstances (Bandura, 2001, 2006). An agentic perspective, therefore, takes on an empowering view of human beings as contributors to their life, and, not simply byproducts of their behaviors. Bandura stated that all individuals are "self-organizing, proactive, self-regulating, and self-reflecting." (Bandura, 2006, p. 164). Furthermore, the capability to self-regulate, according the Bandura (1986) is a core feature of human agency and a prominent feature throughout social cognitive theory (Pajares, 2002).

Teachers' beliefs influence their pedagogical and curricular decisions, along with, the manner in which they interact with students (Bryan & Atwater, 2002; Irivine, 1990; Pajares, 1992). As such, teacher beliefs have been at the core of research that aims to gain a deeper understanding of how teachers perceive the implementation of instructional practices (Pajares, 1992). Nespor (1987) urged the teacher education community to consider the implications of teachers' sense of agency, stating:

> …if we are interested in why teachers organize and run classrooms as they do we must pay much more attention to the goals they pursue (which may be multiple, conflicting, and not at all related to optimizing student learning) and to their subjective interpretations of classroom processes. (p. 325)

While, researchers in the field of teacher education have provided many definitions of beliefs, they are generally rooted in the definitions posited by Milton Rokeach (1968) (Pajares, 1992). As such, the author of this dissertation research is guided by the Rokeach's established definition of belief, wherein a belief is, "any simple proposition, conscious, or unconscious, inferred from what a person says or does, capable of being preceded by the phrase, I believe that…" (p. 113).

Research Purpose

The purpose of this exploratory, mixed methods, multiple case study is to investigate teacher beliefs and sense of agency upon implementing new instructional practices. The research specifically focuses on teaching secondary mathematics or science content infused with the engineering design process (EDP) and culturally responsive pedagogy (CRP). Currently, K-12 schooling in the U.S. lacks exposure to the appreciation and knowledge surrounding the creativity, rewarding work, and positive impact associated with the STEM related careers (NAE, 2008). This lack of exposure especially limits females and students of color, populations which are already underrepresented in the STEM fields (Katehi et. al., 2009; National Science Board, 2017). Hence, while the need for improving the success rates in STEM coursework is pertinent across all racial and ethnic backgrounds, it is especially critical to draw attention towards students from underrepresented and historically oppressed populations that are disproportionately less likely to pursue and persist through STEM-related majors (Leboy & Madden, 2012; President's Council of Advisors on Science and Technology, 2010).

Any reform regarding classroom practices must first begin with a shift in the instructional methods utilized by teachers. Teacher pedagogical expertise alone is not enough to combat the racial and ethnic inequalities and, therefore, must be coupled with culturally responsive practices (Aguirre & Zavala, 2013). Acknowledging that an individual's sense of agency allows them to actively regulate their own experiences emphasizes the value of exploring teacher agency and pedagogical beliefs. Accordingly, this study examined the pedagogical beliefs reported by secondary mathematics and science teachers upon integration of the engineering design process and culturally responsive pedagogy. Moreover, through exploration of teachers' agentic behaviors, this research provides insights regarding challenges teachers experience along the way, and, how they self-regulate their own actions to overcome the barriers encountered.

Research Question

Below listed is the primary research question, followed by the subsidiary research questions that inform this study:

RQ 1. How, and in what ways, are secondary mathematics and science teacher pedagogical beliefs and sense of agency related to the integration of the engineering design process (EDP) and culturally responsive pedagogy (CRP) within their content curricula?

RQ 1a. What are the pedagogical beliefs that secondary mathematics and science teachers self-report regarding EDP and CRP upon implementation of both constructs in the classroom?

RQ 1b. How are the core features of Bandura's human agency (intentionality, forethought, self-reactiveness, and self-reflectiveness) of secondary mathematics and science teachers shaped upon implementation of EDP and CRP in their classrooms?

RQ 1c. How do secondary mathematics and science teachers describe the value of EDP and CRP as it relates to their classroom content?

RQ 1d. What barriers do secondary mathematics and science teachers experience during implementation of CRP and EDP, and, how do they persevere in face of challenges?

RQ 1e. How do secondary mathematics and science teachers perceive their own role in the movement to implement CRP and EDP in secondary science and mathematics curricula?

Overview of Research Design

In an effort to answer the research question, the author utilized an exploratory, comparative multi-case study design (Merriam, 1998) that will employ mixed methods of data collection (Creswell, 2014). The data collected was analyzed and triangulated within and across each case. Quantitative results were obtained through surveys which helped provide insights regarding teachers' self-reported beliefs surrounding the constructs of EDP and CRP. These results were merged and triangulated with the qualitative findings obtained through teaching philosophy statements, interviews, reflective journals, and, insights gained through member checking. A mixed methods approach for this investigation corroborated the qualitative and quantitative data sets collected and analyzed simultaneously to enhance the validity of the research (Creswell & Plano Clark, 2014).

Significance of Research

The findings of this study are expected to contribute to existing literature on the incorporation of the engineering design process (EDP) in secondary math and science curricula. Over the years, the role of engineering design in K-12 education has garnered considerable national traction; however, there is still much to be known about what integration of EDP looks like in a mathematics or science classroom (Stohlmann, Moore, Roehrig, 2012). The National Center for Engineering and Technology Education (NCETE) the authors argued for an integrated approach towards engineering design, whereby the engineering design process is infused into science, mathematics, or other coursework. The authors of the report presented EDP as the best strategy to increase student exposure to the fundamental practices employed by engineers (Daugherty, 2012). Thus, the findings from this dissertation research are not only of value to STEM educators, but, are also timely given the need for reform in STEM teacher preparation and professional development.

This study provides much needed insights on teachers' pedagogical beliefs and sense of agency upon integrated of EDP in content modules. The participating teachers uniquely combine the incorporation of EDP with culturally responsive pedagogy (CRP). Therefore, this research is the first of its kind to investigate the way teachers perceive the implementation of these pedagogical approaches utilized in unison, and, integrated with the teachers' exiting practices and curricula. Through investigating teacher agency, this study also identifies the challenges encountered by teachers who demonstrate intentionality and foresight towards implementation. While there is research supporting the use of each pedagogical construct in mathematics and science content, there remains a lack of research surrounding the combined implementation of the approaches. Moreover, the consideration of how teachers interpret, understand, and are changed by the implementation of new instructional practices is largely overlooked in research. Hence, this dissertation study examined teacher beliefs and agency upon implementation of new pedagogical approaches, specifically, EDP and CRP in mathematics and science curricula. The findings illuminate the understanding related to the pedagogical constructs enacted congruently, along with, the self-reported perceptions of teachers who are enacting the instructional practices. Furthermore, the findings will not only serve as great interest to education research communities, but, also, to teacher professional development programs.

Definitions of Terms

Engineering Design Process (EDP). EDP entails the application of scientific and mathematical principles addressed through an ill-defined problem (Simon, 1984). The series of iterative steps included in EDP are centered around the processes of, analysis, synthesis and evaluation (Cross, 2000). While there is no consensus on a specified model, Cross and Roozenburg (1993) explained that the steps involved serve the purpose of, "organiz[ing] the problem-solving behaviors of designers" (p. 328). Massachusetts Department of Education (2006) provided a framework for EDP that shares similar features to other existing models. These characteristics include: identify the problem, brainstorm, select a solution, develop a prototype, test and redesign as needed, followed by ultimately communicating results.

Culturally Responsive Pedagogy. Culturally responsive pedagogy (CRP) is a philosophy of learning that asserts the need to utilize student cultural identities and experiences as resources for student-centered instruction (Gay, 2000). Often used interchangeably with culturally relevant teaching, this approach urges educators to address student achievement gaps through the critical lens of racial and cultural inequalities (Ladson-Billings, 2009).

> Culturally responsive pedagogy is situated in a framework that recognizes the rich and varied cultural wealth, knowledge, and skills that students from diverse groups bring to schools, and seeks to develop dynamic teaching practices, multicultural content, multiple means of assessment, and a philosophical view of teaching that is dedicated to nurturing student academic, social, emotional, cultural, psychological, and physiological well-being. (Howard, 2010, p. 67-68)

Design, Engineering, and Technology (DET). The DET survey is an instrument that is utilized to gauge teacher perceptions and familiarity with the constructs of design, engineering and technology (Yasar, Baker, Robinson-Kurpius, Krause, & Roberts, 2006). The authors define DET as a process inclusive of the following featured:

> 1) identify a problem or a need to improve on current technology; 2) propose a problem solution; 3) identify the costs and benefits of solutions; 4) select the best solution from among several proposed choices by comparing a given solution to the criteria it was designed to meet; 5) implement a solution by building a model or a simulation; and 6) communicate the problem, the process, and the solution in various ways. (Yasar et al., 2007, p. 205)

Culturally Responsive Teaching Outcome Expectancy (CRTOE). CRTOE stems from outcome expectancy beliefs described by Bandura (1997). CRTOE includes the beliefs teachers hold regarding the expected power of outcomes achieved by a specific approach, in this case, the employment of culturally responsive pedagogy (Siwatu, 2007).

Organization of Remaining Chapters

Chapter two provides an extensive review of literature around the topics discussed in this study. The chapter begins with a review of the theoretical underpinnings that help guide the conceptual framework of this research. Thus, Bandura’s social cognitive theory

(1997) is discussed and connected to self-beliefs and sense of agency. The operational framework links this theoretical foundation to pedagogical beliefs and the core features of teacher agency with regards to integration of the engineering design process and culturally responsive pedagogy.

Chapter three includes the methodology utilized for this study. The researcher describes the research site, participants, and the data collection methods. A rich discussion on the type of methodology employed is provided along with proposed data analysis and ethical considerations. The chapter includes specifics regarding each of type of data source and methods for analysis utilized.

CHAPTER II

THEORETICAL FRAMEWORK AND REVIEW OF LITERATURE

The literature review begins with a presentation of the theoretical underpinnings that guide the operationalized theoretical framework for this research. This study is conducted through the lens of Bandura's Social Cognitive Theory (SCT) and is, thus, driven by the notion that individuals are capable of influencing decisions, functions, and behavior with intentionality (Bandura, 1986, 2001, 2006). Bandura (1986) argued that biological, behavioral and environmental determinants work in conjunction with one another to guide human functionality (Bandura, 1986, 1997; Pajares, 2002). SCT theorizes that these behaviors yield actions which, above all else, are guided by the beliefs one possesses regarding the ability to utilize knowledge and skills (Bandura, 1997; Pajares, 2002; Siwatu, 2007; Soodak & Podell, 1998).

SCT is grounded in a view of human agency which argues that individuals are capable of regulating their own functionality and can produce outcomes from proactively controlling their behaviors and actions. Bandura (2001) simply defined agency as intentionally making things happen by one's actions. "Unless people believe they can produce desired effects by their actions, they have little incentive to act, or to persevere in the face of difficulties" (Bandura, 2006, p. 170). At the core of the agentic behaviors is the set of beliefs that an individual has about their ability to influence and produce outcomes.

Consequently, the theoretical foundation for this study stems from social cognitive theory yielding self-beliefs and human agency, which ultimately result in outcomes. Furthermore, this framework is operationalized to fit the context of this study and, thus, includes teacher agency and teacher beliefs that guide and derive an instructional outcome. Specifically, the instructional outcome entails the integration of engineering design and culturally responsive pedagogy in secondary mathematics and science curricula. The literature review addresses each construct of the theoretical and operationalized frameworks. The chapter also includes a review of literature regarding recent efforts to integrate engineering design and culturally responsive pedagogy in preservice and in-service teacher development and in their mathematics and science instruction.

Theoretical Framework

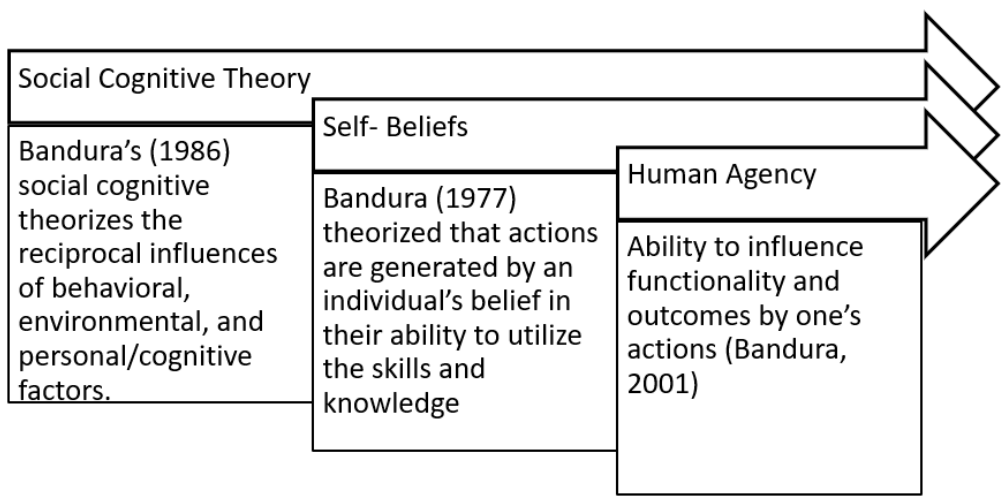

Figure 1.Theoretical Framework for deriving Self- Beliefs and Human Agency from Bandura's Social Cognitive Theory

Social Cognitive Theory (SCT)

The theoretical underpinnings for this study are grounded in Bandura's social cognitive theory (Bandura 1986; 1997). Bandura's social cognitive theory (SCT) takes into account the physiological, sensory, and cognitive contributors to human functionality and development. SCT asserts that learning is a product of the reciprocal interactions between personal, environmental, and behavioral determinants. According to SCT, human behavior is a dynamic process that is inclusive of cognitive, self-regulatory, and vicarious mechanisms (Pajares, 2002); as such, it is not acquired by acting autonomously (Pajares, 1996). Past experiences acquired, and observations collected are all rooted in one's personality. These elements influence and reinforce human behaviors.

SCT deemphasizes the influence of biological or environmental factors alone, and instead highlights the critical role of introspection. Thus, asserting that human behavior results from an individual's own cognitive processes and interpretations of outcomes (Pajares, 2002). Bandura (1986) advocated to examine and focus upon human thoughts and introspection. He argued that, "a theory that denies that thoughts can regulate actions does not lend itself readily to the explanation of complex human behavior" (Bandura, 1986, p. 15). SCT views humans as active agents in their own development who have the capacity to change their behaviors. Central to this notion is the set of self-beliefs that an individual has regarding the ability to influence their own actions coupled with the ability to produce certain desired outcomes (Bandura, 1985). For this reason, SCT has found itself at the heart of much research investigating teacher beliefs and how they influence instructional practices along with curricular decisions.

In 1986, Bandura published *Social Foundations of Thought and Action: A Social Cognitive Theory*. Bandura advanced the understanding of human functioning through discussion on the cognitive processes that guide human behavior, which included mechanisms of self-regulation and self-reflection. Bandura theorized humans as capable of regulating their actions and reflecting upon them in a self-controlled, proactive manner rather simply generating reactive impulses that answer to external or environmental forces. Bandura (1986) coined this iterative interplay of the personal, behavioral, and environmental factors as, reciprocal determinism. By doing so, Bandura (1986) provided a conceptual model of causation, which theorizes the interactions of a) personal factors, such as cognitive, affective, and biological events, b) behavior, and c) environmental factors. The three constructs interact in a cyclical format, working in conjunction, to yield a triadic reciprocity (Bandura, 1997; Pajares, 1996).

According to Pajares (2002) it is this reciprocal nature that allows for interventions and counseling efforts to be directed towards the personal, behavioral, or environmental determinants. Pajares (2002) further described utilizing these features of SCT as a framework to emphasize the impact teachers can have in the lives of their students:

> …teachers can work to improve their students' emotional states and to correct their faulty self-beliefs and habits of thinking (personal factors), improve their academic skills and self-regulatory practices (behavior), and alter the school and classroom structures that may work to undermine student success (environmental factors). (p.1).

Self-Beliefs

Self-efficacy and outcome expectancy framework. According to social cognitive theory (SCT), an individual's self-efficacy beliefs are the most prominent set of thoughts that impacts human functioning (Pajares, 2002). The construct of self-efficacy was first introduced by Bandura in 1977 and was defined as the "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3). The formation of the construct was driven by Bandura's belief that effective functioning was more than just a product of knowledge and skills acquired over time (Siwatu, 2007). Bandura argued that holding a strong sense of self-efficacy was critical for one to put their acquired knowledge and competencies to use (Evans, 1989). Bandura (1977, 1986) theorized that inventories of knowledge and skills are not predictors of future behaviors, rather, action is generated by an individual's belief in their ability to enact skills and knowledge. Self-efficacy serves as a regulator of individual and group behavior as it manages the internal, personal, and, environmental factors. As stated by Rew (2013), groups and individuals utilize their efficacy beliefs "as regulatory mechanisms to engage cognitive, motivational, affect, and selected processes that translate competence into successful action behavior or performance" (p. 32). These processes work in conjunction and serve as mediators between an individual and group's efficacy beliefs and displayed behavior (Bandura, 1999, 1997, 1995).

The second type of expectancy belief that Bandura (1977) introduced was outcome expectancy, which varies from self-efficacy in that it concerns the consequences of participating in select behavior or activities (Bandura, 1978, 1989; Pajares, 1996). Bandura (1977) explained that these outcome expectancy beliefs are ''a person's estimate that a given behavior will lead to certain outcomes'' (p. 193). Furthermore, Schunk (1991) suggested that these perceptions and beliefs are shaped by personal experiences and observation of models. Bandura's constructs of efficacy and outcome expectancy have been widely utilized in educational research to examine the beliefs of preservice and in-service teachers (Pajares, 1996). The investigation of these sets of beliefs has led to the development of a research strand known as teacher efficacy (Siwatu, 2007).

Human Agency

Bandura's SCT can be differentiated from other behaviorist theories in that SCT prescribes to a view of human agency which asserts that each individual is an agent of their own development and can produce change through actions.

> Key to this sense of agency is the fact that, among other personal factors, individuals possess self-beliefs that enable them to exercise a measure of control

over their thoughts, feelings, and actions, that "what people think, believe, and feel affects how they behave. (Bandura, 1986, p. 25).

Therefore, human agency derives a course of intended actions that ultimately yield an outcome (Bandura, 2001, 2006). Bandura explained that these outcomes are not characteristics, but, are rather consequences of agentic acts. According to Bandura (2001), human agency is comprised of four core functions, see Figure 2. The first of which function is intentionality; this is a proactive commitment on the end of the individual towards a desired goal or outcome. The next category, forethought, is the temporal extension of agency allows individuals to foresee likely outcomes resulting from prospective actions. Individuals develop an action plan and strategize towards perceived future events. Agents not only engage in the aforementioned anticipatory acts, but, also self-regulate their decisions and behaviors to reach the desired, likely, consequences of their actions. Thus, the third function of human agency is self-reactiveness. In addition to well-intended planning, individuals must govern the courses of action needed to bring their vision to fruition. Finally, the fourth agentic feature is self-reflectiveness, which asserts that individuals reflect on their beliefs, thoughts, and actions to make the necessary adjustments for achieving contrived goals.

Human Agency: ability to influence functionality and outcomes by one's actions			
Intentionality: Form intentions; action plans	Forethought: Set goals and foresee likely outcomes of actions (outcome expectations)	Self-reactiveness: self-monitoring; corrective self-reactions	Self-reflectiveness: self-examine own functioning; self-evaluate
Planning for course(s) of action		Self-regulating course(s) of action	

Figure 2. Human Agency (adapted from Bandura, 2001)

Operationalized Theoretical Framework

Teacher Pedagogical Beliefs

The concept of exploring teacher beliefs can be traced back to John Dewey (1933) who described the derivation of beliefs through interactions with others. Therefore, beliefs are inclusive of perspectives that are often gathered unconsciously. Dewey's view of beliefs was also later articulated by Rokeach (1968) who explained beliefs as "simple proposition, conscious or unconscious, inferred from what a person says or does, capable of being preceded by the phrase, 'I believe that. . .'" (p. 113). These assertions are in line with Bandura's social cognitive theory (1986; 1997) that suggested that beliefs ultimately yield actions. Furthermore, teachers' perception of an outcome that can be derived due to their theoretical or actual actions, is known as, *outcome expectancy*. Hence, outcome expectancy is a vital component of beliefs and has the power to drive actions (Bandura, 1977).

Accordingly, teacher beliefs have garnered great interest in realm of teacher education (Pajares, 1992) and professional development of teachers (e.g., Dembo & Gibson, 1985; Fang, 1996; Stipek, 2004). Through extensive research over the past decades, teacher beliefs have been correlated to pedagogical practices (Pajares, 1992; Vartuli, 1999; Vartuli & Rohs, 2009). According to Rimm-Kaufman and Sawyer (2004), "teachers' beliefs, attitudes, and priorities are linked closely to their classroom behavior and practices" (p. 322). Teacher pedagogical beliefs consist of their reflections on and perceptions about instructional practices, inclusive of curricular planning, and enactment of pedagogical approaches. Studies have asserted that beliefs regarding pedagogical practices guide instructional decisions and influence the development of instructional materials utilized by teachers for student learning (Gay, 2010; Pajares, 1992; Polat, 2010; Vartuli, 1999). Thus, it is paramount to understand and document the beliefs of teachers as they relate to the enactment of instructional practices and decisions (Nathan et al., 2010).

Teacher Beliefs and Implementation of Instructional Practices

Numerous studies have explored and asserted the impact of teacher's beliefs on the fidelity with which instructional practices are employed (e.g. Fang, 1996; Goodman, 1988; Haneghan & Stofflet, 1995; Rimm-Kauffman, Storm, Sawyer, Pianta, & La Paro, 2006). Researchers have linked teacher's beliefs about learning as factors that directly influence their decisions, and ultimately their actions (e.g., Peterson, Carpenter, & Fennema, 1989; Sherin, 2002). Moreover, researchers have argued that teacher beliefs strongly influence student learning experiences (e.g., Brophy & Good, 1974; Carpenter et al., 1989). A powerful contributing factor during instructional planning, as reported by teachers, includes their perceptions of student ability (see, Borko et al., 1992; Clark & Peterson, 1986; Romberg & Carpenter, 1986; Thompson, 1984).

Provided the extensive influence of teacher beliefs on the enactment of instruction (Gay, 2010; Pajares, 1992, 2002; Siwatu, 2011), researchers in the field of engineering design have also focused efforts on exploring not only teacher knowledge, but, also, their attitudes and perceived ability to implement engineering design related curricula (Nespor, 1987; Yasar et al., 2006; Yoon, Diefes-Dux, & Strobel, 2013). Accordingly, Haneghan, Pruet, Neal-Waltman, & Harlan (2015) asserted that teacher beliefs play a significant role with regards to the implementation of engineering design challenges in K-12 classrooms. The authors explained that these activities are tailored for student-centered instruction which allows opportunities for creativity and collaboration, along with application of mathematics and science. Hence, the beliefs teachers hold regarding the core processes involved in engineering design, as well as, their perceived success with implementation are integral to successful implementation of engineering design activities. Moreover, in the report published by the National Academy of Engineering (Custer & Daugherty, 2009), the authors expressed the critical implications of teachers' beliefs on the enactment of engineering design instruction in K-12 classrooms. Therefore, researchers are encouraged to explore the beliefs teachers have about implementing new instructional practices.

Accordingly, Nathan et al., (2011) explored the role of a professional development program on teachers' beliefs regarding the field engineering and engineering design instruction. The authors reported changes in teachers' views favoring a positive perspective towards the field and implementation of instruction. While the authors cautioned the readers against the generalizability of the population studied, describing their setting as a microcosm of the nation, they argued that teacher beliefs hold substantial implications regarding their integration of engineering design education (Nathan et al, 2011). Similarly, prominent researchers in STEM education have advocated for documenting teacher beliefs which include the factors influencing instructional practices surrounding the inclusion of engineering design (see, Cunningham, 2009; Yasar et al., 2006).

Teacher Agency

Along with an increased focus on teacher beliefs, many scholars have also shifted to acknowledging the value in deepening our understanding about teachers' sense of agency (see, Goodson, 2003; Nieveen, 2011; Priestly, 2011). Extending research and conversation around teacher agency allows for policy makers to move away from traditional prescriptive methods of curricula and professional development to instead focus on teachers' professional agency within the context of their work (Biesta, Priestly, & Robinson, 2014). The choices teachers make guide and inform the implementation of any instructional reform, and, therefore, determine any institutionalization of practices (Bridwell-Mitchell, 2015). Thus, teacher buy-in is critical to educational reform and examining teachers' receptivity towards instructional practices is vital for meaningful change to take place (Cheng & Hong, 2018). The characterization of teachers as human agents who are capable driving change through action entails the understanding that agentic behavior includes the capacity to reflect, learn, and evolve through observations and experiences (van der Heijden, Geldens, Beijaard, & Popeijus, 2015). It is this acknowledgement that underlines the magnitude of value researchers should place upon examining teacher agency, specifically as it relates to their implementation of instructional practices.

Moreover, teacher beliefs surrounding their ability and pedagogical practices play a significant role in determining the extent to which teachers are able to achieve agency

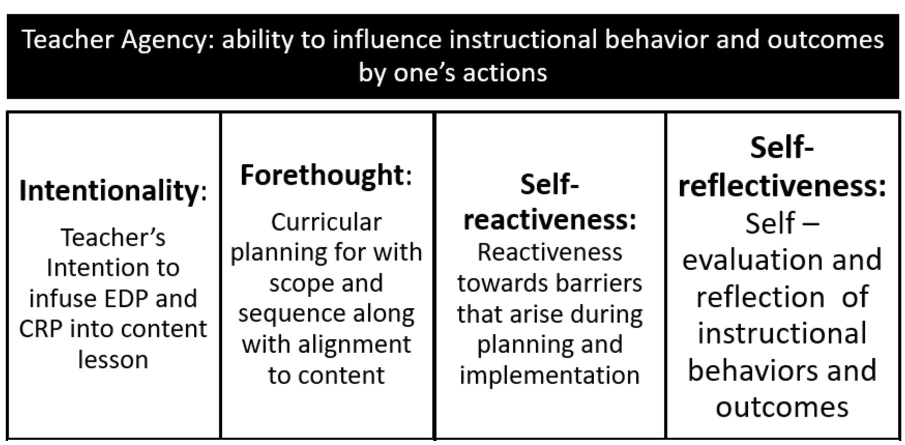

Figure 3. Operationalized Framework for Teacher Agency (adapted from Bandura, 2001)

within the context of their educational ecologies (Biesta et al., 2015). Biesta et al., (2015) explained that, "the promotion of teacher agency does not just rely on the beliefs that individual teachers bring to their practice, but also requires collective development and consideration." (p. 624). Consequently, this research was guided by the notion that teacher beliefs and sense of agency are paramount to any institutional reform. It behooves scholars and policy makers to acknowledge that both teacher beliefs and agency surrounding the implementation of new practices need to be considered and further explored. Accordingly, this study examined teachers' beliefs of their own abilities and their beliefs regarding instructional practices. The researcher also investigated teacher agency, operationalized from the four categories included in Bandura's conceptualization human agency (2001), see Figure 2. Specifically, the study focused on the pedagogical constructs of the engineering design process and culturally responsive pedagogy.

The Engineering Design Process (EDP)

The engineering design process (EDP) is an integral component of what engineers do and how they approach societal problems. The National Center for Engineering and Technology Education (NCETE, 2011) defined EDP as an approach inclusive of defining a problem and developing a model to be refined through data analysis to produce a solution consisting of technological and social elements (Daugherty, 2012; Hynes et al., 2011). According to Katehi et al., (2009), EDP is in fact, "the central activity of engineering" (Katehi et al., 20019, p. 56). Wulf (1998) explained that everyday engineers tackle problems through consideration of constraints and limitations (i.e., cost, materials, time, etc.) while still designing solutions that cater to human needs and wants. Thus, engineering design identifies a problem and works towards a viable solution through a set of practices (Apedoe, Reynolds, Ellefson, & Schunn, 2008). Although the order may vary, the EDP employs a series of critical steps designed to address a particular problem (Atman, Chimka, Bursic, & Nachtmann, 1999).

EDP is initiated by identifying a need or problem (Apedoe et al., 2008) through expressed concerns of customers or clients (Crismond, Lo, & Lohani, 2006). From here, the engineers explore similar problems and solutions from the past, in addition to being mindful of constraints and limitations facing the problem at hand. The research phase is important because it allows the engineer to attain a rich understanding of how the current problem relates to those previously resolved. These prospective design ideas allow for the formation of a prototype or model that embodies the ideas brainstormed. The process of testing and re-testing provides engineers with vital insight about the physical constraints and limitations of the problem. Furthermore, this practice of evaluation, which can take place at any point in the design, allows engineers to obtain feedback on the progress of the solution, as well as generate ideas for forthcoming redesign procedures (Crismond et. al., 2006). Thus, the redesign stage is instrumental to the process because it allows engineers to refine the prototype through informed practices based on data collected and/or feedback received during evaluations (Apedoe et al., 2008).

Engineering the Future: Science, Technology and the Engineering Design Process. (2008).							
Define the problem	Research the problem	Develop possible solutions	Choose the best solution	Create a prototype	Test and Evaluate	Communicate the solution	Redesign

Engineering the Future: a year-long course designed to introduce incoming high school students to engineering and technology.

Massachusetts Department of Education. (2006). Massachusetts Science and Technology/Engineering Curriculum Framework.							
Identify the need or problem	Research the need or problem	Develop possible Solutions	Select the best solution(s)	Construct a prototype	Test and evaluate the solution(s)	Communicate the solution(s)	Redesign

Massachusetts Science and Technology/Engineering Curriculum Framework: state-level standards for K-12 students on engineering-related topics.

T-STEM Center. (2009). Design FRAME, problem solving with the engineering design process. Lubbock, TX: Texas Tech University. Texas				
Frame the problem	Research the possibilities	Analyze the data	Model the design	Execute the design

Texas Tech University T-STEM: A Texas-based initiative to develop STEM curriculum with a focus on engineering-related projects.

Engineering Is Elementary (2003). The Museum of Science, Boston.				
Ask	Imagine	Plan	Create	Improve

Engineering is Elementary is a project of the National Center for Technological Literacy and established by the Museum of Science, Boston to provide nationwide resources to enhance engineering and technology for elementary through middle school levels.

NASA's BEST - The Engineering Design Process (2016).					
State the problem	Generate Ideas	Select a Solution	Build the Item	Evaluate	Present Results

NASA's Beginning Engineering, Science, and Technology (BEST) program provides resources focused on utilizing the engineering design process and introduces students to the methods engineers use to solve design problems.

Figure 4. Prominent version of the Engineering Design Process (EDP). (Guerra, Allen, Crawford & Farmer, 2012; Massachusetts DOE, 2006; NASA's BEST, 2016; T-STEM Center, 2008).

In an effort to emphasize the iterative nature of design, EDP is often illustrated through a cyclical diagram, as opposed to a linear, step-by-step method (Guerra, Allen, Crawford, & Farmer, 2012). Therefore, the procedures of retesting and redesign are employed throughout the experience, as engineers make modifications based on what they learn during each phase (NAP, 2012). Over the years, a variety of reputable organizations and universities have diagramed the iterative, cyclical, steps involved in the EDP through graphical representations sequencing the steps in a similar loop-based manner (Guerra et al. 2012). Figure 4 illustrates six prominent sources that provide a framework for EDP. This generalized framework of practice is supported by the

Accreditation Board for Engineering and Technology (ABET), which while does not specify prescriptive steps, does, provide the following definition on engineering design:

> Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs. (ABET, 2015, p. 4)

Reeve (2016) investigated the extent to which engineering design process utilized in K-12 is reflective of the practices used in the technical and industrial field of engineering. According to the author, the major emerging theme from the study is that the step during which students identify the problem is perhaps the most important skill in the design process with regards to classroom experience connecting with actual practice in the field. Furthermore, the author also noted that in addition to identifying a problem, the customer needs analysis is also a pertinent skill used in the field and should be further emphasized in classroom instruction (Reeve, 2016). Householder and Hailey (2012) stated that given the complexities of engineering design challenges it is imperative that these activities take place at appropriate developmental levels. Thus, the authors argued that teachers must find a balance between what is feasible in the context of the classroom and what is done in the field of engineering. According to the authors, this may include “engaging them to reflect on differences in purpose, process, and product at levels that they understand” (Householder & Hailey, 2012, p.17).

Engineering Design Process (EDP) in Teacher Education

Despite the recent efforts in national standards, K-12 engineering education continues to face the challenge of teachers who feel ill prepared to provide instruction on areas of engineering design (NAE & NAP, 2009). Preservice teacher trainings rarely, if at all, include preparation for teaching engineering (Kateh et al., 2009). Consequently, there has been a rise in professional development for in-service teachers on methods to integrate engineering design into their K-12 classrooms (Cunningham, Lachapelle, & Keenan, 2010). The integration of Science, Technology, Engineering, and Mathematics (STEM) disciplines inclusive of engineering design has proven to connect mathematics and science content in meaningful ways (Carr, 2011). Moreover, according to research, this inclusion results in improved student achievement, as well as, interest in the field of STEM (Katehi et al., 2009). However, according to Lee and Strobel (2014) while professional development and preservice teacher preparation on scientific-inquiry gained momentum in STEM education reform, engineering design did not receive the same level of attention. This discrepancy was caused by an already established foundation and need for science in K-12 curricula (Lee & Strobel, 2014). Thus, researchers have asserted that in order to litigate the absence of engineering design in STEM classrooms an increased emphasis must be placed on high-quality teacher professional development (Brophy, Klien, Portsmore, & Rogers, 2008; Lee & Stohlman, 2014; Roehrig, Moore, Wang, & Park, 2012).

Lee and Stohlam (2014) defined teacher professional development as opportunities for learning and growth that include and begin with preservice preparation and extend throughout the in-service career of a professional educator. According to Park Rogers et al, (2007) professional development for in-service teachers is typically inclusive of the following eight characteristics: (1) enrichment of content and pedagogical knowledge; (2) resources and time to support to teacher growth in the classroom; (3) professional learning communities aimed at supporting design and implementation of instruction; (4) inclusion of a succinct goal or vision for student learning; (5) careful consideration placed on the school or district contextual characteristics along involvement key administrative leadership personnel; (6) need for utilization of student learning data in professional development; (7) research driven design for professional development, and (8) support for teachers to serve and grow into leadership roles within schools and districts (Guskey, 2003; Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003). Furthermore, in the context of STEM teacher professional development, Estapa and Tank (2017) have suggested that teachers must delve deeper to explore methods of integration across the STEM content areas and develop specific understanding regarding integrated STEM education (see also, Brophy et al. 2008; Cunningham and Hester, 2007; Moore, Stohlmann et al. 2014; Roehrig et al. 2012).

Elementary in-service professional development. Exposure to the inclusion of engineering design at a young age has strong implications that are grounded in research and suggest an increase in academic achievement and students' problem-solving capacity in mathematics and science content areas (Cunningham and Hester, 2007). This impact is, however, contingent upon teachers' conceptualization and enactment of engineering design experiences embodied in STEM curricula (Diefes-Dux, 2014). Still, there is a lack of elementary teacher professional development (PD) on engineering design that extends beyond exposure to one activity or lesson (Lee & Stohlman, 2014). Engineering is Elementary (EiE) is a national research driven and standard orientated elementary engineering curriculum (EiE Curriculum, 2018). Developed by the Museum of Science (MoS) in Boston, EiE provides curricula that integrates engineering and technology skills with science content and purposefully connects to mathematics, language arts, and social studies (EiE Workshops & Professional Development, 2018). Over the years, MoS has provided teachers with PD designed to engage teachers' pedagogical knowledge of engineering skills and promote student-centered, inquiry-based methods of teaching (Museum of Science, 2018). Currently, EiE is the largest PD opportunity and curricular resource for engineering practices at the elementary level. Due to scarce opportunities for experience with engineering education in elementary schools, EiE provides PD workshops for elementary school educators that vary in length from two hours to several weeks (Cunningham, 2009). According to Christine Cunningham, founder and director of EiE, the workshops allow teachers to participate in engineering design challenges, interact with the curricular resources and consider implications for integration of engineering and technology concepts in other subject areas (Cunningham, 2009). The PD includes a series of workshops starting with defining technology and engineering in the classroom as it relates to EiE, and, ultimately, engaging teachers with lessons provided in a given unit (Cunningham, Lachapelle, & Keenan, 2010). Moreover, EiE provides online resources for additional support once teachers begin the implementation process (EiE, 2018).

Other examples of elementary teacher PD in engineering integration includes those developed by area universities and schools. For example, the Teachers and Engineers Collaborating in STEM Elementary Teacher Preparation (TEC-STEM-ETP) project is an initiative funded by the National Science Foundation (NSF) at Iowa State University (Horizon Research, n.d.). The project is aimed at revamping elementary teacher preparation at the university through collaboration between engineering graduate students along with in-service and preservice elementary teachers, working together to plan and implement lessons inclusive of engineering content (Estapa & Tank, 2017). The participants engage in a week-long summer PD workshop which is focused on integrated STEM instruction with engineering designed based lessons for science and mathematics. The experience involves initial discussions on approaches for the inclusion of engineering in mathematics and science lessons followed by engagement with engineering design challenges (Estapa & Tank, 2017). The authors discussed that the facilitators, teacher educators, and engineering faculty members involved were deliberate about allowing an opportunity for teachers to improve upon the activities. As such, the engineering challenges intentionally lacked connection to STEM content, thus, encouraging teacher involvement to purposefully plan for their classroom (Estapa & Tank, 2017).

Secondary in-service professional development. A project conducted at the University of Nebraska instituted a PD program intended to support middle school and high school math and science teachers implementing lessons infused with the engineering design process. Through collaborative efforts between faculty members from the College of Engineering and Technology, College of Education, and the College of Human Sciences, the program aimed to provide teachers with viable methods for inclusion of engineering design and support teachers with resources to raise student interest and awareness in engineering (Nugent, Kunz, Rilett, & Jones, 2010). The two-week summer institute provided teachers with exposure to the field of engineering. The PD also included the types of problems solved by engineers including data sets and simulations suitable for instructional use by the teachers. The introductory first week included field trips to engineering research labs and facilities at the University of Nebraska. Meanwhile, the second week of the institute focused primarily on development of lessons that are infused with engineering design and are grounded in mathematics and science content. These lessons were also critiqued by the teachers to ensure clarity along with quality of instructional objectives and procedures (Nugent et al., 2010).

Another NSF grant funded project conducted through collaborative partnership between Northeastern University, Boston Public Schools and Tufts University's Centre for Engineering in Educational Outreach also developed a teacher PD program specifically for middle school teachers (Hynes, 2010). The project was aimed to prepare teachers to implement an after-school LEGO robotics unit with an emphasis on engineering and technology topics. The two-week PD institute included workshops facilitated by guest speakers including faculty in engineering and experienced teachers in the field of engineering and technology education (Hynes & Dos Santos, 2007). The second week of PD was intended to allow teachers the opportunity to utilize half of the day to teach the robotics units to a small group of students, followed by time allocated in the afternoon for teachers to deliberate and reflect on the challenges and successes experienced. However, according to Hynes and Dos Santos (2007), the afternoon time was instead spent providing immediate support to teachers through troubleshooting questions on programming and building components the teachers and/or the students struggled to solve. The authors also noted that any remaining time was spent by teachers planning the next day's lessons rather than reflecting on practices as was originally intended by the PD developers (Hynes & Dos Santos, 2007).

Finally, Project Lead the Way (PLTW Launch, 2018) is perhaps the most prevalent curricular program for engineering education at the secondary level (grades 6-

12) serving over five million students and tens of thousands of teachers throughout all 50 states (Brien, Karsnitz, Van Der Sant, Bottomley, & Parry, 2014; PLTW Launch, 2018). PLTW aims to integrate all disciplines of STEM and includes a program called, Pathway to Engineering, which consists of seven courses on topics of engineering and a culminating research capstone (PLTW Engineering, 2018). As a precursor to teaching the coursework, teachers are required to attend a two-week summer training institute which is offered on an array of engineering and technology related topics (Daugherty, 2008). According to the website, the trainings are intended to provide teachers with engagement in activities and projects included in the curricula and consist of hands-on experiences, as well as, some lecture and demonstrations (PLTW Launch, 2018).

Preservice teacher preparation. One of the reasons argued for the rise of in-service teacher professional development on the inclusion of engineering is the lack of preparation provided by preservice teacher education (Katehi et al., 2009). Consequently, the inclusion of engineering and technology along with science and mathematics in teacher development has been strongly advocated for by researchers and educators over the past decade (see, NRC, 2007; NRC, 2010). Still, elementary teacher preparation continues to require minimal level of mathematics and science related content coursework, and the mandate for engineering and technology content is even more scarce (Custer & Daugherty, 2009). O'Brien, Van Der Sandt, Bottomley, & Parry (2014) insisted that this disparity exists in part due to the perception of engineering as a content deemed appropriate for upper level or postsecondary coursework.

The report, Engineering in Pre-College Settings, recently published by Purdue University, explores the state of engineering education research and practice which included discussion on preservice teacher education (Purzer, Strobel, & Cardella, 2014). According to the report, at least six university-based elementary preservice teacher education programs include coursework on engineering education. Universities such as North Caroline State University, for example, require intentional elementary courses on engineering design. These include hands-on experiences for preservice teachers with design-centric activities that are facilitated by faculty members in the College of Engineering and College of Education. Moreover, teacher candidates are expected to select a STEM concentration that results in additional math and science related coursework (O'Brien et al., 2014). Additionally, one of the earliest adoptions of an integrated STEM elementary teacher preparation model was initiated in 1998 at The College of New Jersey and is now known as the Integrative-STEM (i-STEM) program. This major is one of 11 possible routes selected by K-5 education majors and includes three teaching methods courses on topics of technology and engineering design (O'Brien et al., 2014).

Meanwhile, secondary preservice teacher preparation is reported to follow a much more formalized pathway through requirements placed by secondary certification programs for technology and pre-engineering education. These program and certification requirements vary by state (O'Brien et al., 2014). Still, programs such as PLTW, have helped pave the way for increased integration of STEM disciplines, therefore, raising the focus on teacher preparation (O'Brien et al., 2014). Thus, in order for engineering design-based instruction to take place in K-12 classrooms, it is imperative that not only in-service professional development exist, but, also that preservice preparation evolve to meet these needs (Custer & Daugherty, 2009).

Daugherty (2008) conducted a multi-case study on the five well-established and recognized programs designed to provide secondary teachers with PD on the inclusion of engineering design and concepts in the classroom. Project Lead the Way, Engineering the Future, The Infinity Project, Mathematics across the Middle School MST Curriculum, and INSPIRES were the five selected cases examined by the author. Daugherty (2008) focused on PD design as well as the challenges experienced. The findings revealed that the programs embodied conflicting purposes between a guided focus on strengthening the engineering workforce and providing students with a general STEM literacy regardless of career pathway (Daugherty, 2008). Moreover, the study uncovered that teacher PD provided by these programs lacked consistency on engineering content and included varying pedagogical approaches (Daugherty, 2008). Thus, the author pointed towards a troubling pattern in teacher trainings which include hands-on, design-centric, activities that lack emphasis on content related learning (Custer & Daugherty, 2009; Daugherty, 2008).

Custer and Daugherty (2009) explained that due to an array of engineering education efforts, through funded curriculum initiatives, the current state of engineering related PD at the secondary level is a conglomerate of already existing initiatives. The authors noted that secondary PD is primarily focused on providing tools and resources through engagement with engineering design challenges that are intended for teachers to take back and use in their own classrooms. Absent from the teacher education efforts is the opportunity for pedagogical discussion. Such conversations can allow teachers the time to reflect on their instructional practices and desired student learning outcomes (Custer and Daugherty, 2009).

Implementation of the Engineering Design Process (EDP)

The disparity of content-driven engineering design activities is further heightened at the elementary grade levels due to the lack of instructional time devoted to science instruction (Tank, Moore, Babajide, & Rynearson, 2015). This is an imperative challenge provided the adoptions of Next Generation Science Standards (NGSS) curricula which emphasizes engineering design as a complimentary practice to scientific inquiry (NAE & NRC, 2014). However, a challenge preventing elementary teachers from integrating STEM into their current practices is that they lack the appropriate resources for developing and implementing their own lessons (Guzey, Tank, Wang, Roehring, & Moore, 2014). As such, elementary teachers lack the adequate training to develop the curricular units for themselves.

According to Portsmore, Carberry, and Hynes (2010), students in middle school grades are able to address constraints in an engineering design activity and conduct independent research regarding the challenge leading to the generation of multiple ideas. However, students' in middle school are likely to skip the planning stages and move directly into the building portion of a design task (Portsmore et al., 2010). Students at this level also require teacher guidance to engage in the engineering design phase which asks them to plan for potential solution (McCormick, Henessey, and Murphy, 1993). Similarly, students in elementary school need additional support from their teachers on the methods for testing designs and evaluating the results (Trevisan, Davis, Crain, Clakins, & Gentili, 1998). Meanwhile, high school students should be expected to derive their own testing procedures and conduct data analysis (Trevisan et al., 1998).

Middle school teachers are encouraged to guide their students to envision the prototype as a model utilized for testing constraints and specific aspects of the proposed solution, as opposed to, creating a replica of a real-world object (Portsmore, 2010). Furthermore, at this stage students should be expected to provide reasoning for their engineering design decision in terms of trade-offs, however, they may not yet comprehend the "impact of conflicting requirements and their trade-off decisions" (Ganesh & Schnittka, 2014, p. 98). It is critical to facilitate presentation through the engineering design process. Communicating the solutions, allows students allowing students, especially those in secondary grades, the opportunity to articulate their thoughts around the ideas generated, design decisions made with justification, and analysis of data collected to support proposed design models (Kolodner et al., 2003)The focus on presentations is significant because as Hynes et al., (2011) explained, students in high school, grades 9-12, should be able to complement their presentations with written documents that provide clarity of ideas presented to select audience (i.e., classmates, teachers, and clients). Gassert and Milkowski (2005) further asserted that high school students should include details regarding the limitations, constraints, performance issues, and product specifications in their presentations.

Culturally Responsive Pedagogy

Culturally responsive pedagogy (CRP), often referred to as culturally relevant pedagogy, is a pedagogical model originally coined by Ladson-Billings (1994, 1995). Ladson-Billing (1994) explored the techniques teachers use to effectively teach African American students in a manner that makes their lived experiences normative. CRP is a philosophy of learning that asserts the need to utilize student cultural identities, and experiences as resources for student-centered instruction (Ladson-Billing, 1994, 1995). The implications of tailoring instruction to reflect the culture of ethnically diverse students includes positive impacts on the student achievement of underrepresented minority populations (Hollins, 1996; Ladson-Billing, 1994, 1995). Cultural characteristics of students are inclusive of ethnic background and traditions. These traits encompass varying forms of communications, learning styles, societal contributions, and gender role socialization, all of which are influenced by ethnic and cultural factors (Gay, 2000). Culturally responsive instruction is “a pedagogy that empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes"(Ladson-Billings, 1994, p. 382). Consequently, teachers must move past the faulty ideology of a one-size-fits-all curricular approach, and, instead, adopt an instructional approach that visualizes content through their students’ cultural lens (Aguirre & Zavala, 2013; Gay, 2000, 2002, 2010). The embodiment of CRP demands that teachers not only share content knowledge in meaningful ways, but also create avenues for students to question and challenge the systemic issues in society.

The implications of presenting content through the students’ cultural filter includes improved academic achievement and heightened interest in subject areas (Gay, 2000; Ladson-Billings, 1994, 1995). Recently reported student enrollment data in the U.S. illustrates the shifts in cultural and ethnic background of K-12 student populations with a predicted 56% students of color represented by 2024 (Kena et al., 2015). However, as illustrated by data reported from NCES (2013) teacher demographics remain homogenous even in the face of growing student diversity (Bottiani, Larson, Debnam, Bischoff, & Bradshaw, 2018). According to NCES (2013) roughly 82% of public-school teachers are non-Hispanic white and there is no significant increase expected in the percentage of teachers of color (21%) entering the workforce. Nevertheless, scholars warn that even when the ratio for teachers of color is on par with that of the student population, it does not necessarily yield culturally responsive and unbiased instructional practices (Bottani et al, 2018; Bradshaw, Mitchell & Lead, 2010). Consequently, interventions in teacher education and preparation are critical to bridge cultural divides and promote culturally responsive practices (Gay, 1995, 2010).

The Three Tenets of CRP

Gloria Ladson-Billings (1994; 1995) provided a model for culturally relevant pedagogy, often referred to as culturally responsive pedagogy, that stands on three fundamental pillars: academic achievement, cultural competence, and socio-political consciousness (Ladson-Billings, 1994). The first tenet asks instructors to foster a classroom environment is inclusive of instructional practices designed to help students master the content. According to Ladson-Billings, the teachers in her research, who were able to effectively teach students of color, embodied a sense of responsibility towards preparing students to be academically successful (Ladson-Billings, 1995). She further explained that student learning through CRP "requires that teachers attend to students' academic needs, not merely make them feel good." (Ladson-Billings, 1995, p.160) In her later work, Ladson-Billings (2006) clarified that academic achievement does not equate to student performance on high-stakes achievement tests. Instead, she explained that her vision for the tenet includes student learning that occurs through interactions with skilled teachers (Ladson-Billings, 2006).

The second tenet of CRP asks teachers to cultivate learning experiences that celebrate the social, cultural, and linguistic background of their students. In doing so, teachers reject a deficit-mindset when working students of color, and, instead, view students' culture and lived experiences as assets to their learning. Accordingly, teachers who embrace cultural competence affirm and celebrate their students' cultural identities.

The third tenet of CRP seeks to develop the socio-political and critical consciousness of students (Ladson-Billings, 1995). Teachers who embody CRP cultivate opportunities for students to engage in discourse and activities that question the power dynamics within their communities. Students are, therefore, empowered to challenge the social inequities they may have experienced or witnessed. This tenet also warrants that teachers develop their own socio-political consciousness. However, prominent researchers in the field of CRP have acknowledged that many teachers struggle with doing so, and, instead, only employ the first two tenets (Gay & Howard, 2000).

CRP in Teacher Education

The disparity in academic achievement experienced by African American and Latinx students compared to their Caucasian counterparts led researchers to explore the practices of effective teachers in urban areas (Siwatu, 2011). The findings of these studies (see, Foster, 1994; Ladson-Billings, 1994; Milner, 2006) suggested that teachers who experienced success with high African American and Latinx populations were providing instruction that integrated students' cultural and linguistic background. Thus, prominent scholars in the field have called for reform in teacher preparation to include professional development on culturally responsive pedagogy (Gay, 2000, 2002; Irvine, 1990; Ladson-

Billings, 1994, 1995, 2009). This is especially recommended for programs designed in preparing teachers for diverse classrooms (Ladson-Billings, 2009).

Jackson & Boutte (2018) explained that much like efforts in K-12 schooling it is essential that teacher education programs are also systemic in their implementation. The authors suggested that inclusion of well-thought-out field-experiences that are provided in conjunction with coursework that provides theoretical background, strategies, and an understanding of structural inequities. Jackson & Boutte (2018) argued that many preservice preparation programs lack such institutionalization and instead integrate CRP on a superficial level that lacks support by "practices, instruction, curriculum, policies, and dispositions of teacher educators." (Jackson & Boutte, 2018, p. 87).

Nash (2018) conducted a study with nearly 27 preservice teachers enrolled in two early childhood methods courses spanning over two consecutive semesters, The coursework that took place at predominantly African American elementary school located in the southeastern region of the U.S. preservice teachers studying at a flagship, predominantly white university, engaged with the K-first graders through use of culturally responsive curricula, culturally responsive literacy lesson plans, book club discussions, and they visited the homes and communities of the children. Moreover, the preservice teachers were immersed in literature regarding CRP and attended an African American lecture series. The author explored the perceptions of these aspiring teachers as they participated in these activities. The findings suggested that preservice teachers valued learning about children individually and visiting their homes and communities. The prospective teachers also moved beyond a "color-blind" stance about race and found themselves more comfortable with discussing topics around race and social justice.

Finally, the teaching candidates reflected on the importance of mirroring the ethnic and linguistic background of their students through the books presented in the classroom library, and examples used in instruction. Nash (2018) explained that the paradigm shift experienced by the teachers emphasizes the need for focusing on issues regarding race, racism, and culturally responsive pedagogy in teacher education.

A study by Jackson & Bryson (2018) explored the implications of engaging aspiring teachers in a community mapping project to extend their sociocultural understanding. Specifically, the authors investigated the utilization of community mapping as a culturally responsive pedagogical tool for preservice teachers and how it influences their learning. In order to accomplish this project, the instructors partnered with a school located in urban community. The participating preservice teachers shared their preconceived notions about the community and were divided into groups. Each group was provided with a designated area of the community for which they could collect data regarding resources such as housing, businesses, availability of food, transportation, health care, green spaces, etc. The authors shared their motivation for the project by explaining that a key tenet of developing culturally responsive teachers is engaging them in critical self-reflection (see also, Gay & Kirkland, 2003; Howard, 2003). This assertion is also supported by Bandura (2001) who argued that the act of self-reflecting is perhaps the most human element of agentic behavior. The findings from the research, while not substantial, according to the authors still affirm the need for community centered projects in teacher education that integrate critical reflection and culturally relevant exploration (Jackson & Bryson, 2018).

Bottiani et al (2018) conducted a systemic review of interventions targeted at in-service teachers to promote implementation of CRP. The authors described their careful review process which led to the selection of 10 studies that took place during the period of 1998-2014, and “reported on an empirical examination of the impact of an inservice intervention to promote CRP,” (p. 370). One of the 10 studies included in the systemic review was conducted by McAllister and Irvine (2000) on the role of teacher empathy when working with culturally diverse students. The participants included 34 teachers who took part in a multicultural professional development, Center for Urban Learning/Teaching and Urban Research in Education and Schools, or, CULTURES (McAllister & Irvine, 2000). The purpose of the 40-hour program for teachers from a southeastern city was “to create a professional development center that will assist [local] practicing elementary and middle school teachers to work effectively with culturally diverse students and enhance the quality of teaching and learning in urban schools” (McAllister & Irvine, 2000, p. 435).

The CULTURES program promoted teacher self-reflection, contextualization of theory, and application of skills in their schools and classrooms. The three main strands of the program as defined by the authors included: culturally responsive pedagogy (CRP), cultural awareness, and adapting content to meet the needs of culturally diverse students. The conclusions derived from the research reaffirm with previous studies conducted that while empathy is an essential quality of culturally responsive teachers, it alone is not sufficient when teaching culturally diverse student populations. The authors emphasized that teachers’ beliefs reported in the research agreed with Gay (2000) that empathetic teachers generally have students who perform well in academic, social, moral, cultural avenues. The authors further argued for teacher education programs to include opportunities for critical self-reflection and cross-cultural interactions.

The majority of intervention efforts in teacher education include group or cohort model professional development approaches (see Eberly et al., 2010; McAllister & Irvine, 2002; Ryan et al., 2007; Thompson & Byrnes, 2011). The research related to these programs focus extensively on shifts in teacher knowledge/beliefs (e.g., CRP as a theory of practice, and cultural self-awareness) (Bottiani et al., 2018). In a slightly different intervention approach conducted with inner-city public-school teachers in Chicago to implement CRP, Hammerness and Matsko (2013) examined participants of a voluntary program which provided support through coaching. The program employed by the authors utilized a coaching intervention method during new teacher induction in an attempt to improve teacher beliefs and attitudes with regards to CRP. Through one program director and three instructional coaches, the program supported teachers during a two-year induction period followed by a three-year post-graduate support period. The findings reported by the program staff suggested that teachers reported improvement in culturally responsive beliefs as a result of the ongoing support and coaching.

The overall findings derived from the extensive systematic review of CRP interventions in teacher education, conducted by Bottiani et al (2018), highlighted the challenges experienced by the programs. A key complication included difficulties in operationalizing and measuring CRP, especially, with regards to teachers working within the expectation and parameters defined by their schools and districts. Consequently, Bottiani et al., (2018) urged researchers to focus on measuring outcomes related to CRP. The authors suggested that consistency in CRP outcome measurement would allow for teacher educators and researchers to be held accountable to the same standards of implementation.

> We acknowledge the complexity of CRP and the need to implement CRP flexibly based on the local context of school and diverse backgrounds of students; as such, we suggest this measure may be better presented as a multidimensional index, rather than a unidimensional scale. (Bottiani et al., 2018, p. 380).

CRP in Math and Science

Student achievement in mathematics is often deemed the litmus test for whether or not they are able to advance in STEM related coursework (Boaler, 2002). Participation in STEM courses yields the opportunity pursue STEM career pathways that have social and economic implications (Oakes, 2005). As such, researchers over the past several decades have urged for teachers and teacher educators to incorporate culturally responsive instructional practices in their mathematics curricula (see, Berry, 2008; Davis & Martin, 2008; Gutstein, Lipman, Hernandez, & de los Reyes, 1997; Joseph, 1987; Ladson-Billings, 1997; Lynn, 2006; Martin, 2007; Matthews, 2003; Rousseau & Tate, 2003; Tate, 1995). The shift in student demographics along with data that suggests populations of students are being left behind in the critical subject area of mathematics has led to an urgency in efforts to improve the performance and experiences of cultural and linguistically diverse students around the U.S. (Grossman, Schoenfeld, & Lee, 2005).

Accordingly, CRP in mathematics has gained much needed traction, specifically, Culturally Responsive Teaching in Mathematics (CRMT) as defined by Aguirre & Zavala (2013) which provides “set of specific pedagogical knowledge, dispositions, and practices that privilege mathematical thinking, cultural and linguistic funds of knowledge, and issues of power and social justice in mathematics education.” (p. 163). These constructs are also supported and encouraged by prominent scholars such as, Gay, 2009; Gutiérrez, 2009; Kitchen, 2005; Leonard, Napp, & Adeleke, 2009; Turner et al., 2012). Aguirre & Zavala (2013) provided six dimensions for measuring culturally responsive instruction in a mathematics classroom through a lesson analysis rubric, see figure 5. The first five categories, derived from a protocol developed at the Wisconsin Center for Education Research and utilized by other researchers in the field, include: (1) Intellectual support provided through the lesson for student thinking; (2) Depth of student knowledge and understanding regarding content concepts and procedures; (3) Mathematical analysis; (4) Mathematical discourse and student communication; and (5) Student engagement with the content activity (Aguirre & Zavala, 2013). The last category consists of two parts, (6a) Community/Cultural Funds of

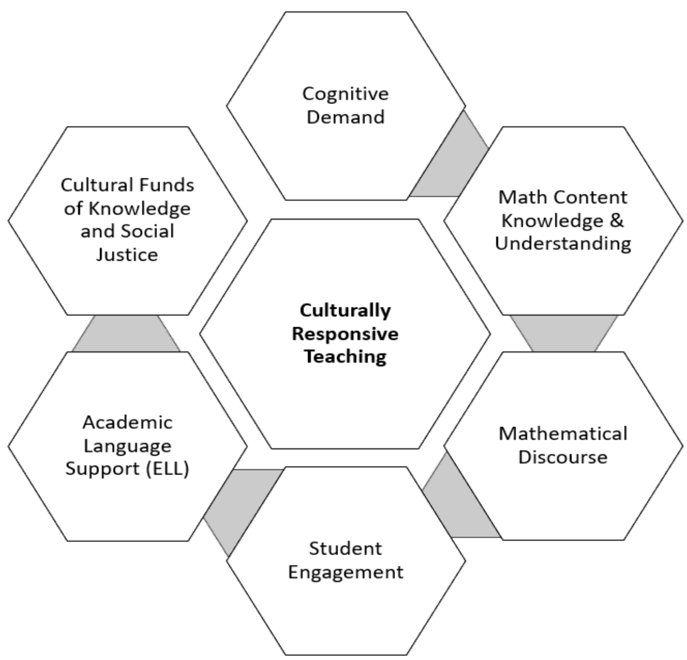

Figure 5. Culturally Responsive Mathematics Teaching (adapted from Aguirre & Zavala, 2013)

Knowledge; and (6b) Social Justice.

The six constructs of culturally responsive instruction, as defined by Aguirre & Zavala, 2013, explicitly focus on research driven culturally responsive pedagogical practices including language, culture, and social justice. The framework utilized by Aguirre & Zavala (2013) connects the paradigms of pedagogical content knowledge (PCK) and culturally responsive pedagogy (CRP) in an effort to emphasize the need for teachers attain expertise in both areas to effectively teach linguistically and culturally diverse students. Aguirre & Zavala (2013) explained that neither CRP nor PCK is enough on its own to provide a learning experience inclusive of content and equity driven instructional practices.

The authors further stated that previous descriptions of PCK have included an optional element of culturally responsive pedagogies (see, Grossman, Schoenfeld & Lee, 2005). However, leaving CRP as an optional strategy is detrimental to the advancement and development for all students (Aguirre & Zavala, 2013), especially those from ethnically diverse or underrepresented backgrounds (Gay, 2000). Additional scholars, when educating novice mathematics teachers, have also utilized frameworks that augment PCK with CRP through integration of social justice and issues of power (Gutiérrez, 2009; Leonard, 2007; Rodríguez & Kitchen, 2005). Thusly, researchers have strongly advocated for educators to empower students to view mathematics as an analytical tool used to challenge inequities through a focus on social justice and civic responsibility (Aguirre, 2009; Gutiérrez, 2009; and Gutstein, 2006).

Gustein (2006) exemplifies this concept by sharing an example of students who examined the political actions and motivations grounded in racism associated with mortgage lending practices practice in the U.S. Moreover, Kitchen & Lear (2000) shared an example of students applying measurement related topics to explore societal messaging regarding body image. Varley-Gutierrez (2011) asked students to utilize multiplication and data analysis to challenge the district's decision about shutting down a local neighborhood school. Aguirre & Zavala (2013) explained that within all of these examples the teacher plays a critical role as the person designing and leading the social justice driven mathematical investigations that challenge power structures often experienced by culturally and linguistically diverse student populations.

> To summarize, culturally responsive mathematics teachers leverage mathematical learning by expanding children's mathematical thinking, building bridges between previous knowledge and new knowledge, supporting bilingualism and academic language development, fostering connections with cultural funds of knowledge and experiences and cultivating critical mathematical knowledge that enables students to analyze [sic] and address authentic problems. (Aguirre & Zavala, 2013, p. 168)

Over the years mathematics educators and scholars have made notable strides in integrating content with CRP through social justice issues and civic responsibility driven projects (see, Aguirre, 2009; Gutiérrez, 2009; Gutstein, 2006; Gutstein, Lipman, Hernandez, & de los Reyes, 1997; Ladson-Billings, 1997). However, science content continues to face challenges caused by practitioners reluctant enact CRP in the so called "hard sciences" that are often viewed as objective and free of cultural context (Boutte, Kelly-Jackson & Johnson, 2010). Still, there are ongoing efforts in place that are creating a shift in moving towards the integration of culturally responsive science instruction and ethnoscience (e.g., Lee & Buxton, 2008; Luykx & Lee, 2007; Roth & Tobin, 2007). Boutte et al (2010) explained that the lack of literature and models of CRP in science may be a result of low priority placed on science instruction in public schools (Wood & Lewthwaite, 2008). This ultimately results in a fact-driven classroom that is absent of instruction that accounts for the experiences and needs of culturally and linguistically diverse students (Boutte et al., 2010; Emdin, 2010; Lee & Luykx, 2005).

Serki (2016) also recognized the disparity of CRP in science. The author urged educators and scholars to place an increased focus on the integration of CRP in science content as it would help broaden participation of students of color in sciences: “Culturally relevant pedagogy fits in science education as a promising pedagogical approach that engages all students—not just a few elites” (Serki, 2016, p. 98). The author also offered two suggestions for science educators wishing to engage in CRP. First, the author advised that teachers practice critical self-reflection as described by Howard (2003) which allows for educators to reflect upon their own experiences around race, and privilege and consider how those experiences translate into their practices in the classroom. Second, Serki (2016) argued that for teachers to adopt a dispositional view of CRP as was advocated by Ladson-Billings (2006, 2012). Ladson Billings encouraged educators to view CRP as a way of being rather than a list of steps or strategies to follow. Thus, CRP is a philosophy of teaching that must be embodied rather than a prescribed strategy utilized sparingly or with specific populations only (Ladson-Billing, 2012).

As discussed by Parsons, Rhodes and Brown (2011) currently science education lacks inclusion of CRP which is at the detriment of students already marginalized and underrepresented by Western science (Aikenhead, 1996; Serki, 2016). Ryan (2008) argued that in the absence of culturally responsive science instruction we risk the omission of diverse worldviews and further validating hegemonic power structures. Boutte et al., (2010) explained the role of CRP in science by stating the following:

> Conceptually, culturally relevant science defies the assertion that there is a singular or normative scientific worldview. It recognizes that there is a wide range

> of scientific skills and ways of knowing that people display in their lived experiences within diverse communities. (p. 14).

Conclusion

It is evident through research that while there is a rise in the momentum for integration of CRP in mathematics and science, there is still much work left to be done (see, Aguirre, 2009; Gutiérrez, 2009; Gutstein, 2006; Lee & Buxton, 2008; Luykx & Lee, 2007; Roth & Tobin, 2007). As such, scholars continue to advocate for teachers and teacher educators to reform the practices of their classroom, so that we can move towards an inclusive system that works to ensure success of all students and not just some (see, Gay, 2002; Gutstein et al., 1997; Joseph, 1987; Ladson-Billings, 1997, 2002, 2012; Rousseau & Tate, 2003; Tate, 1995).

At the same time, research driven by ways to increase student interest and performance in mathematics and science, all the while fostering 21st Century skills, has argued for the inclusion of engineering design as a pedagogical practice (Apedeo et al., 2008; Hynes, 2010; Hynes & Dos Santos, 2007; Katehi et al., 2009; Koehler et al., 2005). A core feature of the engineering design process includes identifying a problem, one that scholars argue should be emulate real-world challenges (Apedoe et al., 2008; Crismond et al., 2006; Hynes, 2010). However, there is a lack of literature on the need for framing those problems through a culturally responsive lens. Furthermore, research on both CRP and EDP suggest that the teacher and teacher development is integral to any instructional reform (see, Aguirre & Zavala, 2013; Brophy et al., 2008; Jackson & Bryson, 2018; Lee & Stohlman, 2014; Roehrig et al., 2012; Siwatu, 2011). Nevertheless, there is a disparity within each construct on studies regarding teacher beliefs and teacher agency.

Thus, the findings from this research aim to spearhead further investigations and discussions on the power of culturally responsive engineering design instruction, as well as, the agency of teachers who are employing these practices. In doing so, this work also contributes to the literature on teacher agency, a developing field in teacher education research that is scarcely explored and reported upon (Cheng & Hong, 2018; Biesta et al., 2015; Vahasantanen, 2015).

CHAPTER III

METHODOLOGY

In chapter two the author discussed the theoretical underpinnings that guide the theoretical framework for this research. Figure 6 extends upon the framework by extracting the constructs of teacher beliefs and agency, and connecting them to the methods, date sources, and analysis techniques utilized in this research. Hence, this chapter provides the methodology employed to explore the research questions including discussion on the participants, data sources, data analysis, and ethical considerations.

Overview of Research Purpose and Design

Over the past several decades, the critical relationship between beliefs and instructional practices has been examined and discussed in teacher education research (e.g. Pajares, 1992; Prawat, 1992; Siwatu, 2007). Despite the value in exploring the implications of teacher beliefs, researchers have suggested to exercise caution provided that teachers may be giving answers they think the researcher wants to hear, as opposed, to how they actually feel (McAllister, 1999). Moreover, Paige (1993) explained that when it comes to conversations around culture, teachers may feel the pressure to provide answers that are perceived as politically correct, especially, if they feel concerned about their beliefs carrying racist or prejudicial connotations.

Consequently, this study is informed by previous research on teacher beliefs. The implications of said research points towards the need to examine teacher beliefs and agentic behaviors as they relate to the incorporation of new instructional practices. Specifically, the author of this study investigated secondary mathematics and science teachers' beliefs and sense of agency upon implementing instruction inclusive of culturally responsive pedagogy and the engineering design process. By exploring the core features of agentic behavior (Bandura, 2001), the author also gained insights regarding teachers' intentionality and forethought regarding future implementations. Additionally, the teachers self-reported the barriers encountered along the way, as well as, how they self-regulated in light of those challenges.

The author utilized a comparative multiple case study design (Merriam, 1998; Stake, 2006) using an embedded mixed methods approach (Creswell, 2014), allowing for the qualitative and quantitative data to be collected and analyzed concurrently. The data collected allowed for case analysis for each teacher along with cross-case analysis between the teachers (Stake, 2006). These cases represented experiences of the select secondary math and science teachers enrolled in a STEM Master's program at University of Houston, a Carnegie Tier One public research university in the greater Houston area of Texas. This exploratory, comparative, multiple case study addressed the following overarching research question:

> How, and in what ways, are secondary mathematics and science teacher pedagogical beliefs and sense of agency related to the integration of the engineering design process and culturally responsive pedagogy within their content curricula?

In an effort to inform the main research question, the study addresses the following subsidiary questions:

1. What are the pedagogical beliefs that secondary mathematics and science teachers self-report regarding EDP and CRP upon implementation of both constructs in the classroom?
2. How are the core features of Bandura's human agency (intentionality, forethought, self-reactiveness, and self-reflectiveness) of secondary mathematics

and science teachers shaped upon implementation of EDP and CRP in their classrooms?

3. How do secondary mathematics and science teachers describe the value of EDP and CRP as it relates to their classroom content?
4. What barriers do secondary mathematics and science teachers experience during implementation of CRP and EDP, and, how do they persevere in face of challenges?
5. How do secondary mathematics and science teachers perceive their own role in the movement to implement CRP and EDP in secondary science and mathematics curricula?

Table 3.1 provides a list of propositions derived from the main and subsidiary research questions along with the data sources and analysis methods. The data collected includes quantitative surveys for each construct, the engineering design process and culturally responsive pedagogy. These results were mixed with the qualitative findings obtained from reflective journals, interviews, teaching philosophy statements, and member checking. All the sources were triangulated within and across each case for cross-case analysis.

Table 3.1 List of propositions, data sources, and data analysis

Propositions	Data Sources	Data Analysis
Pedagogical beliefs about the Engineering Design Process (EDP) and Culturally Responsive Pedagogy (CRP)	Quantitative: CRTOE and DET surveys	Descriptive Analysis
	Qualitative: Reflective Journals; Interviews	Three rounds of content Analysis: first cycle (In Vivo), second cycle (In Vivo and Values), and third cycle (pattern) coding methods
Core of features Human agency: Intentionality Forethought Self-reactiveness Self-reflectiveness	Qualitative: Teaching Philosophy Statements; Interviews; Reflective Journals; Member Checking	Three rounds of content Analysis: first round (In Vivo coding), second round (In Vivo and Values coding), and third round (Pattern coding methods)
Perceived value of EDP and CRP in content area	Quantitative: CRTOE and DET surveys	Descriptive Analysis
	Qualitative: Reflective Journals; Interviews; Member Checking	Three rounds of content Analysis: first cycle (In Vivo), second cycle (In Vivo and descriptive), and third cycle (pattern) coding methods
Barriers encountered during implementation of EDP and CRP	Quantitative: DET survey	Descriptive Analysis
	Qualitative: Reflective Journals; Interviews; Member Checking	Content Analysis: Three rounds of content Analysis: first cycle (In Vivo), second cycle (In Vivo and descriptive), and third cycle (pattern) coding methods
Perceived role in implementation of EDP and CRP in content area	Teaching Philosophy Statements; Interviews; Reflective Journals; Member Checking	Three rounds of content Analysis: first cycle (In Vivo), second cycle (In Vivo and descriptive), and third cycle (pattern) coding methods

Research Methodology

A comparative multi-case study design (Merriam, 1998) that employs mixed methods of data collection (Creswell, 2008) was conducted to explore the research purpose described above. Each participant comprised an individual bounded case (Stake, 1983) and the data collected was analyzed and triangulated within and across each case. Quantitative results were obtained through surveys that provided insights regarding teacher beliefs on the constructs of the Engineering Design Process (EDP) and Culturally Responsive Pedagogy (CRP). These results were merged with the qualitative findings obtained through individual interviews, reflective journal responses, final projects, and member checking. A mixed methods approach for this investigation, thusly, corroborated the qualitative and quantitative data sets collected and analyzed simultaneously, to enhance the validity of the research (Creswell & Plano Clark, 2014).

Examining multiple cases was the most appropriate approach given the nature of the research which explored teachers' beliefs and agentic characteristics upon implementation of new instructional approaches. Stake (1995) stated that a case study research is interested in exploring the particulars of a case rather than focusing on generalizations. Gerring (2007) further supported this notion by explaining that case studies allow researchers to "peer into the box of causality to locate the intermediate factors lying between some structural cause and its purported effect" (Gerring, 2007, p. 45). Moreover, Yin (2003) supported the use of comparative case study design as having more than one case can allow for replication and extend theory development (see, Eisenhardt & Graebner, 2007). In addition to employing quantitative surveys, this investigation aims to gain in-depth and hands-on insights on the particulars of each teacher involved in the study through reflexive journals, and semi-structured interviews (Creswell, 2011; Yin, 2004).

In contrast to using either qualitative or quantitative approach solely, the data collected for this study was merged to attain an in-depth understanding of the research questions (Creswell & Plano Clark, 2018; Johnson, Onwuegbuzie, & Turner, 2007). Additionally, doing so helped provide insight of the cases and to make comparison among the cases. This approach is supported through the assertions of Teddlie and Tashakkori (2008) who explained that a mixed methods investigation allows for synthesis of qualitative and quantitative research questions through integrated themes which help guide research. Researchers have also expressed that using a mixed methods case study design is especially valuable when seeking insight into the complexities of a case (e.g., Luck, Jackson, & Usher, 2006; Plano Clark, & Ivankova, 2015). A convergent approach, first discussed by Jick (1979), also referred to as parallel study (Tashakkori & Teddie, 1998), collects both quantitative and qualitative data sources concurrently. The data is analyzed separately and merged together to provide a comprehensive understanding of the topic (Creswell & Plano Clark, 2018). Consequently, an embedded mixed methods multiple case study design with a parallel (Tashakkori & Teddlie, 1998) or convergent (Creswell, 2014) approach was employed to investigate the beliefs and agency of teachers upon implementation of instruction.

Establishing a Mixed Methods Worldview

Guba (1990) described the term worldview as a “set of beliefs that guide action” (p. 17). Accordingly, researchers utilize a philosophical worldview to inform their practice and investigations. In an effort to answer the research questions in this study a convergent mixed methods case study (Creswell, 2014) will be employed that consists of quantitative surveys and qualitative data acquired through analysis of lesson artifacts, reflexive journaling, and semi-structured interviews. Moreover, for the purpose of determining the worldview that best aligns with the intention of the study it is important to determine how the qualitative instruments will be utilized.

Pragmatism, according to Tashakkori and Teddlie (2003) is the optimal worldview and one that is embraced by several authors, including historical figures such as John Dewey, William James, and Charles Sanders Pierce (Creswell & Plano Clark, 2018). Furthermore, the authors suggested that pragmatism is a problem-centered worldview which is guided by the research questions rather than preference towards methodology.

> The focus is on the consequences of research, on the primary importance of the question rather the methods, and on the use multiple methods of data collection to inform the problems under study. Thus, it is pluralist and oriented toward “what works” and real-world practice. (Creswell & Plano Clark, 2018, p. 37).

According to pragmatism, the research question is the most important factor that helps determine the type of methodology best suited for research. Pragmatic researchers recognize that there are different worldviews that can be used to interpret and plan research (Saunders, Lewis & Thornhill, 2007). Thus, due to its all-encompassing nature, pragmatism is recommended for a study that is inclusive of both qualitative and quantitative data sets which are collected concurrently and merged together (Creswell & Plano Clark, 2018). As such, the author of this mixed-methods multiple case study utilized a pragmatic worldview to answer the research questions through analysis of qualitative findings and quantitative results.

Theoretical Lens

Several prominent researchers have utilized a constructivist view when exploring teachers' beliefs (e.g. Cochran-Smith & Lytle, 1995; Lipman, 1998; McAllister, 1999; Schofield, 1986). Through employing such a constructivist approach, researchers are able to place value on teaches' articulation and interpretation of their beliefs, as opposed to, using and limiting the findings to a predetermined inventory of beliefs (McAlister, 1999). As such, guided by a constructivist approach, the researcher and teachers work in collaboration to unravel the beliefs. Accordingly, the constructivist stance rooted in the approaches for conducting case studies shared by both Stake (1995) and Yin (2003) was the method employed for this multiple case study.

Creswell & Plano Clark (2014) also argued that for multiple mixed methods case study designs, the philosophical assumptions tend to foster a constructivist approach. A constructivist paradigm was the theoretical rationale for this research design given that it values the process with which humans create of meaning, while maintaining a sense of objectivity (Miller & Crabtree, 1999). Crabtree and Miller (1999) emphasized the advantage of using this approach as it fosters a collaborative relationship between the researcher and participants as they share their thoughts and stories. The qualitative component of a case study allows the researcher to explore a phenomenon within a given context through multiple sources for data collection (Baxter & Jack, 2008). Meanwhile, the quantitative instruments augment the insights gained allowing the investigator to ensure that the topic is examined through a variety of lenses yielding multiple facets of the phenomenon.

Stake (1985) and Yin (2003) provided key insights on guiding case study methodological approaches. Both researchers align their worldview with a constructivist paradigm. Social constructivists believe that individuals develop their subjective meanings of the environment through interactions with others, thus, the meanings and perceptions are complex and varied (Vygotsky, 1978). Social constructivism is associated with post-modern era qualitative research and is utilized especially in case research (Andrews, 2012). Through this approach individuals "react or behave according to their subjective and circumstantial perception of the reality around them" (Grimstad, 2013, p. 65). This further allows the researcher to utilize subjective descriptions of phenomena to derive meaning as it relates to development of knowledge, contribution towards theory and construction of meaning. (Grimstad, 2013; Creswell, 2003; Mackenzie & Knipe, 2006).

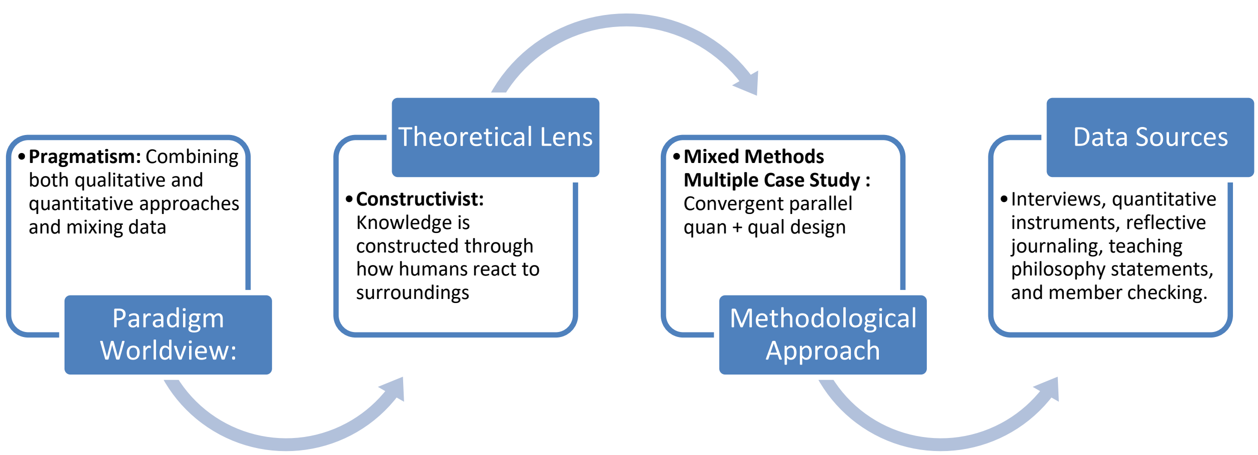

Figure 6. Four Levels of a Research Design (Adapted from Crotty, 1998)

Context of the Study

The LEAD Houston Fellowship

The participants in this study were selected from a cohort of 15 teacher leaders admitted into the National Science Foundation (NSF) funded fellowship at the University of Houston, Enhancing STEM Teacher Leadership Through Equity and Advocacy Development in Houston (also referred to as LEAD Houston). Provided that the data sources originate from the LEAD Houston program and that teacher beliefs and agency are shaped while participating in the fellowship, this section aims to describe the LEAD Houston fellowship. The author hopes that description below will provide the reader with insights regarding the participating teachers' motivation to improve the quality of their instruction. Moreover, the reader should also note the commitment demonstrated by the teachers by applying and moving forward through the five-year fellowship experience.

The LEAD Houston fellowship is designed to develop and retain secondary STEM teachers in high-needs districts through the cultivation of teacher-leadership skills. Selected teachers, also referred to as, Master Teacher Fellows (MTFs) are provided with the opportunity to engage in graduate level coursework, professional development, and mentoring of preservice teachers. Ultimately, the program aspires to build a cadre of STEM teacher-leaders in high-need Houston-area public school districts that are equipped to serve as change agents at the local, regional, and national level.

Funded through a National Science Foundation (NSF) Noyce Track 3 grant, the LEAD Houston fellowship goals include the following activities:

- Supporting 30 secondary STEM teachers over the span of two cohorts by funding tuition and fees of approximating $16,000 for a 14-month master's program in STEM Education with a specialized focus on culturally responsive pedagogy.
- Providing teachers annual stipends of $10,000 for each of the four years subsequent to completing the master's coursework.

- Supporting teachers through professional developments seminars on topics including culturally responsive pedagogy in STEM, instructional coaching, and policy advocacy.
- Prepare MTFs to assume leadership roles in advocating for culturally responsive pedagogy infused with effective pedagogies in STEM through facilitation of professional development, and, mentoring of both preservice teachers and in-service teachers.
- Collaborating with the National Math & Science Initiative (NMSI) to provide MTF's with STEM pedagogical content knowledge courses that MTFs will later infuse with culturally responsive teaching.

The program is designed to provide secondary mathematics and science classroom teachers with a 14-month, funded, master's degree in STEM education along with ongoing professional development on areas of teacher leadership and culturally responsive pedagogy (LEAD Houston, 2018). Candidates for the fellowship are expected to have at least three years of teaching experience and certification in the secondary mathematics or science content area. Thus, the selected Master Teacher Fellows (MTFs) further develop their pedagogical content knowledge (PCK) on STEM related topics, instructional strategies, and pedagogical approaches. This includes experience with engineering education, a discipline of STEM in which majority of mathematics and science teachers lack familiarity (Katehi et al., 2009).

Fundamentals of Engineering Design Course Scope and Sequence

Their first summer in the program, Master Teacher Fellows (MTFs) participate in two consecutive summer courses, the first of which introduces MTFs to research on culturally responsive pedagogy. The latter is a course titled, Fundamentals of Engineering Design which intends to provide MTFs with an introductory scope of engineering, and knowledge of the engineering design process. In addition to hands-on experiences, teachers are also provided with context on the nation's history of K-12 engineering education, including arguments for and against content standards for K-12 engineering education. The fundamentals of engineering design are addressed through a variety of engineering design-centric challenges including inventions and reverse engineering projects. The course culminates with a final curricular redesign project which allows teachers to implement the engineering design cycle in their K-12 math or science classrooms and is also aligned with the research-driven approaches in Culturally Responsive Pedagogy (CRP) in mathematics and science instruction

Week 1: Reverse Engineering and Product Redesign. Working in teams of three to four, teachers are asked to conduct interviews and surveys to generate a customer needs analysis for a commonly used product. The customer needs matrix is utilized to inform the implications for redesign. Teams sketch predicted internal structures of their products then disassemble the product and compare to their prediction. Functional models and activity diagrams are created to gain a deeper understanding of how the product functions.

Week 2: Intro to Engineering Education Literature and Culturally Responsive Teaching. Teachers are engaged in rich discussion surrounding research regarding the incorporation of culturally responsive teaching (CRT) in STEM classrooms. The need and gap in teaching through engineering design with CRT is also addressed as a platform for students to move forward in innovative practices and for STEM education reform.

Week 3: Invention Design Challenge. MTFs develop a prototype for an invention selected through guided brainstorming and working knowledge of scientific and mathematical concepts. Students will construct the prototype using a maker station of materials provided by the course instructor.

Week 4: Curricular Reverse Engineering and Redesign. During the final week of class, MTFs are encouraged to consider hands-on activities for the engineering design cycle in their current course curricula. Students are asked to develop and present preliminary plans for this project that can be embodied into a working lesson plan that is suitable for implementation in the fall.

Thus, the intervention experienced by the secondary mathematics and science teachers includes the coursework discussed above. This is followed by additional graduate coursework completed in conjunction with ongoing professional development. The process builds on the existing pedagogical content knowledge of teachers and challenges them to explore uncharted, or, less familiar instructional approaches. The final project for the engineering design course provides teachers with a lesson planning template that requires evidence for each of the core practices found in the engineering design cycle (see Figure 5). Teachers are also asked to self-evaluate their lessons with the six categories of the culturally responsive mathematics and science lesson analysis tool (Aguirre & Zavala, 2013).

Case Selection

This LEADHouston fellowship program is funded by the National Science Foundation (NSF). The 14-month graduate coursework is part of the five-year fellowship commitment (LEAD Houston, 2018). The admission requirements placed by NSF include three or more years of teaching experience in secondary math or science at a high-need school district, as well as, certification in secondary math and science. The grant team considered the following attributes for selection in order to identify exemplary teachers in high-need school districts: leadership positions held by the teacher, including but, not limited to, serving in the capacity of content team-lead, department chair, and curriculum writing. The team also considered the following: past experience with leading professional development in the school/ district; and participation in professional development opportunities that extend beyond the minimum annual requirement set by the school, state and district.

Cases for this research were selected through purposeful sampling based on the responses acquired from the recruitment for study. The teachers recruited for this multiple comparative case study have completed coursework on topics of engineering education and culturally responsive pedagogy through enrollment in a master's degree in Curriculum and Instruction with a STEM emphasis at the University of Houston. In addition to the number of participants and requirements enforced for enrollment by the program, each case study is also bounded (Stake, 1983) due to the time-constraints of the school year. Of the 15 teachers enrolled in the fellowship program and recruited for the study, nine expressed interest in participation. The author purposefully selected five on the basis of their certainty to implement the lessons or projects that address their course standards through engineering design practices, and, are grounded in culturally responsive pedagogy. As part of their commitment to the study, teachers were asked to participate in interviews, reflective journaling, and surveys.

Data Collection

Qualitative Data Collection

Reflective journaling. Each teacher was provided with reflective journal prompts that aligned to the research questions and the responses were triangulated along with other data sources to help inform the study. Reflective journals are utilized in research to provide participants and researchers with an avenue for expressing thoughts and narrating experiences (Connelly & Clandinin, 1990). In the context of teacher education, reflective journaling strengthens relationships between the instructor and trainee (Bashan & Holsbat, 2017), and, improves the learning process of teaching candidates (Moon, 2006). According to Farabaugh (2007) reflective journaling promotes awareness of the process through recording thoughts and feelings associated with each aspect of the learning process. Moreover, journaling allows the learner to connect theory with practice (Dyment and O’Connell, 2011).

Each reflection journal prompt utilized with the teacher participants was expected to take approximately 10-15 minutes to answer. Thus, teachers were asked to spend an estimated 100-150 minutes to complete the ten short answer journal prompts. These entries were completed following the implementation of the instructional module inclusive of culturally responsive pedagogy (CRP) and the engineering design process (EDP).

Interviews. In addition to reflective journaling, the data collected was also triangulated with the findings attained through semi-structured individual interviews. The interview responses helped provide additional, and integral, insights during the data analysis. Semi-structured interviews help provide a naturalistic environment that enables interviewees to openly discuss their thoughts and ideas (Krueger & Casey, 2000). Furthermore, unlike the generalizations caused by only using surveys, interviews yield insights into human behavior and perceptions (Fern, 2001). Thus, Crotty (1998) suggested that researchers use open-ended questions which provide participants the opportunity to share and discuss their perceptions while the researcher interprets the views expressed. The interviews lasted approximately one hour and took place after the teachers completed their reflective journal prompts and surveys. Doing so allowed the author to strategically pose interview questions guided by the responses obtained through the other data sources.

In an effort to appropriately conduct the interview research, the author utilized the interview protocol refinement (IPR) framework (Castillo-Montoya, 2016). The IPR framework is designed to provide researchers with a set of rigorous steps that help strengthen the reliability of their interview protocols, see Table 3.2.

Table 3.2 Four Steps to Interview Protocol Refinement (IPR)

Step #	Protocol Action
1	Alignment of interview questions with research questions
2	Developing an inquiry-based dialogue
3	Acquiring feedback on the interview protocol
4	Piloting the interview protocol

Source: Adapted from Castillo-Montoya, 2016

The first step of the IPR was ensured through mapping of the interview questions on a matrix that included the key constructs of the operationalized framework which guide research agenda. A few additional questions were added to obtain background information regarding the participants' school setting. Table 3.3 includes a sample of the interview questions with cells marked to indicate which construct of the research is being addressed through each question (Neumann, 2008). The next phase of the framework suggests that the researcher construct an inquiry-driven conversation with the interviewees. Maxwell (2013) explained that this entails composing the interview questions differently than the research questions. "Your research questions formulate what you want to understand; your interview questions are what you ask people to gain that understanding" (Maxwell, 2013, p. 101). Thus, the author of this study utilized everyday language of the interviewees in the questions, and avoided the theoretical language often utilized in writing research questions (Brinkmann & Kvale, 2015). Moreover, to conduct a conversational dialogue that still maintains the goals of the research, the author utilized four types of interview questions recommended by researchers: 1) introductory; 2) transitional; 3) key or integral; and 4) closing questions (Castillo-Montoya, 2016 Creswell, 2007; Krueger & Casey, 2009; Merriam, 2009).

The third phase ensures that reliability and trustworthiness of the interview protocol is strengthened by obtaining feedback. This was provided by the author's dissertation committee members, as well as, an additional mixed-methods researcher who is involved with the NSF grant that funds the LEAD Houston fellowship. For the fourth and final phase, a pilot interview was conducted with an educator not associated with the LEAD Houston fellowship only in an effort to "try out" the research questions and instrument (Baker, 1994). This is an integral phase in the protocol because as explained by Merriam (2009) the “best way to tell whether the order of your questions works or not is to try it out in a pilot interview” (p. 104). Still, while the pilot was not conducted with a group of participants or someone associated with the fellowship, it is important to note that according to Castillo-Montoya (2016) many researchers may only be able to carry out the first three phases of the framework. The author explained that this may be due to a lack of access to resources, time, or willing participants, nevertheless, “those researchers have taken important steps to increase the reliability of their interview protocol as a research instrument and can speak to that effort in their IRB applications as well as any presentations or publications that may result from their research” (p. 827). Consequently, this research utilized IPR framework to develop interview questions that elicit insightful responses with strategic alignment to the research purpose, and, are conducted through a protocol that strengthens the reliability and trustworthiness of the research.

Table 3.1 Sample Excerpt from Interview Matrix

INTERVIEW QUESTION	BACKGROUND INFORMATION	TEACHER AGENCY	TEACHER BELIEFS
Transition Statement: *I’d like to begin the interview by first asking you some questions regarding your school and/or district.*			
Q1. Can you describe your school setting for me?	X		
Q2. How long have you been teaching at this school/district?	X		
Transition Statement: *Great. Next, I’d like to discuss your perceptions about the constructs of engineering design process (which I will abbreviate as EDP) and culturally responsive pedagogy (which I will abbreviate as CRP).*			
In your reflection journal you described how you used EDP to augment your project by <*insert description*> Q3a. How do you define EDP in your classroom context? Q3b. How did the infusion of EDP change this project?			X
Q3c. Do you see room for infusing EDP pedagogy in other curricular projects you are currently using?		X	

Table 3.1. Continued

INTERVIEW QUESTION	BACKGROUND INFORMATION	TEACHER AGENCY	TEACHER BELIEFS
In the reflection journal, you described how you used CRP to augment your project *by <insert description>* Q4a. How do you define CRP in your classroom context? Q4b. How did the infusion of CRP change this project? Q4c. Do you see room for infusing CRP pedagogy in other curricular projects you are currently using?		X	X
Q5. What connection/s have you made between EDP and CRP? Please describe the connections you see or lack thereof.			X

Source: Adapted from Castillo-Montoya, 2016

Teaching Philosophy Statements

In addition to interviews and reflection journals, the participants also provided their philosophy statements. These statements generated an additional self-reported data source that gave insights regarding the teachers' agency, along with, how they perceive their role in educational reform. The statements were analyzed for content, and, merged with other qualitative findings. The author utilized the specifics from the teaching philosophies to align with the teachers' reflections and reactions to the implementation of new instructional practices. Thus, their philosophy on teaching helped support, and explain, their agentic behaviors and beliefs.

Member Checking

Member checking can take place at different points in data collection and can often include sending the transcript of an interview to the participants (Doyle, 2007). The approach utilized in this research provides the participants with a more involved role in the process of telling their story. Member checking through synthesis of analyzed data (Harvey, 2015) allows participants to read through the researcher's interpretations of their statements. In this case, the interpretations include results and findings from surveys, interviews, reflection journals, and teaching philosophy statements. As explained by Brit, Scott, Cavers, Campbell, and Walter (2016), "if studies are undertaken to understand experiences and behaviors and to potentially change practice, then surely participants should still be able to see their experiences within the final results" (p. 1805). This approach also compliments a constructivist approach for data analysis as it allows the participants to reflect upon their own responses and stories while having the opportunity to add more data. Moreover, the transparency involved helps further validate the findings and minimize researcher bias in interpretation (Brit et al., 2016; Doyle, 2007).

Quantitative Data Collection

DET Survey. In an effort to investigate the beliefs teachers hold regarding EDP the participants were asked to complete the quantitative Design, Engineering, and Technology (DET) survey. In 2006, Yasar et al. developed a quantitative instrument to assess the perceptions K-12 teachers hold regarding teaching with design, engineering and technology (DET). This survey has frequently been utilized in engineering teacher education research in an effort to assess perceptions and familiarity with teaching engineering design concepts (Yoon et al, 2013). The DET survey was measured for validity and reliability by the authors in the original study conducted with 98 science teachers throughout the state of Arizona (Yasar et al, 2006). The authors explained that the combination of the design, engineering, and technology approaches allow for "conceiving, building, maintaining, and disposing of useful objects and/or processes in the human-built world." (Yasar et al., 2006, p. 205). The authors further related their definition of technology to that established by the national science standards. As such, DET was defined to include the following characteristics which also mirror the practices outlined by the Massachusetts DOE (2006) along with other prominent engineering design process (EDP) models:

> identify a problem or a need to improve on current technology; 2) propose a problem solution; 3) identify the costs and benefits of solutions; 4) select the best solution from among several proposed choices by comparing a given solution to the criteria it was designed to meet; 5) implement a solution by building a model or a simulation; and 6) communicate the problem, the process, and the solution in various ways. (p. 205).

CRTOE survey. For the purpose of examining teacher beliefs regarding culturally responsive pedagogy (CRP) the study utilized the Culturally Responsive Teaching Outcome Expectancy (CRTOE) Scale (Siwatu, 2007). As is true for the theoretical foundation of this research, Siwatu (2007) was also guided by Bandura's (1977, 1986) theoretical lens of Social Cognitive Theory. The author differentiated between the self-efficacy and outcome expectancy scale, the latter of which is used for this study, by explaining that outcome expectations "are individual judgments about the potential outcomes of their behaviors" (Siwatu, 2007, p. 1088). Siwatu (2006) asserted that the competencies selected for the instruments are rooted in literature that reflects the voices of practitioners and pioneers in research who have advocated for the culturally sensitive and relevant teaching practices that associated closely with a culturally responsive pedagogical approach. The author noted that these instruments were developed due to shortage of scales that measure preservice or practicing teacher beliefs regarding CRP.

> Despite the changing demographics of today's schoolchildren, little research has been done to examine preservice and inservice teachers' culturally responsive teaching self-efficacy and outcome expectancy beliefs. The development of the CRTSE and CRTOE would allow for these needed inquiries. (p. 1089).

Both surveys were administered upon teachers completing their lessons infused with EDP and CRP. These results were merged with the qualitative findings obtained through reflective journal prompts, interviews, teaching philosophy statements, and member checking responses. All of the data collected was ultimately analyzed within and across the cases.

Data Analysis

This exploratory, comparative multiple case study (Stake,) utilized a mixed methods concurrent triangulation design (Creswell, 2003; Creswell & Plano Clark, 2007), thereby, collecting and analyzing the quantitative and qualitative data concomitantly within and across the cases. The triangulation design is the most commonly used approach in mixed methods research as it allows the investigator to "to obtain different but complementary data on the same topic" (Morse, 1991, p. 122), thus, achieving a deeper understanding of the topic or problem. The convergent model of triangulation design (Creswell, 1999) allowed the researcher to compare results derived from quantitative and qualitative approaches in order to validate, confirm, and corroborate the qualitative findings and with quantitative results (Creswell, 2006).

The author examined teacher beliefs regarding the implementation of the engineering design process (EDP) and culturally responsive pedagogy (CRP) through multiple lenses and further verify the findings across the cases (Creswell, 2013). Consequently, this research employed the mixed methods triangulation approach to corroborate participants' survey results (quantitative) with interview transcripts, reflective journal responses, teaching philosophy statements (qualitative) to better understand the beliefs and agency of secondary mathematics and science teachers upon implementing EDP and CRP in their content instruction.

This research utilized an inductive approach (Saldaña, 2013) for coding that minimized researcher bias through search for prescribed themes, and instead allowed for an exploratory study that allowed the participants to drive the findings. All the qualitative data sources, (interviews, reflection journals, and teaching philosophy statements) underwent three rounds of coding in an effort to establish rigor in the analysis, and, thoroughly derive the emerging themes. The first round involved In Vivo coding which is at times referred to as “natural” or “emic” coding, implying that it involves the inductive approach for coding verbatim terms or phrases used by the participant. Saldaña (2013) explained that this approach is most appropriate when the study prioritizes and participants voice in the data analysis process.

The second round of coding utilized both In Vivo and Values coding methods. Values coding is described by Saldaña (2013) as “the application of codes to qualitative data that reflect a participants’ values, attitudes, and beliefs, representing his or her perspectives or worldview. Though each construct has a different meaning, values coding, as a term, subsumes all three” (p.131). Values coding was appropriate for this research not only because it focuses on an individual’s beliefs, a pivotal feature of this research, but, also, because it is recommended for case studies. Furthermore, values coding when applied to multiple data sources, as is done in this research, helps corroborate the coding and strengthen trustworthiness (LeCompte, Pressle, 1993; Saldaña, 2013). Finally, the third and final round of coding utilized a second cycle coding method, Pattern Coding. Second cycle coding allows researchers to “reorganize and reanalyze the data coded through first cycle methods" (Saldaña, 2013, p. 234). Specifically, Pattern coding is utilized to "meta code" or group similarly identifies codes, while, also, ascribing meaning to the newly organized categories or emergent themes. Thus, Pattern codes combine the data from first cycle coding and synthesizes it into more meaningful units of analysis (Miles et al., 2014; Saldaña, 2013).

The quantitative data analysis consisted of utilizing the descriptive data collected through surveys. In addition to the survey responses, this includes teachers' demographical information such as: gender, age, race, number of years of teaching experience, certification, secondary grade level, and content area. If deemed necessary, these factors may result in categorical variables to test for differences across groups. Moreover, descriptive statistics for the schools in which each participant taught is also presented which includes demographical data of student population and mobility rates. The descriptive data was triangulated with the qualitative findings for analysis within and across each case.

Trustworthiness

The process of ensuring trustworthiness is a vital component of naturalistic, qualitative studies. Trustworthiness demands assurance for validity and reliability in qualitative research. During the analysis of qualitative data sources, the researcher serves as an instrument for analysis which includes coding data and identifying themes (Norwell, Norris, White, & Moules, 2017). Consequently, Lincoln and Guba (1985) provided researchers with a series of techniques that can be used for ensuring trustworthiness which include the factors described below for credibility, transferability, dependability and confirmability.

Credibility. In an effort to explore the research questions which guide this study, the author conducted surveys, interviews, provided teachers with reflective journaling prompts, and collected teaching philosophy statements. As such, through data collected from multiple sources the findings were triangulated (Lincoln & Guba, 1985) within and across each case (Creswell, 2017). Moreover, member checking of synthesized findings was conducted as an additional and final data source. This process allowed the participants to provide additional insights, clarify statements, and corroborate the researcher's interpretations.

Transferability. The author utilized thick descriptions to describe the overall research process in an effort to achieve external validity (Lincoln & Guba, 1985). Thick descriptions entail providing detailed accounts of the research procedures applied to acquire data and analyze findings (Holloway, 1997). The descriptions recorded in the methodology and findings of this research were rich in details regarding the procedures used for analysis. The author provided thick descriptions so that the research design may be transferable to other settings similar to those described in the context of this multiple case study.

Dependability and Confirmability. All of the documents pertaining to the study and participants were stored securely. These documents can be available for potential external audits that aim to verify the validity of the research conducted. The author also kept a codebook which entails all of the individual codes associated with emergent themes for each and patterns identified across the cases. Additionally, the descriptive statistics acquired from the quantitative surveys helped corroborate and support the qualitative findings. Thus, the results served as points for triangulation to help answer the research questions and support cross-case analysis.

Role of Researcher

As a primary recipient and interpreter of the data collected for this research, I continuously seek to enhance my knowledge about teacher beliefs, teacher agency. I am particularly interested in how teachers respond to the two pedagogical approaches investigated in this research, the Engineering Design Process (EDP) and Culturally Responsive Pedagogy (CRP). Throughout the process I was concerned with minimizing bias in my data collection and analysis. I was especially concerned about researcher biases because of my close relationships with LEAD Houston fellowship participants. I am a Co-Principal Investigator on the NSF grant that funds the fellowship and was an integral part of writing the grant proposal. Therefore, I have personally invested myself in the vision, as well as, the outcomes associated with the project. Moreover, I am the instructor of the Fundamentals of Engineering Design Course that all Master Teacher Fellows (MTFs) must complete as part of the master's program requirements. During this research process I worked carefully with my committee chair to ensure that the study did not evaluate the course effectiveness or assess participants' instructional abilities upon completing the course. Furthermore, all the recruitment and data collection took place after the participants had already obtained a final grade for the course.

Provided that I had an established rapport with the participants, my professional relationships may have influenced the results of their interview responses. As one of their previous instructors, it is possible that the participants shared answers they believed I wanted to hear. The MTFs and I often engaged in conversations outside of the study through other grant related activities, and, thus, an open dialogue of communication pre-existed when it was time to conduct the interview or collect other forms of data for the research. However, the rapport with the participants may have benefited the research by putting the teachers at ease by lessening their hesitancy and allowing them to openly discuss their thoughts and ideas during the interview. Additionally, throughout the research process and during data collection, I made note of any biases I may have felt and biases that may have influenced the analysis of data collected. These notes were helpful to keep and reflect upon as time went on because they helped me make any necessary adjustments, and further refine the research questions.

Assumptions

This dissertation study was conducted by the researcher with the acknowledgement of a few assumptions. The first assumption is that the responses collected through surveys, interviews, and reflective journals were provided truthfully and are representative of the teachers' perceptions at the time of data collection. Additionally, it is assumed that those who volunteered to participate in the study did so with the intention of informing practices of the program and to deepen the understanding about the topics that were investigated. The teachers committed to the fellowship in an effort to improve upon their instructional practices and work towards STEM education reform. As such, they are invested in the successful implementation of the pedagogical approaches introduced during through the fellowship experience. Lastly, the self-reported demographic information by study participants is assumed to be accurate and reflective of the individuals' background.

Delimitations of the Study

Due to the bounded nature associated with case studies (Yin, 2003) certain parameters were drawn by the author during the planning and conduction of this study. Specifically, participants were selected from a pool of teachers enrolled in a National Science Foundation (NSF) funded STEM teacher fellowship program. The program commitment entails ongoing professional development for four additional years following a 14-month master's degree in STEM education. Therefore, as guided by the fellowship selection criteria, the participants were secondary mathematics and science teachers with a minimum of three years of teaching experience. Additionally, as required by NSF, all of the teachers served in high-need school districts in the Greater Houston Area. This research followed teachers after they have successfully completed an introductory course on the fundamentals of engineering design, which concluded with the teachers designing a lesson or unit that integrates their mathematics or science content with the principles of engineering design and culturally responsive pedagogy.

The findings discussed in this study provide minimal insight into the beliefs held by elementary teachers or those who reside in communities vastly different than the diverse and predominantly urban classrooms of Houston, TX. Moreover, it is important to the note that these findings are reflective of teachers who sought and earned enrollment in a highly competitive NSF funded fellowship for secondary STEM teacher leaders. Still, it is critical explore the challenges encountered by teachers who demonstrate the initiative to improve their instructional practices and embody innovative pedological approaches. The hurdles encountered by these motivated teachers along with how they faced the challenges provide an understanding of how teachers respond to the incorporation the engineering design process and culturally responsive pedagogy.

Limitations of the Study

This research only recruited teachers from high-need public school districts in the Greater Houston Area who, at the time of the study, were also enrolled in a Master's in STEM education. As such, this convenience sample limits the generalizability of the findings shared in this research. Moreover, this mixed-methods study allowed teachers to self-report their beliefs regarding the integration of the engineering design process and culturally responsive instruction. Self-report measures are limiting given the nature of biases which may influence the responses collected (Gall, Gall, & Borg, 2007). Additionally, the participants featured in this research teach at different schools, different grade levels, and, therefore, have different teaching experiences. The variations in school demographics combined with differences in age, race, and years of teaching experience, are all possible factors that may have further influenced the way in which each participant interpreted the questions posed through the surveys, interviews, and reflective journal prompts.

CHAPTER IV

FINDINGS

This study examined the beliefs held by teachers regarding the intersection of the engineering design process (EDP) and culturally responsive pedagogy (CRP) upon implementation in their secondary mathematics or science content classroom. Additionally, the research also investigated how the incorporation of these pedagogical approaches shaped the core characteristics of agency for teachers. In doing so the author focused upon the four categories of agentic behaviors identified by Bandura (2001): intentionality; forethought; self-reactiveness; and self-reflectiveness. The first two categories provided insights on the teachers' willingness and plans for action for enactment of future projects, lessons, and activities that include EDP and CRP. Meanwhile, self-reactiveness examined how teachers persevered in the face of challenges they encountered during implementation. For the final category of self-reflection, the author asked teachers to reflect upon their overall experience with the implementation. Teachers also discussed their perceived role in the movement to reform STEM content curricula with the inclusion of EDP and CRP.

Thus, through exploration of beliefs and agency, the author uncovered the barriers teachers encountered, and, the perceived value teachers hold regarding EDP and CRP upon implementation. The findings also revealed the likelihood for continual enactment of instruction inclusive of EDP and CRP. Below listed is the primary research question, along with the subsidiary research questions that inform this research:

RQ 1. How, and in what ways, are secondary mathematics and science teacher pedagogical beliefs and sense of agency related to the integration of the engineering design process and culturally responsive pedagogy within their content curricula?

RQ 1a. What are the pedagogical beliefs that secondary mathematics and science teachers self-report regarding EDP and CRP upon implementation of both constructs in the classroom?

RQ 1b. How are the core features of Bandura's human agency (intentionality, forethought, self-reactiveness, and self-reflectiveness) of secondary mathematics and science teachers shaped upon implementation of EDP and CRP in their classrooms?

RQ 1c. How do secondary mathematics and science teachers describe the value of EDP and CRP as it relates to their classroom content?

RQ 1d. What barriers do secondary mathematics and science teachers experience during implementation of CRP and EDP, and, how do they persevere in face of challenges?

RQ 1e. How do secondary mathematics and science teachers perceive their own role in the movement to implement CRP and EDP in secondary science and mathematics curricula?

Data was collected through the interviews, reflective journals entries, teaching philosophy statements, and member checking. Additionally, surveys specific to beliefs about EDP and CRP were also administered. The qualitative findings were mixed with quantitative results, and comparisons were drawn across the cases to discuss patterns in emerging themes and potential causes for variance among teachers. Coding was conducted through the qualitative data analysis software, QSR International's NVivo 12 plus Software. Nvivo software allows for researchers to conduct unstructured qualitative research that assists in the data analysis of qualitative findings. NVivo is a query tool through which the researcher codes significant pieces of data into ‘containers’ called *nodes* (QSR International, 2019). For this research, NVivo was used to manage the qualitative data from teacher philosophy statements, reflective journal entries, and interview transcripts. Through NVivo, the data was coded, and emergent themes were categorized for each case. After themes were coded they were analyzed for identification of overarching patterns across the cases. In an effort to the answer the main and subsidiary research questions, emergent themes were specifically explored for teachers’ beliefs regarding the pedagogical constructs of EDP and CRP. Moreover, the four categories of human agency, as defined by Bandura (2001), were also examined.

For the purposes of this study, the author followed Saldaña’s (2013) method for first and second cycle coding. The first cycle was inclusive of two rounds of coding: In Vivo and Values respectively. The thematic coding was followed by meta Pattern coding across all five cases for cross-case analysis. As such, the research utilized the *Code In Vivo* feature of the Nvivo software (QSR International, 2019). Through this feature the researcher identified noteworthy statements. The coded statements were later categorized in emergent themes for each case. Value coding was also performed to code for sentiments and beliefs expressed by the teachers, as is recommended by Saldaña (2013) for case study research. Once the emergent themes were identified for each case, derived through In Vivo and Value coding, all the nodes were then analyzed to identify meta patterns (Saldaña, 2013) during cross-case analysis.

The five case studies are presented in this chapter with an introductory profile for each teacher. The profiles include the teachers’ self-reported demographical characteristics and professional background, along with school demographics. Each case includes an introductory teacher profile followed by the emerging themes which are listed under the categories of pedagogical beliefs. Emergent themes were also categorized under the four types of agentic behaviors described by Bandura (2001). During the cross-case analysis, the qualitative findings and quantitative results were mixed to describe the two core components of the research question, teachers' beliefs and agency.

All participating teacher names were changed to pseudonyms. Additionally, the quotes utilized in this chapter were derived from one of the following data sources: teaching philosophy statements, interview transcripts, and reflective journal entries. Each of these sources is referenced alongside the quote with the teacher's pseudonym and the abbreviated data source placed in brackets: teaching philosophy statements [tps], interview [int], and reflective journal entries [rje]. For example, a quote taken from David' interview is referenced as such, [David, int]. While some statements were paraphrased to explain the findings, the overall meaning of the quotes was not compromised.

The findings in this chapter begin with an introduction of the demographics of the teacher participants, followed by quantitative results from the surveys utilized in this research. Next, each participating teacher's case is presented with an introductory teacher profile and emergent themes derived from the qualitative data sources. Individual case discussion is followed by a cross-case analysis that is inclusive of the meta-patterns identified across the emergent themes from all participants. The chapter concludes with a summary of the most significant findings.

Descriptive Analysis

The five identified cases consisted of teachers with experience ranging from six to thirteen years in the classroom, as shown in Table 4.1. Four of the participants are science teachers while one teaches mathematics. Moreover, three of the participants are middle school teachers and two teach high school. Three of the teacher participants have bachelor's degrees in their content area while the other two have background in education or interdisciplinary studies.

Table 4.1 Teacher Participants' Educational Profiles

Teacher	Number of years teaching	Grade level	Content area	Bachelor's degree
Ashley	9	6-8	Science	Interdisciplinary Studies
Michelle	4	6-8	Science	Biological Sciences
Sophia	11	9-12	Mathematics	Mathematics
David	6	9-12	Science	Kinesiology
Karen	13	6-8	Science	Education

Source: Educational profile data was collected from survey and interview responses.

Of the five cases included in this study, four teachers identified as female. Three participants identified as Hispanic, while the other two identified as Non-Hispanic/White. Table 4.2 shows the combinations of gender and race/ethnicity included in this study.

Table 4.2 Self-reported Teacher Demographics

Teacher	Gender	Self-identified race or ethnicity
Ashley	Female	Hispanic
Michelle	Female	Hispanic
Sophia	Female	Non-Hispanic/ White
David	Male	Hispanic
Karen	Female	Non-Hispanic/ White

Source: Data reported was collected from demographical survey questions.

Table 4.3 shows the characteristics of the schools and districts in which the five participants are currently teaching. All, with the exception of one, teacher participants work for schools with over 40% of the student population classified as economically disadvantaged. These schools also house over 50% of students identified as part of minority populations.

Table 4.3 Teachers' School Characteristics

Teacher	School Type	School Minority Pct.	School Eco Dis. Pct.	District Minority Pct.	District Eco Dis. Pct
Ashley	6-8	59.0%	49.4%	67.0%	56.0%
Michelle	6-8	96.2%	82.5%	67.0%	56.0%
Sophia	9-12	78.1%	97.6%	94.4%	80.3%
David	9-12	75%	46%	78.4%	77.1%
Karen	6-8	32.1%	7.9%	48.2%	28.8%

Note. Pct. = Percentage of total. Eco Dis.= Economically Disadvantaged.
Source: All data is reported by schools to government based on the 2015-2016 school year, and accessed through U.S. News & World Report, 2019.

Culturally Responsive Teaching Outcome Expectations (CRTOE). The CROTE survey is designed to provide insight on the set of beliefs that teachers hold about the positive outcomes associated with culturally responsive teaching practices. The survey is a self-reported measure whereupon teachers rate the possibility of positive student outcomes achieved through 26 culturally responsive instructional techniques. The teachers rate each strategy on a scale from zero which is indicative of "entirely uncertain" to 100 which implies "entirely certain." Siwatu (2007) developed the survey and described the items as a measure of, "teachers' beliefs that engaging in culturally responsive teaching practices will have positive classroom and teaching outcomes." (p. 1090). Therefore, high scores on the CRTOE scale reflect greater beliefs associated with positive outcomes that result from culturally responsive instruction. Tables 4.4 provides the descriptive statistics each item on the CRTOE survey. Additionally, Table 4.5 includes the participating teachers' overall scores and mean values. The CROTE scores for teachers in this research ranged from 2330 to 2595 out of a maximum possible score of 2600. The teachers had a mean (M) score of 2532.60 and standard deviation (SD) was 273.72. The item that yielded the highest level of positive teaching outcomes expectation was for the possibility that “students’ self-esteem can be enhanced when their cultural background is valued by the teacher” (M=98.40; SD=2.06). Teachers also expressed high levels of outcome expectancy for the following possibilities: “students’ academic achievement will increase when they are provided with unbiased access to the necessary learning resources.” (M=98.20; SD=1.94); “providing English Language Learners with visual aids will enhance their understanding of assignments. (M=98.20; SD=2.23); “connecting my students’ prior knowledge with new incoming information will lead to deeper learning” (M=98.20; SD=1.83); “a positive teacher-student relationship can be established by building a sense of trust in my students” (M=98.20; SD=1.83). The last statement was also the highest scored item for Siwatu (2007) who developed the survey and measured the beliefs of 275 preservice teachers. Meanwhile, the teachers’ CRTOE beliefs were lowest for the possibility that, “simplifying the language used during the presentation will enhance English Language Learners’ comprehension of the lesson” (M=84.40; SD= 15.47). This was also the item with the highest level of standard deviation with a minimum score of 65 and the maximum score of 100. The next lowest scored item for outcome expectancy was, “matching instruction to the students’ learning preferences will enhance their learning” (M=88; SD: 10.18).

Table 4.4 Means (M) and Standard Deviations (SD) for items on the CRTOE survey

Outcome Expectancy Inventory Items	*M*	*SD*	*Max*	*Min*
1. A positive teacher-student relationship can be established by building a sense of trust in my students.	98.20	1.83	100.00	95.00
2. Incorporating a variety of teaching methods will help my students to be successful.	93.00	6.03	100.00	85.00
3. Students will be successful when instruction is adapted to meet their needs.	94.40	5.04	100.00	85.00
4. Developing a community of learners when my class consists of students from diverse cultural backgrounds will promote positive interactions between students.	97.80	3.92	100.00	90.00
5. Acknowledging the ways that the school culture is different from my students' home culture will minimize the likelihood of discipline problems.	95.80	4.40	100.00	90.00
6. Understanding the communication preferences of my students will decrease the likelihood of student-teacher communication problems.	94.40	5.57	100.00	86.00
7. Connecting my students' prior knowledge with new incoming information will lead to deeper learning.	98.20	1.83	100.00	95.00
8. Matching instruction to the students' learning preferences will enhance their learning.	88.00	10.18	100.00	72.00
9. Revising instructional material to include a better representation of the students' cultural group will foster positive self-images.	96.80	4.12	100.00	90.00
10. Providing English Language Learners with visual aids will enhance their understanding of assignments.	98.20	2.23	100.00	95.00
11. Students will develop an appreciation for their culture when they are taught about the contributions their culture has made over time.	94.20	4.58	100.00	88.00
12. Conveying the message that parents are an important part of the classroom will increase parent participation.	95.40	3.77	100.00	90.00
13. The likelihood of student-teacher misunderstandings decreases when my students' cultural background is understood.	94.40	5.00	100.00	85.00
14. Changing the structure of the classroom so that it is compatible with my students' home culture will increase their motivation to come to class.	95.20	5.34	100.00	85.00
15. Establishing positive home-school relations will increase parental involvement.	95.60	5.54	100.00	85.00
16. Student attendance will increase when a personal relationship between the teacher and students has been developed.	93.20	6.11	100.00	83.00
17. Assessing student learning using a variety of assessment procedures will provide a better picture of what they have learned.	97.00	4.00	100.00	90.00

Table 4.4. Continued

Outcome Expectancy Inventory Items	*M*	*SD*	*Max*	*Min*
18. Using my students' interests when designing instruction will increase their motivation to learn.	96.00	5.62	100.00	85.00
19. Simplifying the language used during the presentation will enhance English Language Learners' comprehension of the lesson.	84.40	15.47	100.00	65.00
20. The frequency that students' abilities are misdiagnosed will decrease when their standardized test scores are interpreted with caution.	96.20	4.07	100.00	89.00
21. Encouraging students to use their native language will help to maintain students' cultural identity.	93.20	6.40	100.00	81.00
22. Students' self-esteem can be enhanced when their cultural background is valued by the teacher.	98.40	2.06	100.00	95.00
23. Helping students from diverse cultural backgrounds succeed in school will increase their confidence in their academic ability.	96.80	3.71	100.00	90.00
24. Students' academic achievement will increase when they are provided with unbiased access to the necessary learning resources.	98.20	1.94	100.00	95.00
25. Using culturally familiar examples will make learning new concepts easier.	95.80	5.60	100.00	85.00
26. When students see themselves in the pictures that are displayed in the classroom, they develop a positive self-identity.	94.80	7.52	100.00	80.00

Table 4.5 Teacher Scores and Mean (M) values on the CRTOE survey

Teacher	*Score*	*M*
David	2595.00	99.80
Ashley	2548.00	84.93
Karen	2453.00	81.77
Michelle	2337.00	77.90
Sophia	2330.00	77.67

Design, Engineering, and Technology (DET). The DET instrument was developed to measure teacher perceptions of teaching with engineering design. The authors defined DET to include the following skills:

1) identify a problem or a need to improve on current technology; 2) propose a problem solution; 3) identify the costs and benefits of solutions; 4) select the best

solution from among several proposed choices by comparing a given solution to the criteria it was designed to meet; 5) implement a solution by building a model or a simulation; and 6) communicate the problem, the process, and the solution in various ways. (Yasar et al., 2006).

The authors utilized the survey with ninety-eight elementary and secondary in-service science teachers across the state of Arizona. The items were reduced from the original 69 to 41, and, distributed four categories: 1) Importance of DET; 2) Familiarity with DET; 3) Stereotypical Characteristics of Engineers; and 4) Barriers in integrating DET. For the purposes of this research, only categories one and four were utilized with the teacher participants to gain insights on their beliefs regarding the engineering design process (EDP). The definition for DET provided by the authors is synonymous to other prominent frameworks in the field including, the Massachusetts Department of Education (DOE) Science and Technology/Engineering Framework (Massachusetts DOE, 2006).

Table 4.6 Means (M) and Standard Deviations (SD) for items on the DET survey

Factor 1: Importance of DET	*M*	*SD*	*Max*	*Min*
1) I would like to be able to teach my students to understand the use and impact of DET.	5.00	0.00	5.00	5.00
2) I would like to be able to teach my students to understand the science underlying DET.	5.00	0.00	5.00	5.00
3) I would like to be able to teach my students to understand the design process.	5.00	0.00	5.00	5.00
4) I would like to teach my students to understand the types of problems to which DET can be applied	4.80	0.45	5.00	4.00
5) My motivation for teaching science is to promote an understanding of how DET affects society.	4.00	0.00	4.00	4.00
6) I am interested in learning more about DET through in-service education.	4.80	0.45	5.00	4.00
Factor 1: Importance of DET	M	SD	Max	Min
7) My motivation for teaching science is to prepare young people for the world of work.	5.00	0.00	5.00	5.00

Table 4.6. Continued

8) My motivation for teaching science is to promote an enjoyment of learning.	5.00	0.00	5.00	5.00
9) I believe DET should be integrated into the K-12 Curriculum.	4.80	0.45	5.00	4.00
10) I am interested in learning more about DET through workshops.	4.80	0.45	5.00	4.00
11) I am interested in learning more about DET through college courses.	4.80	0.45	5.00	4.00
12) In a science curriculum, it is important to include the use of engineering in developing new technologies.	5.00	0.00	5.00	5.00
13) I am interested in learning more about DET through peer teaching.	5.00	0.00	5.00	5.00
14) My motivation for teaching science is to help students develop an understanding of the technical world.	4.60	0.55	5.00	4.00
15) My motivation for teaching science is to educate scientists, engineers and technologists for industry.	4.80	0.45	5.00	4.00
16) In a science/math curriculum, it is important to include planning of a project.	5.00	0.00	5.00	5.00
17) DET is important for pre-service teachers	4.80	0.45	5.00	4.00
18) DET has positive consequences for society.	5.00	0.00	5.00	5.00
Factor 2: Barriers in Integrating DET	M	SD	Max	Min
19) Barrier in integrating DET – lack of teacher knowledge.	5.00	0.00	5.00	5.00
20) Barrier in integrating DET – lack of training.	4.80	0.45	5.00	4.00
21) Barrier in integrating DET – lack of time for teachers to learn about DET.	4.80	0.45	5.00	4.00
22) Barrier in integrating DET – lack of administrative support.	3.20	1.09	4.00	2.00
23) Most people feel that minority students can do well in DET	3.20	1.09	4.00	2.00
24) Most people feel that female students can do well in DET	3.20	1.09	4.00	2.00

The responses regarding barriers encountered helped provide a deeper understanding of what teachers expect to self-react towards as part of agency when implementing a project inclusive of the EDP. It is interesting to note that teachers displayed the highest level of variation on the responses regarding barriers in integration DET. Specifically, statements 22-24 each garnered a mean of 3.2 and standard deviation (SD) of 1.09 with responses ranging from 4 (max) to 2.00 (min) on a 5-point scale (see table 4.6). This variation is striking when considering that on all other questions the mean value was 4.60 or higher, and SD was 0.55 or lower. Moreover, 10 questions out the total 24 resulted in a mean value of 5 (SD=0). An additional nine questions resulted in mean of 4.80 (SD=0.45). Lastly, the survey also resulted in one question each for mean value of 4.60 (SD=0.55), and mean value of 4.0 (SD=0). Statements 22-24 questioned how strongly teachers agree or disagree upon whether the lack of administrative support is a barrier when implementing DET. The statements also questioned how strongly teachers agree or disagree with “minorities and women” being perceived by others as populations who do well in DET. This variation may be suggestive of teachers’ personal experiences, along with those reported from their students who belong to these underrepresented populations in STEM.

Table 4.7 provides the total scores and mean values for each teacher participant. The scores ranged from 110 to 114, out of a maximum possible score of 120.

Table 4.7 Teacher Scores and Mean (M) values on the DET survey

Teacher	*Score*	*M*
David	112.00	4.67
Ashley	112.00	4.67
Karen	110.00	4.58
Michelle	113.00	4.71
Sophia	114.00	4.75

Below is a presentation of each case with an introductory teacher profile and a description, provided by the teacher, of the project implemented that incorporated the engineering design process (EDP) and culturally responsive pedagogy (CRP). Following the introduction are the emergent themes identified for each case and categorized under teacher beliefs and properties of agentic behavior. Hence, the findings are organized to align with the theoretical framework and research questions, which are guided by Bandura's social cognitive theory with specific attention to beliefs and agency (Bandura, 1977, 1986, 2001).

Case I: Ashley, Middle School Science Teacher

Ashley currently teaches sixth grade science at a high need public school district in the greater Houston Area. Ashley earned a bachelor's degree in Interdisciplinary Studies and has nine years of experience teaching third, fourth, and sixth grade science. Ashley has been awarded Teacher of the Year once at the elementary school she worked for, and, once at her current school. The latter resulted in her being recognized as a finalist for the District Teacher of the Year award. Currently, she serves in the following capacities: team leader for sixth grade science, mentor teacher to preservice teachers, and, a part-time instructional specialist for her school.

Most recently, Ashley advocated for her school to include a course on engineering design, by sharing her own experiences during the graduate level course, Fundamentals of Engineering Design (discussed in Chapter 3). Ashley utilized her engineering design notebook, produced during the course, as evidence for the caliber of instructional experiences to be expected for students. She was successful in convincing her school leadership and earned the opportunity to develop and teach an engineering design/problem solving course offered starting fall of 2019. In her teaching philosophy, Ashley describes herself as someone who hopes to "unlock the passions, talents, and skills that each child has inside" [Ashley, tps]. Furthermore, Ashley states that her high expectations of students are designed to prepare them for future jobs that may not even exist yet [Ashley, tps].

In her reflective journal entry, Ashley provided the following description of the project she incorporated in her class during the fall of 2019. Through this project, Ashley integrated the engineering design process (EDP) and culturally responsive pedagogy (CRP). Ashley's understanding of these constructs, along with that of the other teacher participants', was informed by their experiences in the LEAD Houston fellowship graduate coursework. Ashley shared:

> For my first engineering design and CRP lesson, I incorporated thermal energy transfer with tech and engineering. Students were given the following problem: There are no microwaves for student use in the cafeteria. Home-cooked food (which should be served warm) cannot be brought to school because of this. Students will build a prototype that will either keep food warm or warm food up without the use of electricity. They were not allowed to bring materials from home, nor purchase building supplies. I also provided each group with oatmeal to test on the "test day." They completed the data sheets and engineering design handouts via google. Students created a shared folder and used it like a portfolio. They uploaded images of sketches and answered questions using different colors/fonts. I believe that the "level playing field (all supplies provided by teacher)" and the appreciation for home culture (home-cooked meals/leftovers) increased the CRP. I also think that the ability to communicate through the google drive allowed for increased communication and more accessibility for English language learners and varied student levels. [Ashley, rje].

Category: Pedagogical beliefs

Emerging theme: The value of problem-solving. Through her reflective journal entries and interview responses, Ashley emphasized her belief in the value of providing students with problem-solving opportunities, especially as they relate to projects inclusive of the engineering design process (EDP). When asked to define EDP, she first began by discussing the need to provide students with a problem that they can identify and solve. It is worth noting that identifying a problem is one of the most integral steps of the EDP according to prominent researchers' in the field (Apedoe et al., 2008; Atman et al., 1999; Crismond et al., 2006; Hynes et al., 2011). Ashley further explained the steps she believes are most vital in the EDP through her reflective journal entry:

> The Engineering Design Process (EDP) is a cycle that engineers and students work through to solve problems. Once the problem is identified, you consider what is needed and what is available, brainstorm solutions, then build and test the best solutions. You evaluate and communicate the results. Most importantly, this is a non-linear cycle. You may build and test, then move back to evaluating the problem based on results. The EDP is a process that promotes engagement, critical thinking, problem-solving, creativity, and communication. These are all skills that promote 21st century learning and jobs. [Ashley, rje].

Ashley's mention of 21st Century skills in the statement above is of significance because through her teaching philosophy statement she expressed her desire to be the type of teacher who helps foster 21st Century skills in her students [Ashley, tps]. Furthermore, it was the problem-solving component of the EDP that Ashley found to be most conducive for inclusion of culturally responsive pedagogy (CRP). "When we started the design process with a problem related to bringing food from home, it became culturally responsive." [Ashley, int]. The notion of contextualizing the problem in the EDP with students' culture is also recommended by Householder and Hailey (2012). Thus, through statements in reflective journal entries and interview responses, Ashley shared pedagogical beliefs surrounding the value of problem-solving. She also noted the need for embedding relevance in the problem-solving component of EDP through use of students' lived experiences and background.

Emerging Theme: Heightened student engagement. In her reflective journal entry, Ashley stated that she believes the project allowed for "a level of engagement that was higher more consistently due to the hands-on aspect (engineering) and the fact that all students could access the project (CRT)." [Ashley, rje]. Ashley discussed student engagement throughout her interview, mentioning that the "open-ended" [Ashley, int] and “student-driven” [Ashley, int] nature of the project allowed for a level of engagement she had not witnessed prior in her classroom. Ashley attributes this student outcome to the inclusion of the EDP and CRP. When asked how the incorporation of EDP and CRP changed the project, Ashley stated the following, “It was night and day. What ended up happening was much more student centered than it had been previously… This time it was all student driven, so it was very, very different this time.” [Ashley, int]. As such, Ashley repeatedly expressed her belief that providing students with instruction that includes the constructs of the EDP and CRP can result in heightened student engagement. She especially found this to be true of her lower-achieving students, some of whom, she stated had never responded to a project with such enthusiasm and interest [Ashley, rje; int].

Emerging Theme: Incorporating students’ funds of knowledge. In her reflective journal entry and interview, Ashley shared her beliefs regarding CRP by discussing the importance of getting to know her students in an effort to utilize their funds of knowledge in her instruction. Ashley also expressed her belief that the incorporation of CRP is able to yield positive student outcomes. This was shared in her reflective journal entry where she provided her own definition of CRP:

> Culturally Responsive Pedagogy (CRP) is teaching that acknowledges, celebrates, and promotes the student's culture in the classroom. One of the most important parts to CRP is identifying and incorporating students' funds of knowledge. Funds of knowledge consider and validate students' varied experiences that lead to knowledge outside of the school setting. By incorporating that into the lessons, students have more buy-in in the classroom and can make stronger connections to the content. [Ashley, rje].

The definition Ashley provided in her reflective journal speaks towards her belief that through the inclusion of students’ funds of knowledge in classroom instruction, teachers are able to yield positive student outcomes. This philosophy is widely affirmed by researchers in the field of CRP (see, Irvine, 2002; Ladson-Billings, 1995, 2009; Moll, Amanti, Neff, & Gonzalez, 1992). Ashley further connected this belief to her own school setting by suggesting that the diverse student population at her school (see table 4.3) is an "opportunity to appreciate and empower so many different students, and we have an opportunity to get them to appreciate each other and learn to work with each other." [Ashley, int]. Thus, Ashley expressed her belief that CRP requires getting to know the students in your school and classroom. She explained that the cultural characteristics of the student population can ultimately drive classroom instruction. Ashley further asserted her belief that connecting content to students' culture is capable of heightening student engagement and producing positive student learning outcomes. In order to meet her goal for providing instruction infused with CRP, Ashley shared specific actions that she can take:

> …finding connections to their lives outside of the classroom, and making those connections is where I would start…and really being able to elicit that information from them through conversations and making things more open-ended for students, getting their input into it [Ashley, int].

Teacher Agency Category: Intentionality

Emerging Theme: 100 percent. Ashley's intentionality towards future implementations was evidenced throughout her reflective journal entries and interview. When asked about the likelihood of future implementations of EDP and CRP, both separately and in combination, she positively confirmed each. Ashley explained that she "100 percent, yes" planned to also utilize the project she implemented this year, in addition others [Ashley rje; int]. Toward the end of the interview, Ashley was provided with the opportunity to share any additional thoughts or attitudes towards the experience.

Her response helped provide deeper insights into her intentionality for future implementations:

> I'm just all in. I can't go back now. I would say I had more of my students completely engaged in this activity than I did in any other unit.. I could tell that they were all in. I think it was because they had buy-in, they felt empowered. It was hands on and it fun, and they learned, and they got a product at the end to be proud of. The more I can provide those opportunities to the students, the better. This is definitely my goal now. [Ashley, int].

Teacher Agency Category: Forethought

Emerging Theme: Planning for time. While Ashley cleared established her intentionality to reuse the project and implement future projects infused with EDP and CRP, she also, shared courses of action to manifest those intentions. These actions included revisions to the project by incorporating a reflective component for students that yields a strategic discussion around the connection between student designed prototypes and content learning standards. She mentioned that this was not included in fall 2018 implementation due to lack of allotted instructional time. “In the future, I would just carve out more time for it to begin with.” [Ashley, int]. Ashley’s willingness and foresight to plan for additional time, demonstrates commitment to foster improved and meaningful experiences for her students with regards to EDP and CRP.

Teacher Agency Category: Self- reactiveness

Emerging Theme: Materials management. While Ashley discussed that she found the EDP to be a structured approached, she also described the implementation of it as, “messy,” both in the literal and figurative sense, through five different statements during the interview. Although she initially viewed this aspect of the project as a hurdle, Ashley ultimately stated that “I've decided that I'm going to be okay with a messy room.” [Ashley, int]. Thus, overcoming the obstacle of managing a disorderly classroom through managing her own reaction towards the situation. With regards to materials, she also shared that she used Google Drive with her students for the purpose of digital collaboration. While it was a learning process for her students that did consume some unexpected instructional time, Ashley still found it to be worthwhile. Ashley explained that students were able to familiarize with a new online resource because of participation in the project. According to Ashley, the financial constraints of her school and department allowed for limited resources available for students to use. She had to be creative, specifically with the sketching of prototypes, and presentation of images. Therefore, using a shared platform such as Google Drive, was Ashley's solution to the challenge, and another example of her self-reactiveness to obstacles encountered during implementation.

Teacher Agency Category: Self- reflectiveness

Emerging Theme: The teacher's role. All throughout the reflective journal entries and the interview, Ashley reflected on the implementation of the EDP and CRP. She shared whether she sees room for future projects that incorporate these processes, along with the value of each construct, both separate and combined. She explained the barriers encountered, and, how she overcame those challenges. An additional, and distinct theme of self-reflection was Ashley's perception of the teacher's role as an impactful figure in a student's life. This connects back to Ashley's teaching philosophy statement in which she discussed her reasoning for becoming an educator. Ashley shared the impact her parents had on her, as well as, her first-grade teacher whom she recalls fondly as someone who made her feel "special" [Ashley, tpe]. She also spoke towards the encouragement her parents provided by fostering a sense curiosity towards her surroundings. Ashley explained this experience as an informal exposure to engineering design, “I think along the way my parents were trying to get me to understand that I did have a little engineer in me.” [Ashley, int].

Ashley’s empowerment from supportive adult figures in her childhood is coupled with some negative experiences that also shaped her teaching philosophy. For example, Ashley recalls that when she unable to answer specific questions posed in elementary school the teacher labeled her as “not a great student” [Ashley, int]. She explained that her inability to answer those questions was related to her lack of background experience in that area. However, the teacher did not know that because she did not take the time to get to know her students. Instead, according to Ashley, she was labeled by the teacher as a potentially low-performing student. Ashley’s reflection of this story is significant because it provides insight on the value she places towards students’ funds of knowledge, which is a noted theme under the pedagogical beliefs category. Ashley emphasized the impact had by teachers which drives her motivation to instill pedagogical approaches that deems valuable to student learning. Ashley also reflected upon the responsibility she feels for future instructional implementation:

> I kind of feel like I've crossed this line where I know that my students can be successful, and I know that all of the other students can be successful, and so I feel obligated. I owe it to the students to ensure that they're getting more experiences like this. [Ashley, int].

Case II: Michelle- middle school science teacher

Michelle teaches seventh grade science at a high-need public school district in the greater Houston area. She teaches at an at-risk, low-socioeconomic status middle school with a high Latinx student population, and over 80% of students are classified as English Language Learners (ELL). Table 4.3 provides for additional school and student demographical characteristics. Michelle describes herself as someone who is concerned with how students, especially those from underserved areas, learn best [Michelle, tps]. During the fall of 2016, Michelle founded and continues to sponsor a student organization, Concrete Flowers, for her school. Concrete Flowers is geared to providing support systems to goal-driven minority females on campus. Additionally, Michelle is a member of an organization called, Vanguard Cohort III. Through this endeavor she, along with the other members, is charged with integrating cutting-edge technology in her instruction.

Michelle provided the following description of the project she designed and implemented in her class during fall semester of 2018. Michelle took an existing project and infused it with the engineering design process (EDP) and culturally responsive pedagogy (CRP):

> The lesson was tied into the state standards where they had to identify the structures and functions of the skeletal and muscular systems. Students used everyday objects to create an arm to pick up various objects. The document that was given to them provided opportunities to go through the engineering design process. Before the lesson, we watched videos on how engineering is improving the quality of life with those who are missing limbs or have abnormalities in their limbs. These discussions carried on during the building process. [Michelle, rje].

Pedagogical Beliefs

Emerging theme: Relevance Matters. Michelle's belief in the power of instruction that is relevant to students was evidenced through her discussions regarding prospects for future projects. "This is our culture, and if these are the things that we're identifying as problems, then okay, let's use the engineering design process in our science content to address those issues." [Michelle, int]. Although this may have been a belief she held in years prior, it does appear that the project reaffirmed this notion and is a key motivator for future implementation. In the quote below, Michelle discussed some ideas for future concepts, keeping relevance to her students as a central component of the potential project:

> We could talk about climate change. We could talk about areas of Houston that are clean and areas that are polluted. We can talk about how we are doing in taking care of our communities. It may not be incorporated in "culture" as far as ethnicity but maybe generational culture. How does the younger generations view environmental issues? We could talk more about climate change and be more environmental savvy… [Michelle, int].

This belief about the value of relevance, especially, when teaching minority populations is one that Michelle shares with many scholars in the realm of culturally responsive pedagogy (see, Gay, 2000, 2002; Ladson-Billings, 1994, 1995). Also, Michelle noted the category of generational differences when defining culture which is rarely discussed in literature. Michelle identified generational identify as a part of her students' culture and viewed it as a resource for instructional relevance. Furthermore, building relevance to connect with students and ultimately gain their buy-in, is reflective of beliefs Michelle shared in her teaching philosophy. "I truly believe that the whole child should be priority when teaching. First you capture their heart...then you can capture their mind." [Michelle, tps].

Emerging theme: Student engagement. Much like Ashley, Michelle also noticed some significant changes in the interactions with her students regarding their performance and interest in the subject-matter. Michelle, spoke about how this initially took her by surprise, especially, the lack of needed redirection. She attributes this to the belief that students are more likely to feel invested in their own learning through a project infused with the EDP and CRP. "I think it made them more engaged and care more about the content…they were paying attention and they were engaged, I didn't have to persuade them to do this." [Michelle, int]. This level of engagement noted by Michelle, along with her beliefs regarding relevance in instruction, relates to the definition of CRP Michelle provided. In her own words, Michelle stated that it is first and foremost "a student-centered approach to teaching" [Michelle, rje].

Emerging theme: Building confidence. Perhaps the most recurring term coded for in Michelle's interview and reflective journal entries was, "confidence. This confidence was not only something she believes the project instilled in her students, but also a shift she noted in herself. "I feel like with EDP and I don't know if this is the same at every school but at least for my students anyway and for myself, I feel like it definitely is a confidence builder." [Michelle, int]. The rise in self-assurance, Michelle, explained has also allowed students to feel more comfortable in her classroom. Moreover, Michelle, discussed how she handled student projects which did not work properly, something she noted is common with engineering-design projects. She explained that once she was able to show her students all of things their prototype accomplished, the students were filled with a sense of pride in their work.

Teacher Agency Category: Intentionality

Emerging theme: Ready for the next project. Throughout her interview, Michelle's established her intentionality by stating that she is willing and ready to try additional projects infused with the EDP and CRP. For instance, when asked about her intentions to implement these pedagogical approaches in the future, Michelle responded with "For sure. For sure." [Michelle, int]. Moreover, she set an additional intention for the coming school year, stating next time she would not only use projects such as this with her Pre-AP (advanced placement) classes, but, also, with her Academic (on-level) students. Michelle explained that she was unsure of how the students would react to the project, as well as, her own ability to implement the project successfully. She shared that she felt safer enacting the project with her high achieving students. However, Michelle later explained that she regretted not using the project with her academic students by expressing that she was upset with herself for not doing so. Her intentionality was especially shaped by the reactions she describes from her academic students, who asked her the following, "Why are we not doing this?" to which Michelle reacted with, "Argh. It hurt my heart. I thought, okay, I'm never doing that again." [Michelle, int]. In that statement, Michelle was referring to her decision of not including her academic students this project, and thus, setting the intention to include them next time.

Teacher Agency Category: Forethought

Emerging theme: Solving problems. During the interview, Michelle immediately began sharing specifics regarding future projects and implementation. "I've already started thinking about how I want them to build a model of the circulatory system." [Michelle, int]. Michelle also spoke about building connections between climate change and hurricane Harvey for a separate project, discussed under the emerging theme of, relevance matters. Nevertheless, Michelle's foresight for specifics in instructional planning suggest that her commitment towards future implementations has already transformed into a plan of action.

Teacher Agency Category: Self-reactiveness

Emerging theme: Materials and time. Michelle described the lack of materials and time as her two biggest obstacles encountered during the process. However, rather than letting these obstacles hinder from planning for the future, Michelle explained that she is looking into using DonorsChoose.org, an online platform where teachers can post ideas or request for their classroom in an effort to seek donations from individuals or entities willing to support the endeavor (Donorschoose.org, n.d.). “I’m definitely going to do this again next year. So, I’m going to do a Donors Choose or like incentives, that give me some materials for it, since now I know.” [Michelle, int]. In one of her journal entries, Michelle also spoke towards the lack of time to conduct such projects, but, also shared a potential solution for how she could make better use of the time available:

> I would have liked to have had more time to have exposed them to the engineering design process before this lesson. I think next year I would have a mini team building lesson that integrates the EDP at the beginning of the year. [Michelle, rje].

Teacher Agency Category: Self-reflection

Emerging theme: A sense of responsibility. Although Michelle’s reflections are evidenced through the themes discussed above, one recurring sentiment that she reflected upon was a sense of responsibility towards her students. Michelle’s ability to relate her own K-12 experiences to those of her students’, provides further insights into her agentic behaviors and beliefs about the pedagogical approaches. For example, at one point in the interview, Michelle began to describe how she perceived the feeling of being able to solve a problem by building a prototype:

> I built something like I feel smart, you know like I feel like I’m capable, you know, like I did that. And so, I think when they’re building something and they’re proud of it, I mean I think all people if you built something and you’re proud of it, it does something to you… [Michelle, int].

For Michelle to see this connection between her reaction towards experiencing the EDP and the way her students responded to it is of significance. In her teaching philosophy, Michelle made the following assertion:

> As a young teen, I was never motivated by school and wasn't really interested. As I made my way through college, I realized how fulfilled earning an education made me feel. I wanted to be a teacher to help students like me! [Michelle, tps].

Thus, as in accordance with her philosophy of teaching, Michelle continues to see herself when possible in her students. This yields a sense of responsibility within her to embody instructional practices that foster student confidence and engagement. Consequently, rise in student confidence and engagement were two prominent themes that emerged from Michelle's interview responses, and journal entries.

Case III: Sophia- high school mathematics teacher

Sophia teaches mathematics for a high-need school where approximately 80% economically disadvantaged students, and 97% students are classified as part of minority populations. Sophia described her student population as, "majority of them being on free or reduced lunch so they are low SES students, but I have really awesome kids." [Sophia, rje]. Sophia, currently in her 11th year of teaching, has taught Algebra and Geometry, AP Psychology, and Pathways to College and Careers. Additionally, Sophia has assisted the school district in curriculum writing, and has aided in text book adoptions. In the past she served as sponsor for UIL Academics, specifically, in the areas of Mathematics, Calculator Applications and Number Sense. Moreover, Sophia serves on her school's Mathematics Leadership Team, an endeavor through which she facilitates and leads school professional development efforts.

When asked to describe the fall 2019 project in which Sophia incorporated the engineering design process (EDP) and culturally responsive pedagogy (CRP), she provided the following explanation:

> The students were first shown a video for the engage part of the lesson. The video had the top 50 architectural fails. They were then told they would need to research a famous structure (building, bridge, ancient ruins etc.) and determine the fail that was made in the design of that structure. They had to give a reasonable solution to fix the problem. Then, they had to design a new structure with their solution in mind. Students had to draw both isometric and orthographic images of the structure, as well as make a 3-D model with a scale factor that they determined based on the original dimensions and their model's dimensions. The lesson had high cognitive demand, as well as mathematical discourse as students worked with a partner or group to complete their project. It was also ideal for my English Language Learners (ELL) students since they had to do research and could easily translate information into their native language and the drawings and models are visuals that doesn't discriminate between languages. Lastly, because students had a choice of which structure they recreated, it gave them an opportunity to learn about their world or other countries and cultures. [Sophia, rje].

Pedagogical Beliefs

Emerging theme: Student ownership. Sophia repeatedly shared her belief that through experience with the engineering design process (EDP) and culturally responsive pedagogy (CRP), her students displayed a strong sense of ownership. She attributed this to the problem-solving driven nature of EDP along with an added sense of relevance attained by allowing students to customize their prototypes.

> …I think it added that more critical thinking component and then the fact that they had to come up with a solution as well made it kind of more like they were owning the project because they were coming up with the solution themselves, no one was telling them how to solve the problem. [Sophia, int].

In her interview Sophia mentioned that she wants to pass along her passion for mathematics to her students, and even shared specific examples of how she tries to do so in each lesson. This desire to spark interest in STEM content is in alignment with her teaching philosophy. Sophia explained, “I have always been challenged by and have a passion for mathematics and for helping others.” [Sophia, tps]. Thus, it is of significance that Sophia believes the feelings of student ownership brought on by the project have the potential to yield heightened student interest in mathematics.

> I do think that the engineering process of having a problem that is relevant to them and having them come up with solutions using each other and using what they do know, their prior knowledge and what connections they can make from not just my class but also from their middle school classes, all of that is going to create more intrinsic motivation and hopefully passion for mathematics as well. [Sophia, int].

Emerging theme: Communication and Collaboration. Sophia shared that she believes providing students with the opportunity to engage in communication and collaboration is vital. This was evidenced in her reflective journal entry where she was asked to define CRP and used the following verbiage, “The content must be challenging, it must require students to collaborate and communicate…” [Sophia, rje]. Sophia views her classroom as an opportunity for students to engage in the types of skills that she believes are essential for their preparation to be successful beyond high school. Sophia believes the incorporation of the EDP and CRP is a viable route to reinforce 21st century competencies.

> They have to be able to communicate with each other in a mathematical way because otherwise they’re just chatting and talking, and it doesn’t really relate to not only their lives but also to the math that we’re learning. So, bringing the engineering process is a way to get them to use mathematical vocabulary to make their point clear and get them to think critically about problems but also compromise with each other and collaborate. [Sophia, int].

Teacher Agency Category: Intentionality

Emerging theme: Moving forward. Throughout her interview, Sophia reflected on many ways in which she could improve the project; however, her intentionality was demonstrated in her ability to think forward and plan for curricular projects ahead. Sophia listed specifics actions she can take to achieve the desired outcomes, which suggests that she is moving forward with CRP and EDP integration in her mathematics classroom. She even pondered the idea of collaborating with the engineering teacher at her school for a future implementation:

> It would be so cool to have her students come and partner with one of my students in class and then do a project together, whether it's a week-long thing or even just something short and simple. Another thing that I've been considering is whether we get the funding is kind of dependent on this but taking my classes to the fab lab. [Sophia, int].

This "fab lab" referenced by Sophia is a maker-space in the greater Houston area, which Sophia later mentioned she has already contacted to initiate a potential collaboration. Moreover, when asked about her intentionality to use this project or others like it, Sophia responded with "100%" and "Yes, definitely" [Sophia, int]. Thus, Sophia consistently affirmed her intentions for future instruction infused with CRP and EDP.

Teacher Agency Category: Forethought

Emerging theme: Community Involvement. As mentioned under the intentionality category, Sophia shared specific ideas for projects that may have potential for implementation in the future. A theme emergent within those prospective ideas is Sophia's desire to involve the community. In the quote below she describes deriving problems through utilization of student surroundings:

> …say they find something structurally wrong with a building or a structure you know where they all live and maybe that's something that could - even if they're just walking around one day and they're like oh my gosh this swing set is broken, you know what I mean? Or something like smaller scale could make it more connected to their everyday life and also their community and even if they were to come up with reasonable cost-effective solutions we could take it to like the school board or the community town hall. [Sophia, int].

Furthermore, when planning for future projects, Sophia discussed providing students with a survey designed to attain insights regarding their background and lived experiences. This would allow Sophia to plan instruction rich in her students' cultural context. She explained that this survey would also provide a deeper understanding of students' personal interests. Therefore, the survey can assist her to help to uncover students' intrinsic motivations. Sophia's ideas to involve the community and embed student background within her instruction are indicative of her foresight to plan for future projects that incorporate the EDP and CRP.

Teacher Agency Category: Self-reactiveness

Emerging theme: Difficult but necessary. Sophia did not hesitate to share the difficulties she encountered when implementing this project, or the amount of time it would take to revamp additional units. However, even as she shared these concerns, she was willing to acknowledge the necessity of doing so regardless of challenge.

> … sitting and revamping all the lessons will be time consuming but it's worth it to make the students see the connections and go to the process and practice that process more than just once or twice in a year. Cause those are the same things that are going to be required of them when they get into college and the real world. [Sophia, int].

Another challenge Sophia is willing to self-react towards, in an effort to accomplish her instructional goals, includes collaboration with colleagues. When asked if her team members would be willing to incorporate such a project, Sophia mentioned that their traditional, teacher-centered, approach would prevent from them from doing so. Moreover, according to Sophia, being the youngest member on the team lessens her chances of being taken seriously by her colleagues when suggesting curricular reform. However, as the discussion continued she made the following statement:

> I could be making all these assumptions and they could just be like oh my god thank you so much. This is wonderful. I didn't even think about doing this. And like be so pleased and I'm just making it out to be this - the anticipation is scarier than the actual act of just, hey, what do you guys think about putting some of this engineering into our lessons. [Sophia, int]

Teacher Agency Category: Self-reflection

Emerging theme: Change starts with self. The emergent themes above are documented because of the reflections shared by Sophia through reflective journals and interviews. A central theme found within her reflections was a desire to work towards change, starting with her own instruction. She acknowledged that her project lacked a strong emphasis in CRP, "I think it wasn't as culturally connected as I know that things can be." [Sophia, int]. Sophia went on to explain that she wishes it would connect to students' everyday lives. Therefore, she considered the prospect of a take home survey that could assist in this endeavor. Sophia further explained that these improvements were not only appropriate for this project, but for others as well. "I mean with a small amount of change and tweaking they could become more engineering type of lessons and more culturally connected to the students." [Sophia, int]. Ultimately, when asked how she perceives her role in the movement to incorporate these pedagogical approaches Sophia explained that any change possible must start with her. "I'm definitely going to start with me, my own lessons and things. I'm more confident in my ability to accept those changes and want to implement them." [Sophia, int]. Sophia's willingness to try things even though they are difficult, and, embark on instructional from within her own classroom, are sentiments deeply rooted at the core of her teaching philosophy statement. Sophia asserted that to be a teacher is to be, “a lifelong learner.” [Sophia, tpe]. Hence, the lifelong learner in Sophia demonstrated a willingness to continue seeking ways to enhancing her instruction through the EDP and CRP.

Case IV: David, high school science teacher

David teaches biology at a magnet high school located in Houston independent school district. David is currently in his sixth year of teaching and has been with the high school since the start of his career. Nearly 50% of school’s student population comes from economically disadvantaged households, Also, 75% of the students enrolled identify as part of minority populations, (see table 4.3). David, a native Texan, completed his bachelor’s degree in Kinesiology, and shortly thereafter began his career as a secondary science teacher. He mentors preservice teachers from two public universities in the Houston area, and is involved in curriculum writing endeavors for his campus. David also helps with in-service professional development for his campus department.

In his reflective journal entry, David provided the following description of the project he implemented during the fall of 2018, which incorporated both culturally responsive pedagogy (CRP), and the engineering design process (EDP).

> The class was tasked with a hair blow dryer disassembly. The students documented the disassembly by creating an exploded view of the dryer before they began to take it apart. They then created an exploded view during and after the disassembly alongside pictures documenting their every step. The students used this as an analogy for a cell and were tasked with creating a cell model analogy. The hair dryer is a common product that many kids will know and be able to compare to a cell. The do now (warm up) tasked the students with

> creating an Instagram profile of an engineer relevant to them. The students then explained why the scientist was relevant to them as an oral presentation. [David, rje].

Pedagogical Beliefs

Emerging theme: Students inclusion. A recurring theme throughout David's interview was his belief that educators have the responsibility to include not just some, but, all students in their instruction. This was also reflected in the following belief statement made in his teaching philosophy, "My teaching philosophy is to reach my students at their individual level…Every student needs the same opportunity to flourish, and I am here to do my part in that." [David, tps]. When asked to describe his school setting, David shared that they had new school leadership, which may ultimately yield some changes that cultivate a positive learning environment, "I think it's getting to that level to where we're able to look at all of the students and actually make them feel like they're at home in our school." [David, int]. Thusly, when David spoke of the project, he discussed the ways in which he believed a project inclusive of CRP and the EDP had the power to reach students who otherwise did not show interest in class. He specifically discussed a girl in whom he noticed this rise in engagement which dissipated once the project was over and the class had moved on to other lessons:

> She opened up. She's the one who's doing the exploded view. She'd drawing everything. She's telling others to take pictures. And then the next lesson after that which wasn't an engineering one or didn't have her using her artistic side, she went back into her shell [David, int].

This was also evidenced in his account of another student. The CRP component of the lesson asked students to create a social meda profile of an engineer who they perceived as representative of themselves. In this case, the student could not find an engineer who fit his racial or ethnic background. David recalled this having a powerful impact on the student, which he believes led the student to take this project very seriously. David explained this was because the student wanted to prove that there could be famous engineers who looked like him and came from his background. Moreover, the student created a “ghost profile” which was merely a picture of a silhouette rather than an actual person and listed various statistics regarding the lack of racial diversity in the field of engineering.

> He was like, 75% of the engineering world is white male. These laws have been put in place like affirmative action. They're put in place to help people get there– and I was like "Wow." Actually, this kid was 13. So, he is younger than my sister, yeah. And so that was one of the ones that really stood out to me was that this kid took it that far. [David, int]

Emerging theme: Open-Ended. Another belief David shared regarding the pedagogical approaches of EDP and CRP was that he truly valued the open-ended nature of the project. His attributed this to his desire for students to blossom into independent thinkers. “I want the students to have their own minds. You know they're not always going to have me. The whole thing is to have them be independent. And that's my whole goal.” He mentioned that other teachers, who do not share this belief, feel compelled to assist students by providing them with guidelines to successfully complete the task.

> Whereas with me, it wasn’t hard not to tell them anything. And they hated me for this, because they were like, "You're just trying to make life hard. You don’t want to give us any answers." And I'm like, You're right [David, int].

Teacher Agency Category: Intentionality

Emerging theme: Making the effort. David was very open and direct about his intention to continue implementation of projects that infused the EDP and CRP. For him it was not a matter of whether he would do it, but, rather, how he could ensure that it took place. This included considering possible improvements for the next year. David mentioned in his interview that while he was implementing the project he was also considering ways to scale it up for next year. He discussed seeking funding which he suspects will be an increasingly difficult obstacle to overcome. He explained that he has initiated conversations with his principal to identify potential funding sources for the project, and that he is planning to reach out to sources himself, “I'll reach out and try to get some funding next year you know… I'm going to try my hardest really.” [David, int]. This “can-do” attitude has been evidenced throughout his career from the moment he decided to pursue teaching. “After high school I knew I wanted to teach. I got into the school of education at The University of Texas at Arlington and knew there was no looking back.” [David, int].

Teacher Agency Category: Forethought

Emerging theme: Planning for the year. In addition to his clear intentionality for continued implementation of the fall 2018 project, David also shared that he started work on additional lessons and units. According to him, “every new unit, every new topic and even a lot of the lesson has a CRP component to it now.” [David, int]. As such, David has put his intentions into action by revising specific components of lessons through the inclusion of CRP. He also modified projects to include engineering-design and was able to list specific curricular units that would benefit from revisions, such as, the digestive and circulatory system. Therefore, David demonstrated not only his desire for change, but, also, his plans for moving forward.

Teacher Agency Category: Self-reactiveness

Emerging theme: Securing funds. As discussed in the emerging theme related to intentionality, David expects that cost of materials for the project will be an obstacle for the years to come. This was true for the implementation during the fall of 2018. He stated that the cost of the hair dryers, needed for disassembly, was approximately $650. In an effort to acquire these funds, David repeatedly met with the new school principal and discussed the benefits of the project. His efforts ultimately led the principal to approve the costs for materials. However, the process of requesting and advocating for the project was so lengthy, that David wondered if it would even happen. Still, he persisted, and the results were in his favor. David stated, “I only got the funding about two weeks before the actual project was supposed to take place. I was coming down to the wire like, "Man, this isn’t gonna happen. This isn’t gonna happen." [David, int]. Hence, it was David’ self-reactiveness to the challenge of securing funds that ultimately allowed the project to take place.

Teacher Agency Category: Self-reflection

Emerging theme: Comfortable with being uncomfortable. All throughout the interview, reflective journal entries, and his teaching philosophy statement, there is a sense of David’s willingness to move forward with what he deems necessary even if the road to success is full of challenges. In his interview he reflected on his nature to try new things even though they may seem scary first. He described initiating curricular reform as “daring,” and further added “I’m not afraid of doing these things.” [David, int]. He was referring to incorporating innovative instructional approaches such as CRP and EDP, although his colleagues remain reluctant and unwilling. Some, he recalled, hesitated due to safety concerns and seemed appalled at the idea of handing their students tools for disassembly. That fear, according to David, keeps teachers from trying new strategies in their classrooms. This is not to say that David expressed he was comfortable with change. Still, he reflected on how he could, and did, move past those feelings of apprehension, “I think you need a comfort level of just being uncomfortable with it saying and "Hey, we still got to do this. We gotta do this." And so, he did.

Case V: Karen, middle school science teacher

Karen teaches eighth grade science at an affluent middle school located in a high-need public school district. Karen is in her thirteenth year of teaching and has spent her entire career at this school which she demographically described as, “rather mixed – we primarily have students from India and China, with a small minority of Hispanics and Blacks. Our white population, last I checked, was about 45% of our population.” [Karen, int]. Regardless of her school demographics, Karen, through her teaching philosophy statement, reflective journal entries, and interview responses, articulated a strong desire to serve not some, but all students, “I firmly believe that teaching styles must adapt to student needs, not that students should adapt to a teaching style.” [Karen, tps]. This belief is evidenced throughout the emergent themes reported in the categories below.

Karen provided the following description of her project, implemented during the fall of 2018, which incorporated the pedagogical approaches of culturally responsive pedagogy (CRP) and the engineering design process (EDP):

> My lesson was a major 2-week project done after the completion of two units that covered Speed, Velocity, Acceleration, and Newton’s 3 Laws of Motion. Student groups of 2 researched, designed, and constructed rubber band powered vehicles that could travel a distance and carry a load. They then tested their vehicles and collected data. Without modifying the vehicle, they added weight, retested, and collected more data. From a review of their data, they made modifications to their

> vehicle, retested, and collected more data. Once again, they evaluated their data and made one last modification, retested and collected their final data. A part of their data collection involved the usage of Vernier Motion Detectors. Students calculated for speed and translated their raw data into graphs. I had our coach and librarian create a video pleading for student help and apparently this touched the students more than I thought. I felt kind of bad during the planning process for their vehicles when some of my students found out they really weren't creating a vehicle large enough to carry books and football pads. [Karen, rje].

Pedagogical Beliefs

Emerging theme: Greater depth. From the start of the interview, Karen was candid about one of the motivating factors that drove her willingness to incorporate CRP and EDP into her lesson. Karen explained that the project, as it was conducted in years prior, lacked substance and depth, which she perceives as essential qualities to any learning experience. She recalled her thought process during the planning stages by sharing the following in a reflective journal entry:

> "One of the things that was my goal in this project was to take something that was just really kind of a fun activity that had been done in the past, and to give it some real depth and educational meaning." [Karen, rje].

Karen's efforts proved to be fruitful as she was able to reflect upon the student learning outcomes produced through the project when compared to those achieved from previous iterations. In prior years, the project lacked inclusion of CRP or EDP. The results, Karen shared, affirmed her belief that through incorporation of these two pedagogical approaches the level of rigor, student learning and engagement are heightened.

> I'm sitting there looking at their CERs and I'm like, "Yeah, you had fun, but you learned more this year than you did last year." I know I didn't have the same kids last year, but you know what I mean, if I were to compare the two groups to each

> other. This group walked away with a greater understanding of physics than my group did last year. And it was all because of the combination of the CRP and the engineering process. [Karen, int].

Emerging theme: Community involvement. Karen shared that she was pleasantly surprised with the parent and student interactions attained through parental involvement during the building process. She explained that initially she asked for parent volunteers because of an injury that she knew would prevent her from using certain building tools that require adult supervision and assistance. However, upon experiencing the involvement of parents and community members, Karen now believes that this added to the cultural responsiveness towards her students. Karen explained that students were given the opportunity to build their project alongside members of the community who have expertise in the scope of carpentry or building. Students were able to learn and engage with members of the community who otherwise would not have been involved in their learning process. Karen shared that she believes these interactions added to the "cultural competency" in her project [Karen, rje].

An additional component through which Karen involved the community was by aligning the product students were asked to design with solving a solution that helped the school librarian and/or football coaches. Students were able to choose whether their cart would support the weight of books or sports equipment and added specific design considerations based on who the product was intended to serve. "A sense of community was achieved when students were also able to connect their learning to a real-world situation by helping the librarian or coach solve a problem." [Karen, int]. Thus, Karen believed that through community involvement she was able to cultivate a cultural connection with students.

Teacher Agency Category: Intentionality

Emerging theme: We can do more. Karen's intentionality was rooted in her reflection of her practices prior to incorporation of CRP and EDP. She shared that she feels there is not enough hands-on instruction involved in the current curriculum. This is coupled with her belief that "hands-on" learning must be met with substance in terms of content learning, and that through CRP and EDP she is able to achieve this ideal combination. Hence, her intentionality is a result of the positive outcomes she witnessed and experienced through this project. Karen explained that while she acknowledges the need for inclusion of CRP and EDP, and plans to move forward in that direction, she does not know the specifics of how to do so.

> I can really see - I know that this was for Newton's law, but when we're talking speed, velocity, and acceleration, I see a lot of what we could do with engineering process with it. I'm just not sure exactly what to do. [Karen, int].

Teacher Agency Category: Forethought

Emerging theme: Setting the tone. As mentioned under the intentionality category Karen anticipated that she will use the pedagogical approaches of EDP and CRP in other parts of her curricula, especially, physics related content. During the interview she contemplated some specific topics that could benefit from such incorporation. Although she was unsure about the specifics, she did articulate her plans and reasoning for placement of these approaches:

> I think because the beginning of the year for us in science starts off with chemistry and physics, that if I can captivate them and get them really deep into science, I think that it will help start off the year well, where they're excited about science. [Karen, int].

As Karen reflected on the success of her project, she acknowledged the benefit of having had the time to prepare this project during her summer coursework. Karen shared that she hopes to move her plans and intentions into action by using time over the summer to strategically plan for curricular reform:

> I think that was probably one of my best takeaways from the summer program, having that opportunity of being able to concentrate time to developing something like that. So, I'm hoping that happens this next summer that we'll have some opportunity to create some things that we can actually take back into our classroom and implement. [Karen, int].

Teacher Agency Category: Self-reactiveness

Emerging theme: Student inclusion. In her interview and reflective journal entry, Karen discussed the challenges she encountered when sharing the project with her team members. Although, she was ultimately successful in ensuring all students, and not just those in Pre-AP classes, were able to experience the project. She recalled that initially she was met with push-back. Karen described the exchange below:

> …when they read the project, they were just like, "Oh my Gosh, this is amazing, this is amazing. Yeah, they're going to get so much out of this. They're going to get so much out of this." But then they said, "That's great for pre-AP, so what are we going to do with academic?" And I'm like, "This?" [Karen, int].

Karen further provided context of how she refuted the claims that this wasn't a project for all students:

> I just kind of sat back and said, ‘Why can’t they do this project?” They responded, “Well, they just can’t.” My response to that was, “Well, no, you've got to tell me why they can't or we're forging forward with this." I said, because there's no reason why these students can't do it, and you know that the best vehicle that was produced in my classroom was produced by a young lady and a young man in my academic class. [Karen, int]

Karen’s willingness to advocate for her students is reflected in how she defined the teacher’s role when incorporating CRP, “a teacher needs to use a student’s funds of knowledge to his/her benefit in structuring a classroom environment in which ALL students can experience success” [Karen, rje]. Moreover, her teaching philosophy statement begins with a belief that explains her self-reactiveness to ensure all students in her team are able to experience quality instruction, “I strongly believe that all children are teachable.” [Karen, tps]. Karen did admit that outside of their reluctance with using the project in their academic (on-level) courses, they were very receptive to the implementation. She explained that her team members even offered some helpful feedback that she was happy to incorporate. Another form of Karen’s self-reactiveness was evidenced when Karen invited parent volunteers to participate in the project development. Karen did so due to encountering a hand injury which prevented her from assisting students during the building process. By inviting parent volunteers, Karen was able to ensure that all her students received proper attention.

Teacher Agency Category: Self-reflection

Emerging theme: Seeing the change. Throughout Karen’s interview and reflective journal entries she referenced the impact she witnessed in her students’ engagement and learning. As she shared her big takeaways and how she intends to move ahead, a reoccurring theme was how the transformative experience of her students is shaping her instructional decisions. Karen reflected upon where she currently stands in the reform process, “Am I completely comfortable with implementing both of them at this point? No. But am I willing to try and make an effort and do it? Yes. Because I see where this can all go.” [Karen, int]. She reflected on how she had initially suspected that this project would produce the type of results it ultimately did. Karen recalled her reasoning: “their engagement with their academics is going to increase through using engineering process and CRP with that situation by helping the librarian or coach solve a problem.” [Karen, int]. In her reflective journal entry, Karen also reflected on the actual experience, which, according to her, did yield positive academic outcomes:

> I see a huge difference in my student’s understanding of the material for Units 3 and 4. Seeing my students take pride in what they built when they bemoaned the project at first with the attitude that they “can’t build” was satisfying. [Karen, rje].

Cross-Case Analysis

Each case was analyzed separately and findings for the individual cases were reported independently. After two cycles of coding in accordance with Saldaña’s (2013) method for qualitative analysis, the author examined emergent themes from each case (see figure 7) to identify meta-patterns. Consequently, figure 8 illustrates the four distinct patterns were derived through the cross-case comparisons.

Case 1: Ashely	Case II: Michelle	Case III: Sophia	Case IV: David	Case V: Karen
Value of problem solving	Relevance Matters	Student ownership	Student Inclusion	Greater Depth
Heightened student engagement	Student Engagement	Communication and Collaboration	Open Ended	Real-world connections
Utilizing students' funds of knowledge	Building Confidence	Moving forward	Making the effort	Community Involvement
100 percent	Ready for the next project	Community Involvement	Planning for the year	We can do more
Planning for time	Solving problems	Difficult but necessary	Securing funds	Setting the tone
Materials Management	Materials and time	Change starts with self	Comfortable with being uncomfortable	Student Inclusion
The reluctant team member	A sense of responsibility			Seeing the change
Teacher's role				

Figure 7. Emergent themes identified for each case.

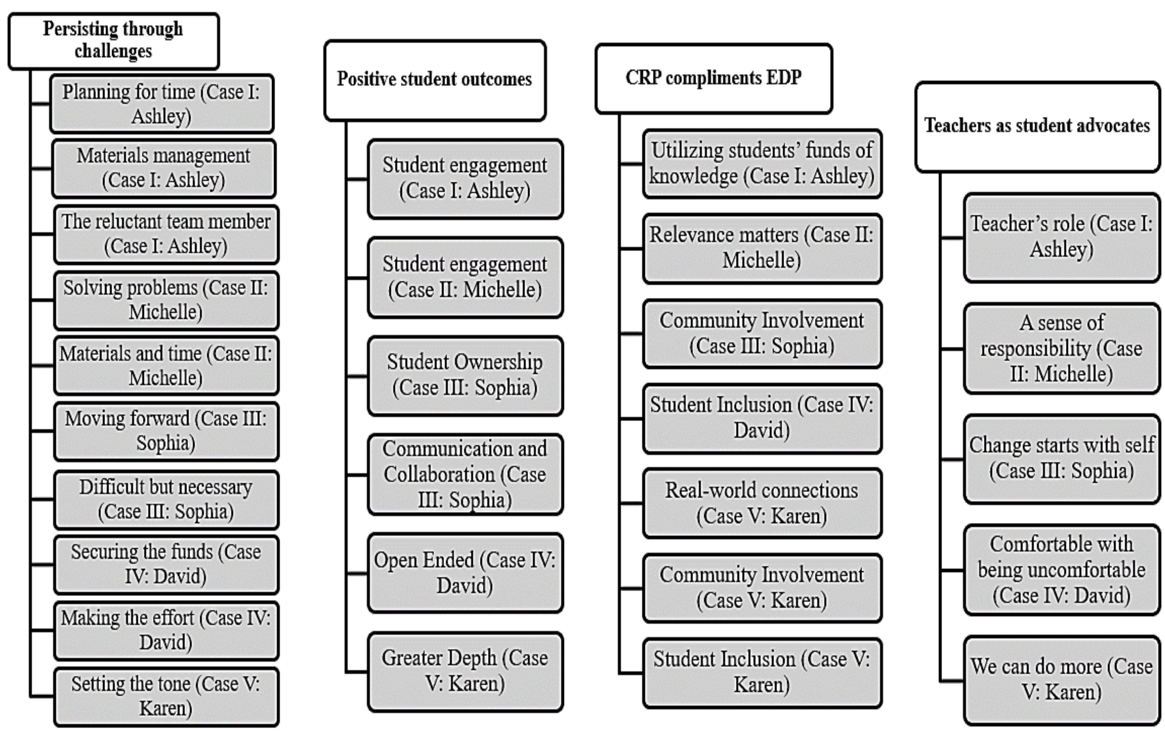

Figure 8. Emergent themes and meta-patterns analyzed through cross-case analysis.

Emerging Pattern: Persisting through challenges. The most prominent pattern that emerged upon examining the themes and nodes analyzed throughout the cases, was the persistence with which teachers met, and, are willing to meet, challenges. The themes and nodes associated with this pattern especially stood out under the teacher agency categories of forethought, and self-reactiveness. Thus, these findings provide insight on how teachers plan to enact their intentionality for instruction inclusive of the engineering design process (EDP) and culturally responsive pedagogy (CRP). Also, the patterns discussed highlight how teachers plan to persevere in the face of obstacles. The challenges teachers shared include lack of instructional time, high cost of materials, and working with reluctant colleagues. However, outside of the commonality that all teachers faced similar challenges, what emerged was the way in which teachers self-reacted and continued to implement the innovative instructional approaches.

During her interview, Ashley shared that due to a lack of time she was unable to conduct the project to its full potential. Specifically, she explained that she was unable to include time for classroom discussion about prototype improvements. However, Ashley shared that in the future she plans to allot for the next year. She also stated that it was difficult to manage the chaos in her classroom due to the "messy" nature of EDP which involves building and using materials [Ashley, int]. However, she explained that the mess was something she needed to embrace instead of fear, stating, "I think after this year I've decided that I'm going to be okay with a messy room." [Ashley, int].

All five teachers shared experiences with reluctant team members, and, outside of Karen, the other teacher participants were unable to convince all of their colleagues to integrate their projects. Nevertheless, the teachers shared their intentionality and plans for involving their team members in future implementations. Sophia noted that since she is the youngest member on her team. However, as the interview continued, she shared that perhaps her team members may be open to the project if they were presented with information about the pedagogical constructs first.

Furthermore, the teacher participants found that having experienced the project for themselves, they are now equipped with student outcomes and positive experiences which will allow them to challenge the reluctance of their team members. Ashley stated the following about her team members:

> I think that she didn't see the students running to the cafeteria, so excited about their projects, and she didn't see the buy-in that my academic students had. I think maybe if she had seen that, if I had been a little clearer about how they were doing with it, that maybe she would be a little more interested. [Ashley, int].

Cost of materials was another obstacle many of the teachers encountered. Both Michelle and David shared their plans for raising the necessary funds for future projects. For David, this entails involvement and support of his principal, whom he repeatedly presented the project to and shared the positive student benefits accomplished through EDP and CRP. David admitted in his interview that he wasn’t sure if his efforts would prevail, however, merely two weeks before the planned enactment of the project, he was able to obtain school approval and funding for the project. David shared that he has already started planning for crowd sourcing funds necessary for next year. Similarly, Michelle, who also encountered difficulty when attaining the needed funds for her project, stated that she is looking into donor organizations to help alleviate the costs for future projects.

Although the process of revising curriculum is time consuming, both Sophia and Karen shared their willingness to persist through the amount of effort needed because as noted by Sophia, “…it’s worth it to make the students see the connections and go to the process and practice that process more than just once or twice in a year.” [Sophia, int].

Karen also stated that her curriculum needs revision specifically for the purpose of incorporating the EDP and CRP into curricula. She admitted she wasn't confident in her ability to write such curriculum, but she asserted her willingness to keep striving for improvement. She explained, "Am I completely comfortable with implementing both of them at this point? No. But am I willing to try and make an effort and do it, yes. Because I mean I see where this can all go." [Karen, int].

Emerging Pattern: Positive student outcomes. The next common pattern noted among the coded themes was positive student outcomes. This pattern emerged through teachers reflecting upon how the fall 2018 project varied from those they conducted in years past. Specifically, the teachers were asked about how, in their opinion, the incorporation of the EDP and CRP transformed the project. All five teachers shared that they noticed a huge difference in how students responded, and the products generated. David recalled his thoughts from when he was in the process of implementing the project, "It was one of those days. It was like, "We should have been doing this a long time ago." [David, int].

Sophia reflected on the how the incorporation of these two constructs led to more student ownership, and, therefore, more creativity:

> It was overall a really positive change that I made to the project. I enjoyed it because I got to see some buildings that I had never even heard of before because a lot of times I've done this project maybe the last three or four year and I get the same ones over and over…it really blew my mind to some of the things that the students found. [Sophia, int].

Similarly, Ashley shared how strikingly different the student reactions and involvement were during the redesigned project. She explained that in the past, teachers including herself, would conduct demonstrations about insulators and conductors, followed by station activities. According to Ashley, although students received some hands-on exploration, it did not instill the level of excitement and ownership the fall 2018 project provided through inclusion of the EDP and CRP.

> It was night and day. What ended up happening was much more student centered than it had been previously… This time, I mean, it was all student driven, so it was very, very different this time." [Ashley, int].

Michelle, also, found herself pleasantly surprised at the level of transformation that took place in the project and student experience due to the changes she made to instill principles of engineering design and CRP. "It changed so much more than I even realized it would." [Michelle, int]. Michelle explained that her school had a 3D printer that was seldom utilized prior to this project. However, as a result of this project, students, who ordinarily would not take a class assignment seriously, were deeply immersed in building their prototypes in an effort to develop prosthetics for kids in need. Meanwhile, Karen was astonished by the increase in content acquisition from her students. She not only found that the project had more relevance to students, but she also felt that the mastery of topics, compared to that of students from previous years, was significantly improved:

> To me, it made it purposeful, meaningful. Like I said, I think that they - not I don't think, I know that they got more out of it this time. Last time, they had fun. It was a great fun project; they enjoyed it, and everything. But this time, they walked away with greater knowledge about Newton's laws. They had a head knowledge of the laws, but now they actually got to see them in action, and it was really cool. [Karen, int].

Emerging Pattern: CRP compliments EDP. During interviews, each teacher was asked about whether they found the pedagogical approaches to have a connection, especially as it relates to their content instruction. All the teachers stated that they did find the two to be connected, and, what stood out even more than their affirmation of this, was the way in which they described the relationship. Overall, the teachers seemed to believe that while it is possible to incorporate CRP without doing engineering design related projects, the EDP certainly benefits from a culturally relevant context. So much so, that as Karen described, it is hard to imagine EDP without CRP. “I guess you could do CRP by itself and never do the engineering process. But I don't think you can do the engineering process and not have the CRP.” [Karen, int]. Karen, Michelle, and Sophia shared that most conducive phase to interlace CRP and EDP would be through the cultural contextualization of the problem. This assertion supports the arguments posited by Householder (2013) who also advocated for framing the problem around the culture of the study population. Michelle further explained the connectivity between the EDP and CRP:

> There’s definitely a connection and maybe that’s the connection, is that there is cultural problems, there is – whether it’s race, gender, you know generational culture, whatever, there are issues…This is our culture and these are the things that we’re identifying the problem in those and then okay, let’s use engineering design process in our science concept to address those issues. [Michelle, int].

David also found there to be a harmonious relationship between the two approaches. “I did see a big-time connection between the both. Especially with that one group that I was speaking of where they didn’t see themselves represented.” [David, int]. In this quote, David is referencing two students who, when asked to identify famous engineers whom they perceived as representative of themselves, were not able to do so. The students shared that this was due to the scarcity of prominent people of color in the field of engineering. David also explained other ways in which he incorporated CRP in his curricula. However, when it came to engineering design, David, much like the other teacher participants, also argued that the EDP benefits from a culturally relevant context.

Emerging Pattern: Teachers as student advocates. A common theme among all the teachers was a desire to advocate and work towards change in an effort to provide students with instruction that is inclusive of cultural relevance and engineering-design. This advocacy for students was especially noted for inclusion of those students who are enrolled in on-level or "Academic" sections of the course.

> "…my academic students are fully capable of everything that any other student in the school is capable of. They were all in, they loved it, and I think they felt heard and they felt like they had a voice, or maybe some empowerment. I think taking that and trying to replicate that in any way that I can, it's going to be the next step for me, for sure." [Ashley, int].

Teacher participants shared that their colleagues found the project to be of value, however, they shared reluctance to implement such instruction with the academic students:

> I had to really fight with my team for this activity to be done as I created with our Academic students. They wanted to offer an alternative activity for these students because they thought it would be "too difficult" for them. [Karen, rje].

> They were scared. Like, "No, we're not bringing screwdrivers and want anybody hurt." And I'm just like, "Man, just safeguard, you can do it…You know the first-year teachers and the second year were like, "No, we're not gonna. We don't know that. That's too new for us." And the older teachers, they're like, "No. We're just this is us. This is who we are. We're stuck in our ways." [David, int].

Karen, David, and Ashley were able to utilize their projects with both academic and pre-ap students. Karen did so through her on-level sections, along with those of her team members. Meanwhile, David and Ashley implemented the project with both, their Pre-AP, and, on-level students. Each of them shared that the best results were produced from students enrolled in the academic coursework.

Michelle explained her reasoning for not including her academic section, while also expressing regret for making that decision:

> "Looking back though, I really do regret not doing it… it's not that I doubt their abilities, I think it's because I doubt my ability to scaffold. I'm still learning

> engineering design process myself. So, I'm like how am I supposed to scaffold something that I still don't know exactly how it looks like pulled off? And so a lot of my academic kids were like, "Why are we not doing this?" And I'm like "Argh." Like my heart is like argh. I'm never doing that again." [Michelle, int].

Sophia, unlike the other participants in this research, only teaches Pre-AP sections. She shared that her colleagues were not open to the idea of using the project with their on-level. Still, she shared her intent and desire to advocate for the pedagogical approaches during the next implementation:

> I'm definitely gonna start with me, my own lessons and things. I'm more confident in my ability to accept those changes and to want to implement them. I'm motivated to do all those things but I do know that eventually I need other teachers to take hold of that as well. It doesn't just need to be pre-AP, it's gonna take a whole school. [Sophia, int].

Member Checking

In accordance with the recommendations of Harvey (2015) the member checking was conducted through synthesis of analyzed data. The teachers were provided with their individual cases and the cross-case analysis for review. In addition to the opportunity for editing any of their quotes for clarity, the teachers were also asked the following questions (Harvey, 2015):

> Question 1. Do the findings match your experience?
>
> Question 2. Do you want to change anything? If so, feel free to share it in this response or make edits via track changes in the document.
>
> Question 3. Do you want to add anything?

All of the teacher participants reported that the findings were representative of their experiences. The teachers edited their quotes from the interviews for grammar and clarity, although, their edits did not alter the intention and meaning behind the statements. Ashley and Michelle noted some technical details in their teacher profile. Michelle clarified the organizations she serves on and Ashley noted specifics about her teacher of the year awards. David responded to the third question and emphasized that he intends to incorporate the EDP and CRP in his class moving forward. The remaining teachers did not have any additional information to add.

Summary

The findings in this chapter addressed the beliefs and agentic behaviors of secondary mathematics and science teachers upon implementation of a project they revised to include the engineering design process (EDP) and culturally responsive pedagogy (CRP). The teacher participants in this study were selected from a cohort of teachers enrolled in an NSF funded five-year, fellowship program inclusive of a master's degree in STEM education and professional development. The projects were developed during a summer 2018 course titled "Fundamentals of Engineering Design" and were enacted by the teacher participants during the fall 2018 semester. Teachers shared their beliefs and reflections of the experience through qualitative data sources including, teaching philosophy statements, reflective journal entries, and semi-structured individual interview responses. Teachers also participated in quantitative surveys which provided additional insights about their beliefs regarding each pedagogical construct. The findings in this chapter are presented through teacher participants' individual cases, and, cross-case analysis. The author reported emergent themes for each case and analyzed those themes to identify meta-patterns across the cases.

While the survey results provided some insight, they essentially confirmed the findings derived from the qualitative data sources. Based upon the scores and mean values (see tables 4.6 and 4.7) teachers were fundamentally in agreement with each other on the survey items. This can be explained given that the teachers are in a cohort together through an NSF funded master's degree and professional development program. Their selection for this program included their embrace and commitment towards student-centered instruction. Thus, the like-mindedness of the teachers in this study explains the lack of variation in their responses for the quantitative and qualitative responses data sources. All the beliefs expressed by teachers about the pedagogical approaches were centered on the positive student outcomes achieved through the integration of CRP and the EDP. This is also explained by the participants' shared philosophies of teaching that were reviewed as during the fellowship program selection process. Still, the beliefs and sense of agency of these teachers is of value because they are highly motivated and clearly able to finds ways to persistent in face of challenges. Moreover, the positive student learning outcomes the teacher participants identified as a result of these pedagogical approaches are of significance. The findings support researchers' assertion that teacher beliefs regarding pedagogical approach matter because they drive the instructional practices and decisions (Pajares, 1992; Polat, 2010; Siwatu, 2007; Vartuli, 1999). Therefore, it is important to examine teachers' experiences with these novel pedagogical approaches. The way in which teachers respond to, and perceive, the instruction holds implications for professional development providers, stakeholders, and researchers. Accordingly, these implications, along with recommendations, contributions to literature, and conclusions, are presented in chapter five.

CHAPTER V

DISCUSSION

Overview of purpose and research questions

This study examines the beliefs and agency of teachers upon implementation of new instructional practices. Specifically, the study involves secondary mathematics and science teachers who incorporated the engineering design process (EDP) and culturally responsive pedagogy (CRP) in their content curricula. The participating teachers are part of a prestigious NSF funded program called the Leadership through Equity and Advocacy Development (LEAD) Houston Fellowship at the University of Houston. As part of their experience, selected teachers pursue a funded master's degree with concentration in STEM education followed by four subsequent years of professional development. The selection process for the fellowship is highly competitive and seeks to recruit secondary STEM educators who are interested in pursuing leadership roles and endeavors while remaining in the classroom. The participants for this study were selected from the pool of 15 LEAD Houston fellows, all of whom were invited to participate. Based on their responses to the recruitment form, five teachers were selected to participate. These teachers indicated that they planned to integrate CRP and EDP during the fall of 2018, and, thus, fit the timeline for this research.

During their first summer of graduate coursework the teachers enrolled in a course that introduced them to CRP, followed by a course titled Fundamentals of Engineering Design. The latter provided an introduction to the EDP, through first-hand exposure with engineering design projects. Teachers also engaged in discussion about literature on the integration of the EDP in mathematics and science curricula. As a final assignment the teachers revisited a project they previously used in their classroom to incorporate EDP and CRP. Teachers self-assessed their projects with the Culturally Responsive Mathematics/Science Teaching (CRM/ST) rubric, originated by Aguirre and Zavala (2013). Teachers were also asked to provide evidence for each of the steps in the engineering design process as illustrated in the prominent engineering design cycle produced by the Massachusetts Department of Education (2006) (Massachusetts DOE, 2006; Portsmore et al., 2010). This sequence of the EDP aligns with the iterative cycle defined by the authors of the Design, Engineering, and Technology (DET) survey that is utilized as a quantitative instrument in this research (Yasar et al., 2006).

This research focuses on beliefs and human agency as posited by Bandura (1977, 1986, 2001) through his work on the social cognitive theory. Bandura explained that human behaviors produce actions which are guided by beliefs (Bandura, 1986, 1997). Beliefs are indicative of how one perceives their ability to accomplish tasks and utilize skills. Additionally, these beliefs also include the values and outcome expectations one associates with those tasks and skills (Bandura, 1997; Pajares, 2002). Beliefs are, therefore, at the core of human agency which includes the self-regulated behaviors that allow one to take the necessary actions to yield desired outcomes (Bandura, 2006). These agentic behaviors include intentionality and forethought which guide the planning for action, as well as, self-reactiveness and self-reflection which allow individuals to preserve through challenges and self-examine their progress (Bandura, 2001).

The beliefs and agentic behaviors of teachers matter because they are the guiding force behind instructional decisions and actions (Pajares, 1992; Rokeach, 1968; Siwatu, 2007; Vartuli, 1999). There is a sufficient amount of research on the topics of the EDP and CRP that supports the positive student outcomes associated with each approach (see, Cochran-Smith, Davis, & Fries, 2004; Daugherty, 2012; Gay, 2000; Katehi et al., 2009; Ladson-Billings, 2009; NAE, 2008). However, much like other prominent instructional strategies, the response, beliefs, and understanding teachers have about the techniques is largely overlooked (De Floria, 2016). This is problematic given that teachers are the most integral factor in any type of curricular reform, and, therefore, their beliefs and sense of agency matter. Accordingly, the findings from this research will add to the significant gap in literature surrounding how teachers perceive EDP and CRP upon implementation. Moreover, through examination of agentic behaviors, the author uncovers the motivating factors that drive teachers' intentionality to move forward with future integrations. The findings also provide insights regarding the barriers encountered and how the participating teachers persevered in the face of those challenges.

The teacher participants completed reflective journal entries regarding their beliefs and perceptions about the implementation process, shared teaching philosophy statements, and were interviewed individually. These qualitative data sources were combined with quantitative survey results from the DET survey, and, the Culturally Responsive Teaching Outcome Expectancy (CRTOE) survey (Siwatu, 2007; Yasar et al., 2006). Saldaña's (2013) coding techniques were utilized for qualitative analysis to identify emerging themes in each case. The thematic codes were then analyzed to identify meta-patterns across the cases. The descriptive statistics derived from the quantitative instruments served to provide additional insight regarding teacher beliefs during the cross-case analysis. Below are the research questions that guided the methodology, and, are situated in the theoretical underpinnings of social cognitive theory (Bandura, 1977, 2001):

RQ 1. How, and in what ways, are secondary mathematics and science teacher pedagogical beliefs and sense of agency related to the integration of the engineering design process and culturally responsive pedagogy within their content curricula?

RQ 1a. What are the pedagogical beliefs that secondary mathematics and science teachers self-report regarding EDP and CRP upon implementation of both constructs in the classroom?

RQ 1b. How are the core features of Bandura's human agency (intentionality, forethought, self-reactiveness, and self-reflectiveness) of secondary mathematics and science teachers shaped upon implementation of EDP and CRP in their classrooms?

RQ 1c. How do secondary mathematics and science teachers describe the value of EDP and CRP as it relates to their classroom content?

RQ 1d. What barriers do secondary mathematics and science teachers experience during implementation of CRP and EDP, and, how do they persevere in face of challenges?

RQ 1e. How do secondary mathematics and science teachers perceive their own role in the movement to implement CRP and EDP in secondary science and mathematics curricula?

Summary of Findings that Support Literature

Pedagogical Beliefs about CRP and EDP

The teachers defined the pedagogical constructs of culturally responsive pedagogy (CRP) and the engineering design process (EDP) during their reflective journal posts and individual interviews. The definitions remained consistent between the data sources and were also common in language between the participants. For instance, teachers described the EDP as an iterative cycle inclusive of identifying a problem, brainstorming solutions, followed by, designing prototypes, and redesigning as needed to reach a solution (Katehi et al., 2009; Massachusetts DOE, 2006; Yasar et al., 2006). Meanwhile, CRP was defined by teachers as a philosophy centered on students' cultural backgrounds and life-experiences that are incorporated into instructional content to build relevance and utilize students' funds of knowledge (Aguirre & Zavala, 2013; Gutiérrez, 2009; Siwatu, 2007, 2011). The shared language and understanding of the constructs is expected given that the teachers experienced a common introduction to the pedagogical approaches through their master's coursework. Still, upon completing the summer courses, each teacher returned to their individual school/district and implemented the project that was personalized to fit their content curricula. Teachers also experienced varying levels of support from administrators and team members at their schools. As such, capturing their beliefs about the pedagogical constructs after implementation was important because they reflect their definitions shaped through experience. Moreover, doing so, also allowed for teachers to reflect upon their perceived success, and, the value they associate with CRP and the EDP upon viewing student outcomes.

The Engineering Design Process (EDP). The definitions teachers provided for EDP were consistent with those rooted in literature (Hynes et al., 2011; Yasar et al., 2006). The teachers described the steps which include defining the problem (Cross & Roozenbvurg, 1993), researching solutions, identifying constraints, building prototypes, testing, redesigning, and communicating solutions (Massachusetts DOE, 2006). One of the participants, Michelle, discussed helping her students acknowledge the value in their prototypes even when the products did not function properly. She shared that she had her students verbalize all the ways in which their prototype was successful and reflect on lessons learned along the way. This is in alignment with research that argues the EDP can foster a sense of perseverance in students through the design and redesign steps involved in the experience. (Lotterro-Perdue & Parry, 2016). The iterative nature of engineering-design assumes that the first few prototypes will not function successfully or provide the best solution to the identified problem (Cunningham & Carlson, 2014). This process of failing and moving forward is productive as students and engineers learn and obtain data through trial (Lotterro-Perdue & Parry, 2016). Petroski (2012) explained the role failure in the field of engineering and the EDP:

> Because every successful design is the anticipation and obviation of failure, every new failure no matter how seemingly benign presents a further means towards a fuller understanding of how to achieve a fuller success. (p. 45)

Thus, the experiences acquired through the EDP encourage students and teachers to embody a growth mindset, defined by Ricci (2012) as “a belief system that suggest one’s intelligence, or skills, or talents, can be grown or developed with persistence effort, and focus on learning” (p. 3). Growth mindset has proven to yield positive student learning outcomes through enhanced academic performance in the classroom (Blackwell, Trzesniewski, & Dweck, 2007). The EDP cultivates a growth mindset through student engagement with “test to failure experimentation” (Lotterro-Perdue & Parry, 2016, p. 50). Accordingly, the *Framework for K–12 Science Education* has specifically included testing for failure as one of the core ideas found in k-12 science and engineering practices (NGSS Lead States, 2012; NRC, 2012):

> Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. (NGSS Lead States, 2013)

All the teacher participants stated that they observed high levels of student engagement and creativity during the course of the projects. Overall, the teachers found themselves pleasantly surprised regarding the increase in student involvement through participation in the EDP. David expressed that the feedback from his students led him to wish that the he had learned about, and incorporated, EDP earlier in his teaching career. Similarly, all teacher participants also shared that they witnessed heightened levels of engagement in students who otherwise lacked interest in daily instruction. Therefore, due to the creativity and student ownership resulting from the EDP projects, students were more likely to experience positive attitudes towards content topics (Goeser et al., 2009).

David discussed a student in his class who was deeply immersed in the sketching and development of her prototype designs. However, David noted that after the project concluded, this student returned to previous behavioral characteristics, which meant lower levels of engagement and involvement in the classroom. Hence, the utilization of the EDP as a vehicle for teaching mathematics or science content provided a hands-on alternative to routine-based, traditionalistic teaching practices (Hynes et al., 2011). Furthermore, the iterative nature of EDP naturally allowed for the incorporation of scientific reasoning and mathematical problem- solving (Lachapelle & Cunningham, 2014; NGSS Lead States, 2013). Consequently, the secondary mathematics and science teacher participants in this research affirmed the positive student outcomes associated with the EDP. These beliefs were also reflected in the overwhelmingly positive responses expressed by the teachers regarding future use of the recently implemented project, along with, future integration of the EDP in their content curricula.

Culturally Responsive Pedagogy (CRP). When asked to define CRP all teachers emphasized the value in learning about their students' backgrounds. The teachers explained that doing so would allow them to tailor their instruction by connecting the students' lived experiences to content topics. This concept of building relevance with students is an integral component mentioned in scholarly definitions of CRP (see, Gay, 2002; Irvine, 2002; Ladson-Billings, 1995, 2009). Sophia shared that she planned to survey her students to use specific pieces of their cultural and family background into her projects. This is reminiscent of the community mapping project described by Jackson & Bryson (2018). Community mapping is an activity through which current and prospective teachers can include walks around the neighborhood and engage in conversations with local residents. The purpose of the exercise is to provide teachers with insights about students' culture and their life experiences outside of school (Jackson & Bryson, 2018). The value of cultivating relevance is grounded in CRP research and was prevalent in this dissertation study through the teacher participants' responses about their beliefs. This was also evidenced through the teachers' high scores and mean values resulting from the culturally responsive teaching outcome expectancy (CRTOE) survey responses (see tables 4.4 and 4.5).

Furthermore, as David's students learned, the STEM workforce is not always representative of a diverse student body. David asked his students to develop social media profiles for famous engineers to whom they could relate. Some of the students, specifically those of color, struggled to do so, and, one ultimately developed a profile with a silhouette to recognize the lack of diversity in the field of engineering. In the U.S. only 4.3% and 7.0% of all engineers self-identify as part of African-American and Latinx populations, respectively (NSF, 2017). This student's personal crisis with the STEM workforce was an important realization for him to have as it led him to acknowledge the disparity in the field, and, aspire to change the national statistics. It is this disproportionate representation of Black and Latinx populations that scholars have cited as a vital reason for taking into account the cultural and linguistic background of students (Aguirre & Zavala, 2013; Gutiérrez, 2009; Gutstein, 2006; Siwatu, 2011).

Although David's project did yield conversations about race and representation in STEM, absent from the CRP integration in all projects was a strong focus on social justice. Ladson-Billings (1994) defined CRP through three prominent tenets for instructional practices: 1) upholding high expectations for all students; 2) guiding students through the development of their cultural competence; and 3) fostering a sense of critical sociopolitical and cultural consciousness in students. The third outcome described by Ladson-Billings (1994) involves the development of critical consciousness which fosters the cultivation of an individual's sociopolitical awareness through cultural, social, and political engagement (Mustakova-Possardt, 1998). CRP empowers students to identify and tackle the injustices and inequities that impact their lives, and, represent the experiences of disenfranchised populations (Aguirre, 2009). Consequently, social justice has gained traction as an integral component of culturally responsive instruction, especially in the field of mathematics (Aguirre, 2009; Gutiérrez, 2009; Gutstein, 2006). The incorporation of CRP in mathematics concepts has shown to tackle a variety of topics ranging from the institutionalization of racism in mortgage lending practices (see, Gutstein, 2006) to the use of quantitative analysis to challenge a school district's decision for closing a neighborhood school (see, Varley-Gutierrez, 2011). Consequently, for teachers to embody the aspect of CRP that encourages social justice, they must acknowledge that teaching their content is a political, rather than neutral, exercise (Aguirre & Zavala, 2013).

Some of the projects designed by the participating teachers addressed social inequities in terms of access to resources and lack of diversity in the STEM workforce. Still, the socio-political consciousness was not directly evidenced in any of the projects. During the summer course and planning for the project, teachers were asked to align their projects with the eight dimensions of the culturally responsive mathematics and science teaching (CRM/ST) lesson analysis tool, originated by Aguirre & Zavala (2013). See figure 5. The teachers all indicated that their projects met the cultural competence category which ensured the lesson utilized students' funds of knowledge, culture, and community support. Additionally, this competency was evident throughout the themes and meta-patterns identified in this research. Still, the use of critical knowledge to address social justice was lacking in the projects, and, therefore, not indicated on the teachers' alignment to the CRM/ST rubric. However, that is to be expected provided that this was the teachers' first year in the master's degree program and fellowship. Therefore, the projects were based upon their initial introductions to CRP, and representative of their first attempt at integration.

While the projects teachers designed did not include social justice at this juncture, the concept of empathy was prevalent throughout student experiences and teacher self-reflections. Ashley's project allowed students to acknowledge that they lack access to warm meals, unless purchased, at their school. They developed prototypes for insulative-heaters which the students tested by self-utilization of food brought from home. Given that Ashley's school has no microwaves in the cafeteria, her students expressed that they were happy to have developed their protype. Students explained that, prior to doing so, many of them were consuming cold meals for lunch. In this case, the students were able to reflect upon how the topics in their science class can be used to provide access to resources for their community. Karen's students had a similar realization as they were given the option to develop a heavy load carrier for the librarian or the coaching staff. Students felt so motivated to help their selected recipient that many asked if they would ultimately scale their prototype to size to ensure that they could truly be of service. Additionally, Michelle shared that her students were deeply motivated by the concept of developing prosthetic models for veterans and others in need. She explained that her students researched additional disabilities, beyond those included in the assignment, and began brainstorming prototypes that would make life easier for those individuals.

This desire from the participating teachers to incorporate a sense of service in their students contributes towards the research offered by McAlister & Irvine (2002) on the role of empathy in CRP. An empathetic disposition on behalf of the teachers is a quality that researchers have associated with effective instructional practices especially in urban and diverse school settings (Darling Hammond, 2000; Gordon, 1999). This quality allows individuals to foster sensitivity towards other cultures and approach situations by bearing others' perspectives and experiences in mind (Goleman, 1998). McAlister & Irvine (2002) further explained the impact of empathetic teachers in diverse classrooms by stating the following:

> Teachers are better able to modify pedagogy and curricula to fit their students' needs, such as the teacher who changed a classroom ritual to be more comfortable for her Vietnamese students by simply offering her students multiple ways to say

> goodbye rather than obliging them to hug her before they left the classroom. (p. 2002).

The participating teachers' willingness to promote these qualities in their students is a reflection in what they value within themselves. The teachers shared the need to utilize their students' funds of knowledge, experiences outside of school, and cultural backgrounds when designing curricula. Additionally, they expressed that they felt connected to their students, even those who aren't engaged. The teachers reiterated throughout their interview and reflective journal entries their desire to spark students' interest and creativity in STEM related topics. Hence, the teachers emphasized the need for culturally responsive instruction, not only for the students enrolled in advanced courses, but, even more so, for the students in their on-level or academic classes. The teachers advocated for these students in front of colleagues who felt the integration of CRP and the EDP would be better suited for high-performing students. Moreover, teachers stated that they felt inspired by the results from the project, which indicated not only improvement in academic performance, but, also, involvement from students who otherwise remained on the sidelines of the classroom. Consequently, the findings from this research support the notion that the empathic disposition of teachers allows them to make efforts in utilizing their students' funds of knowledge (McAllister & Irvine, 2009). Furthermore, the findings suggest that emphatic teachers are likely to design and value instruction that fosters a sense of service in students.

Teacher Agency

In addition to beliefs about novel pedagogical approaches this research also investigated the four properties of human agency (Bandura, 2001) as they relate to the teacher participants' implementation of novel instructional practices. Bandura presented an agentic perspective regarding human development, adaptation, and change (Bandura, 1986, 2001). Bandura (2006) explained that humans are unique in their ability to intentionally influence the quality of life experiences through self-guided actions and behaviors.

> People are self-organizing, proactive, self-regulating, and self-reflecting. They are not simply onlookers of their behavior. They are contributors to their life circumstances, not just products of them. (Bandura, 2006, p.164).

The operating factors of human functioning are rooted in the beliefs one holds regarding their ability influence actions that produce desired outcomes (Bandura, 2001). Therefore, it is essential to examine the specific behaviors that occur during the planning and enactment of said actions. Bandura theorized agentic behaviors through four core properties: intentionality, forethought, self-reactiveness, and self-reflection (Bandura, 2001). Intentionality includes the action plans and strategies one forms when setting goals. A forethoughtful perspective extends beyond planning and entails the visualization of anticipatory outcomes which guides future efforts. The third category of agency is self-reactiveness, individuals enact the intended action plans and self-govern their reactions to reactions towards challenges. The fourth and final property of agency is self-reflectiveness, which argues that humans not only plan and enact actions, but, also, self-examine their functionality.

The intentionality of the teachers in this study was measured not only in terms of the action plans that resulted in the current implementation, but, also, strategic planning towards future curricular integrations of culturally responsive pedagogy (CRP) and the engineering design process (EDP). All teachers unequivocally confirmed that they would continue with efforts to employ the instructional practices in future lessons. They also described specific plans regarding the units and lessons they want to redesign through infusion of CRP and the EDP. Furthermore, the teachers shared their forethoughtful perspective by explaining that the change they witnessed in their students' through heightened engagement was a motivating factor to continue with the planning and enactment of instruction through the EDP and CRP.

When discussing their self-reactiveness, the teachers shared the types of obstacles encountered and how they self-regulated their actions to meet those challenges. A common barrier that teachers encounter when integrating projects with the EDP is a lack of resources to afford materials for building prototypes (Cullum, Hailey, Householder, Merrill & Dorward, 2008). David's school has a new principal and since her arrival David has conducted meetings to share with her the value of engineering design and gain administrative support for funding. Similarly, Ashley is also working with her school administrators to attain funding for materials needed to build prototype for future projects. Meanwhile, Michelle shared that she is currently looking into online platforms that provide teachers with financial assistance and scholarships to use towards classroom materials. Overall, the teachers faced with this challenge did not seem concerned that this limitation would obstruct their plans moving forward. Instead, the teachers demonstrated their determination to persevere by immediately working towards solutions.

Another challenge the participating teachers encountered was the reluctance of their team members to incorporate the project inclusive of CRP and the EDP. Scholars have argued that in order for teachers to foster culturally responsive instruction it is imperative that they first believe all of their students can succeed (Gay, 2000, Howard, 2003, Ladson-Billings, 1994). Accordingly, the teachers felt compelled to advocate for students who were dismissed and underestimated by their colleagues. Karen's colleagues argued about whether students in the on-level classes were capable of completing the project successfully. However, through multiple discussions she was able to convince them that the project and constructs were, in fact, suitable for all students. Similarly, all teachers discussed advocating for the inclusion of students enrolled in academic (on-level) classes. Ashley, Karen and David implemented the project with their Pre-AP and academic students. They shared that the best products were designed by students from their academic sections.

Teacher participants were also critical of their own ability to ensure that all students received opportunities for engagement with CRP and the EDP. For instance, Michelle did not use the project with her academic students because she was unsure of how they would react to it, and, whether it would be a successful implementation. However, she expressed deep regret upon witnessing the impact the project had on her Pre-AP students, along with receiving questions from her academic students who inquired why they weren't allowed the same opportunity. Michelle stated that she was never going to leave her academic students out of a CRP or EDP project again. Sophia only teaches Pre-AP and explained that she did not share the project with her colleagues out of fear of their reaction. Nevertheless, she also regretted not being able to offer the opportunity to the academic students and stated that she would do so in the future. The encounters teachers experienced when collaborating with their colleagues are reflective of Bandura's assertions regarding collective agency (Bandura, 2006). While agents possess control over their life circumstances, they do not function in total autonomy.

Many goals are achievable at a great level through interdependent efforts. This is true of the teacher participants advocating for CRP and EDP with their team members in an effort to ensure all students in the grade level experience the pedagogical approaches.

Teacher-education programs interested in the development of culturally responsive teachers are urged to incorporate opportunities that cultivate reflective educators who are mindful of their own beliefs and attitudes as they relate to instructional practices (Cochran-Smith, 2004). Moreover, critical reflection includes questioning the decisions, actions, and behaviors one makes during the planning and enactment of instruction (Schwartz, 1996). Thus, through discussions about their experiences and beliefs, the teacher participants actively engaged in the fourth and final core property of human agency, self-reflection (Bandura, 2001). A reflective disposition was evidenced through their candid statements regarding setbacks and struggles encountered. The teacher participants acknowledged that they are still learning how to appropriately implement the constructs of CRP and the EDP in their instruction. The teachers admitted that they are not experts in the either field, but, emphasized that they believe in the value associated with the approaches. Moreover, the teachers asserted that they aspire to share their efforts and experiences through professional development designed for fellow teachers and conference presentations. Karen has already submitted proposals to embark on this next venture in the process and the other participating teachers established intentionality for doing so in the future. Still, as Sophia mentioned, all routes to change start with her own classroom, as such, she feels compelled, much like the other teachers, to continue furthering her own development.

These findings support Bandura's assertions about agentic behaviors (Bandura, 1986, 2001, 2006). The beliefs teachers hold about the constructs drive their intentionality to plan for future instructional modules, and, guide the anticipatory outcomes they associate with the constructs. Additionally, the value teachers place on the results produced by CRP and EDP equips them with the motivation to self-regulate through challenges encountered. The teacher participants are reflective of their practices and identify methods for improvement during future implementations. Furthermore, teacher participants recognize that their personal agency is not enough to cultivate the level of change they strive towards. It is because of these beliefs that the teachers feel empowered in their agency to forge the path ahead in curricular reform. Therefore, they are determined to build the collective agency of the teachers in their team, department, and field.

Contributions to Theory

Teachers as Change Agents

The findings from the participating teachers featured in this study support the assertions of past researchers who explained that a human's agency is responsible for governance over one's behavior through actions that are purposeful and reflective (Calabree Barton, 2001; Bandura, 2006; Moore, 2007). The agentic behaviors demonstrated by teacher participants were coded under the four core properties of human agency theorized by Bandura (2001, 2006), Additionally, the author of this dissertation study coded for the pedagogical beliefs that teachers expressed regarding culturally responsive pedagogy (EDP) and engineering design process (EDP). This research also supports Bandura's assertion that beliefs are the foundation of human agency, and, are the core operating factor that influences individual's actions to produce desired outcomes. These self-guided actions, driven by beliefs, allow humans to have agency over their decisions and life circumstances (Bandura, 2001, 2006).

Agency is integral to enactment of change. The concept of teachers' utilizing their agency to cultivate change is rooted in the progressive education movement led by John Dewey (Cobb, 2001). Dewey believed that in order for societies to transform the educational system, the teachers must serve as an agent for the desired change (Dewey, 1932). These views were echoed by philosophers and researchers who helped envision teachers as change agents (Apple, 1978, 1987; Giroux, 1983, 1988). Cobb (2001) further explained the role of a teacher serving in this capacity:

> The teacher who is a change agent believes that schools must not simply perpetuate the present social order but seek to effect change by assuring that all students have the necessary skills for equal access to the job opportunities that, in turn, will provide access to the good life. (p. 91).

This definition is supported by the behaviors and actions of the participating teachers in this research who overwhelmingly argued that not some (i.e. Gifted and Talented), but, all students deserve the opportunity to engage with innovative teaching practices. Moreover, according to Lukacs and Galluzo (2011) teachers serving as 'change agents' are defined by their well-developed pedagogical content knowledge coupled with their sense of responsibility to solve problems in their schools. Thusly, the beliefs and values of the teacher participants in this research indicate that they view their classrooms as more than just a means for science or mathematics content acquisition. Instead, they are utilizing the engineering design process as a vehicle to teach skills such as creativity, problem solving, and collaboration. Furthermore, they are embedding culturally responsive pedagogy to foster empathy towards those in need and developing prototypes that have relevance to their students' experiences.

Teacher leaders versus teacher change agents. Lukacs (2009) explained that while teachers can be leaders in school initiatives that does not necessarily translate to them serving as change agents. For instance, a teacher involved in leading the school or administration agenda might attend meetings bring back pertinent information and tasks for his or her colleagues to implement. However, the teacher who is a change agent will trailblaze an agenda or initiative cultivated through their own agency and creativity. Therefore, while both teachers are leaders, only the latter is a change agent (Lukacs, 2009). Lukacs and Galluzo (2011) provided four defining characteristics as part of the Teacher Change Agent Scale (TCAS) (Lukacs, 2009) to further distinguish teachers who are change agents from those who are school leaders:

> Teacher change agents: 1) can read their school environment; 2) enable the participation of their colleagues in generating solutions; 3) possess the skills to address the problems they identify in their schools; and 4) feel a sense of ownership with regard to those problems. (p. 103).

These agentic characteristics are evidenced in the teacher participants of this research. David, for example, began his interview by explaining that his school had a new principal and that she seemed like the type of leader who can help create a more student-centered environment. David explained that he began meeting with the principal to share the pedagogical approaches he has learned through the fellowship and advocate for funding to support the resources needed for his project. Similarly, Ashley sought out her instructional specialist and shared the engineering notebook developed during her summer coursework on engineering design. This led to conversations with her principal, and ultimately resulted in an opportunity for Ashley to author a brand-new course offered in the fall of 2019. As such, supportive administrative relationships are essential for teachers to effectively exercise their agency (Thoonen et al. 2011; Thurlings et al. 2014).

Not all teachers were successful in garnering the support of their colleagues. Still, all teacher participants established intentionality for continued efforts in seeking cooperation from colleagues. Sophia discussed overcoming the fear of her colleagues refusing to incorporate her ideas because she has less years of experience in comparison to them. Meanwhile, David explained that the turnover his department is expected experience in the coming school year will work to his advantage when recruiting teachers for collaboration. The acknowledgement that there is value in collaboration, not only to meet their own goals, but to further their own professional development is necessary for teacher change agents because they cannot transform education by working alone (Doppenberg et al. 2013; Meirink et al. 2010; van der Heijden, Beijaard, Geldens, & Popeijus, 2018).

Evidence of teacher agency. Due to their participation in the LEAD Houston fellowship, the teachers are equipped with the skills, resources, and support to embark on the journey towards implementing culturally responsive pedagogy (CRP) and the engineering design process (EDP). The teachers were selected for this competitive cohort because of their receptiveness to innovative instructional practices and their desire to dismantle the traditionalistic teacher-centered approaches prevalent in public education. As such, the participants' beliefs and behaviors reflect the assertions that teachers who are change agents have an innate willingness to take on "initiatives due to their desire to sustain interest in their work and create challenges." (van der Heijden, 2018, p. 349). Moreover, the teachers used words like "bold" and "daring" to describe the work they, and, their cohort members, are doing to integrate new instructional approaches into their schools and districts.

Lastly, during the individual interviews, teachers were asked about how they perceive their role in the movement to integrate CRP and EDP in their content instruction, the responses confirmed that the teachers feel a strong sense of responsibility to drive change. Ashely stated that given the results she has witnessed, there is no going back to her previous methods of instruction. Sophia explained, that in her opinion, change starts with her own classroom, which means that she will continue to work towards future curricular integration for her students. Karen shared that she is excited to share these pedagogical practices, and, her experiences with implementation with other teachers. She hopes that by doing so more teachers can join her on this journey. Michelle and David expressed similar sentiments of eagerness to serve, and, willingness to be bold in face of traditional instructional expectations. The ownership demonstrated by these teachers, combined with their efforts to acquire administrative support, and, creatively problems-solve through barriers encountered, supports the attributes associated with teacher change agents by scholars and researchers (see, Angelle & DeHart, 2011; York-Barr & Duke, 2004).

> Coupling this concept of agency, or the drive to action, with change, teacher leaders who behave in the interest of their students, to mitigate and remedy the inherent inequities of the educational system fall under the conceptualization of change agents. (Ali, 2015, p.62).

Student outcomes drive teacher agency. At the core of all the agentic behaviors demonstrated by the teachers featured in this research is their desire to produce outcomes that promote a higher level of student engagement and learning. Figure 9 illustrates student outcomes as the driving force at the heart of the four agentic behaviors identified by Bandura (2001). The power of student outcomes to guide teacher agency was evidenced throughout the themes identified for each case and the meta-patterns recognized during cross-case analysis.

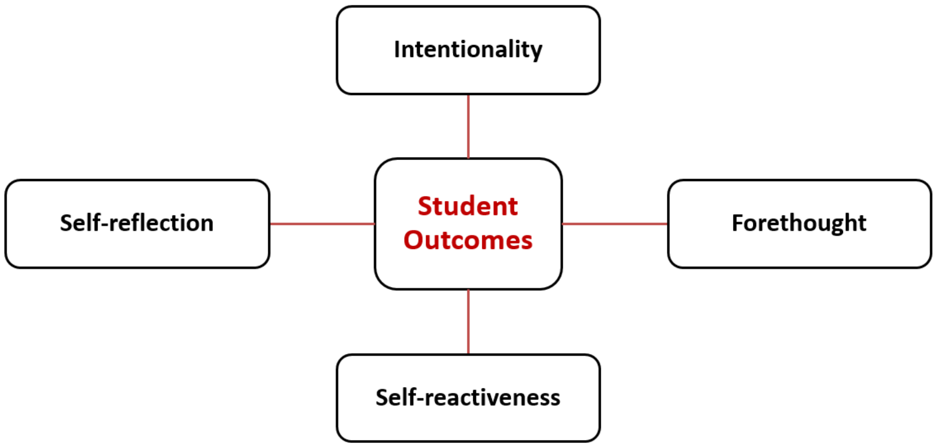

Figure 9. Framework for teacher agents, adapted from Bandura's framework for human agency (Bandura, 2001).

A strong sense of motivation is essential for teacher change agents because they are attempting to transform traditionalistic approaches, and, will be met with challenges that can deter progress. Teacher change agents must remain focused and maintain their intentionality to enact innovative instruction in the face of obstacles, and creatively problem solve as needed. They need to stay determined by the cause that drives their agency and allows for the sustainment of their commitment. Consequently, the agentic behaviors documented in this research support and add to the important research and literature on defining categories and assertions about teachers theorized as change agents.

Contribution to the Field

This research is grounded in the assertion that it is of great significance to examine the ways in which teachers perceive and define new pedagogical approaches upon implementation. The insights provided by teachers have implications for how professional development providers and teacher educators present instructional practices to attain teacher buy-in. Moreover, the beliefs teachers hold about the pedagogical constructs will guide their curricular decisions. Therefore, the pursuit of teachers' endorsement is important because it determines the likelihood of teachers' engaging in the novel practices. It is through investigation of the participating teachers' beliefs that the author uncovered a vital pedagogical perspective that is indicative of how teachers will approach future implementations. The synergistic relationship between culturally responsive pedagogy (CRP) and the engineering design process (EDP) is discussed in this section and contributes to the literature in each field of practice.

The Culturally Responsive Engineering Design Process (CREDP)

Teachers are at the forefront of impacting significant changes in student persistence through enactment of instructional practices that aim to increase the retention of all students especially those from underrepresented minority populations (Castaneda & Mejia, 2018; May & Chubin, 2003). This is needed across all areas of STEM, especially, in the field of engineering given the disproportionate representation of females and minorities (NSF, 2017). To counter the deductive, teacher-centered approaches often prevalent in K-12 and university-level STEM coursework, scholars and researchers have extensively advocated for asset-based approaches in education (Castendeda & Mejia, 2018). Culturally responsive pedagogy (CRP) has gained momentum in recent years due to its focus on inclusivity and attention to student backgrounds (Grimberg & Gummer, 2013). Studies have shown improvement in students' academic performance when the teachers facilitating instruction are employing CRP in their practice and interactions with students. The achievement gains reflect positive outcomes associated with connecting

STEM concepts to topics that are relevant in students' lives and communities (Grimberg & Grummer, 2013).

CRP has accrued prevalence in mathematics instruction (see, Aguirre, 2009; Aguirre & Zavala, 2013; Gutiérrez, 2009; Gutstein, 2006) and has slowly started to make strides in science education (see, Boutte et al., 2010; Ryan, 2008; Serki, 2016). However, the field of engineering education is still lagging in efforts to incorporate curricular reform efforts that can help diversify the field (Castaneda & Mejia, 2018). Although not in a K-12 setting, Castaneda & Mejia (2018) presented a model to connect the three tenets of CRP as defined by Ladson-Billing (1994) with the standards established by the Accreditation Board for Engineering and Technology (ABET) for a civil engineering program, see table 5.1. The authors explained that they were motivated by the research on CRP in mathematics and science classrooms, along with the alarming shortage of females and minorities in the field of engineering. Although this effort for integration is in its early stages, it is of significance provided that dearth of research on the integration of CRP in engineering education (Castaneda & Mejia, 2018).

Table 5.1 Student learning outcomes established by ABET (2015) connected with the three tenets of CRP as defined by Ladson-Billings (1994)

Student Outcome	Description	Tenets of CRP
a	An ability to apply knowledge of mathematics, science, and engineering	I
b	An ability to design and conduct experiments, and to analyze and interpret data	I
c	An ability to design a system, component, or process to meet the desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	I
d	An ability to function on multidisciplinary teams	II
e	An ability to identify, formulate, and solve engineering problems	I
f	An understanding of professional and ethical responsibility	III
g	An ability to communicate effectively	II
h	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	III
i	A recognition of the need for, and an ability to engage in life-long learning	III
j	A knowledge of contemporary issues	I and II
k	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	I

Note: Reprinted from Culturally Relevant Pedagogy: An Approach to Foster Critical Consciousness in Civil Engineering, by Castaneda & Mejia (2018)

The introduction to the field of engineering for K-12 varies between formalized coursework in engineering, and, the integration of fundamental engineering practices referred to as, the engineering design process (EDP) (Apedeo et al., 2008; Katehi et al., 2009; Koehler et al., 2005). The latter approach has gained traction due to the positive student learning outcomes associated with the strategy including heightened student engagement, interest, and achievement in the critical areas of mathematics and science (Haneghan et al., 2015; Katehi et al., 2009). An essential component to the EDP is the identification of a need or problem (Reeve, 2016). The models for the EDP encourage teachers to link the problems students are solving to real-world examples (Householder & Hailey, 2012). By doing so, teachers are able to expose students to the multitude of areas through which engineers extend their impact and are able to make a difference. Moreover, the purpose of real-world connections in the EDP and inquiry-based instruction is to promote relevance in the classroom. Although, for some curricular efforts these connections and problems may be framed around the context of students' cultural and linguistic background, the literature on formalized approaches for doing so is limited. Householder & Hailey (2008) cautioned teachers to steer away from problems that are solely focused on content, and, instead advised that students should "identify engineering problems that arise in their personal lives, in the lives of people they know, or in their schools or communities." (p. 22). The authors argued that the relevance students find through problems that are framed around their lived experiences results in higher levels of engagement and ownership. This notion affirms the arguments set forth to promote culturally responsive pedagogy (Gay, 2000; Ladson-Billing, 1994, 1995).

Consequently, a key pattern and finding that emerged from this research is that upon integration in unison, teachers perceive a strong connection between the pedagogical constructs of culturally responsive pedagogy (CRP) and the engineering design process (EDP). Moreover, while teachers are able to conceive the possibility of implementing CRP in the absence of the EDP, they are unable to do so in reverse. In other words, the value that teachers associate with implementing engineering design through a culturally responsive context is so strong that they are unable to commit to an integration of the EDP without CRP. Although, when asked during the interview if the teachers perceived one construct as more conducive to their classroom than the other, all teachers stated that they found value in both and want to continue incorporating each approach in their content instruction. However, teachers explained that through combined implementation they were able to reap the benefits of both constructs simultaneously. Therefore, based on the findings from this research, formalizing the relationship between the two constructs has the potential to yield greater teacher buy-in which is essential for all curricular reform efforts (Cheng & Hong, 2018). Table 5.1 illustrates Castaneda and Mejia's (2018) efforts to present the ABET student learning outcomes and their relationship to the three tenets of CRP, as defined by Ladson-Billings (1994). The authors provided this framework to offer a method for connecting CRP into college level civil-engineering curriculum. This research confirms the connections asserted by Castaneda and Mejia (2018), and, adds to literature on the integration of CRP in K-12 engineering design. Table 5.2 links the three tenets of CRP with the steps commonly found in prominent versions of EDP (see, Massachusetts DOE, 2006; T-STEM Center, 2008, NASA's BEST, 2016).

Table 5.2 The Engineering Design Process in relation to the three tenets of Culturally Responsive Pedagogy

Steps in Engineering Design Process	Tenets of Culturally Responsive Pedagogy
Identify the problem	Tenet I: Upholding high expectations for all students Tenet II: Guiding students through the development of their cultural competence Tenet III: Fostering a sense of critical sociopolitical and cultural consciousness in students
Brainstorm and research the problem	Tenet I: Upholding high expectations for all students
Develop solutions	Tenet II: Guiding students through the development of their cultural competence
Select best solution	Tenet II: Guiding students through the development of their cultural competence
Create a protype	Tenet I: Upholding high expectations for all students

Table 5. 2. Continued

Steps in Engineering Design Process	Tenets of Culturally Responsive Pedagogy
Test and collect data to evaluate design	Tenet I: Upholding high expectations for all students
Communicate the solution	Tenet II: Guiding students through the development of their cultural competence
Redesign	Tenet II: Guiding students through the development of their cultural competence

CRP Tenet I. Gloria Ladson-Billings (1994, 1995) described in her first tenet for CRP the importance of teachers adopting a mindset that expects all students to become academically successful. She later clarified the term "academically successful" so to differentiate from student outcomes on high stakes standardized tests:

> What I envisioned is more accurately described as 'student learning' what is that students actually know and are able to do as a result of pedagogical interactions with skilled teachers. (Ladson-Billing, 2006, p. 34).

As such, a teacher embodying CRP will need to approach students through an asset-based philosophy (Villegas & Lucas, 2002). This entails viewing students' cultural and linguistic background as an opportunity for involvement in content versus a characteristic that inhibits student potential. The practices in the EDP which include allowing students to identify the problem or need, research the problem, develop, test, and evaluate models for solution, are all grounded in this tenet of CRP. It is important to note that the problem or need students are addressing must be framed around the students' cultural context. This was also identified as an important facet of their projects by all the participating teachers because it allowed for purposeful incorporation of CRP into the EDP. Moreover, providing students with the opportunity to design their own solution or prototype entrusts them with ownership over the problem and enables them to creatively address the problem (Householder & Hailey, 2012; Hynes, 2009). This was evidenced by the teachers' self-reported observations of their students' learning and engagement. Allowing students such experience naturally produces a student-centered classroom. However, it is this nature of the EDP, when employed with cultural relevance to students, that can meet the objectives of tenet I as described by Ladson-Billings (1994). Therefore, it is critical when connecting CRP with the EDP that the problem have a culturally responsive or relevant context.

CRP Tenet II. According to Ladson-Billings (2006) the concept of fostering cultural competence in students is the most challenging component of CRP to convey to educators. Cultural competence does not necessarily mean cultural sensitivity, but, rather, "helping students recognize and honor their own cultural beliefs and practices while acquiring access to the wider culture." (Ladson-Billings, 2006, p. 36). In other words, students are not only learning to be respectful of other cultures, but, truly delving into the intricacies of cultures in a way that builds the conceptualization of their personal and collective cultures. This tenet is associated with students designing solutions to solve a problem or need that is steeped in culturally relevant context. Accordingly, to develop prototypes, conduct data analysis, and communicate solutions, students must be immersed in understanding the cultural and/or linguistic context associated with the project. Providing students with the opportunity to engage in these steps allows for the inclusion of tenet II into the EDP.

CRP Tenet III. Tenet III involves sociocultural and political consciousness. This area of CRP was the least evidenced in the teachers' projects and is often less likely to appear in projects designed by teachers who are not well-versed or comfortable with CRP

(Gay & Howards, 2002; Young, 2012). Additionally, teachers often struggle with this concept of CRP because they are lacking in their own sociopolitical consciousness (Gay & Howards, 2002). Still, should a teacher be willing to infuse this tenet in their instruction, the EDP can be operationalized by solving a problem that is not only relevant and capable of fostering cultural competence, but, also, charged with addressing inequities and injustices in social, cultural, and political settings. For example, in the culturally responsive mathematics assignment shared by Varley-Guitierrez (2011), students use data analysis to challenge a school district's decision to shut down a neighborhood school due to budgetary concerns. A potential extension through incorporation of EDP for the same problem might include developing prototypes or blueprints for modifications to the school that can result in efficiency and save the district money.

Recommendations for Stakeholders

The findings from this research offer valuable recommendations for teacher educators, professional development providers, and researchers. The research, while premised around culturally responsive pedagogy (CRP) and the engineering design process (EDP), examined beliefs and agentic behaviors of teachers. The participating teachers are part of a master's program and fellowship designed to promote teacher leadership and cultivate teachers' pedagogical content knowledge around CRP and other innovative instructional approaches. Thusly, the teachers', prior to their integration of CRP and the EDP, already displayed signs of agency and motivation to improve their own instruction and impact the practices of others.

The author of this research recognizes that examining beliefs and agentic behaviors is a complex process which is dependent upon self-reported data (McAllister, 1999; McAllister & Irvine, 2002). To further clarify the intentionality of the author, this research does not purport to draw any relationships between the teachers' experiences in the fellowship to their self-reported beliefs and instructional outcomes. The research instead seeks to understand the reactions teachers have to the pedagogical constructs of CRP and the EDP upon implementation. The study examines how teachers define each construct after the experience, the value they associate with approaches, and how those beliefs relate to their agency regarding continued implementation. Below are recommendations that emerged from the findings and should be of interest and value to stakeholders in the field of teacher education.

Teacher Educators

Teacher educators include those who design professional development, serve as school and district leaders, (i.e. coordinators, specialists, and instructional coaches). Also included in this group of stakeholders are school and district principals or administrative leaders. These individuals often drive and make the instructional decisions that impact the curriculum teachers implement in their classrooms. These individuals, through their roles, are able to interact, and familiarize with teachers who are making strides in the classroom. Teachers' agentic behaviors are evidenced through their ability to connect with students and the actions they take to improve their own practices. Should these teachers go unnoticed, unappreciated, and lack support, their talents and skillset can become lost in the vast field of instructional initiatives that disregard their voices and input.

Although there is a lot of discussion and research surrounding the value in allowing students to take more ownership of their own learning, this notion, though strongly emphasized upon teachers, is rarely is applied to teachers as learners. Teachers receive directives from their administrative and instructional leaders on the types of approaches they should employ. These suggestions and demands are often met with a prescribed set of curricula or strategies that the teachers are expected adopt. The manner in which instructional reform is presented raises the question about who is responsible for leading change in the classroom. The findings from this research argue that teachers are the most important aspect of change in instruction and can serve as the agents who drive curricular transformation. Teachers are integral to the successful implementation of any new instructional approach in the classroom which is why they should be included in the processes and decisions that yield change. This research asserts that teachers who are willing and motivated to improve the quality of instruction can become change agents should they be recognized and provided with support. This support can include access to resources, along with, opportunities for professional development and curriculum writing.

Providing teachers, who display interest and intentionality towards improving their students' learning, with a platform to apply their agency can result in reform that begins with their classroom, but ultimately extends into the department and beyond. Such is the case for the teacher participants who were recognized and selected by the LEAD Houston fellowship committee for their drive and desire to grow as educators. Upon acceptance they were provided with support through opportunities such as, attending national conferences on STEM education research. They were also immersed in coursework that was intended to both challenge and augment their notions about teaching. While this research does not evaluate the fellowship or graduate level coursework experienced by the participating teachers, it does urge teacher educators to realize the urgency of recognizing and empowering the teachers who are working towards positive change in the classroom. Moreover, once these teachers are noticed they must be provided with the trust, support, and resources to guide and lead instructional practices. The participants shared that implementing the pedagogical constructs of culturally responsive pedagogy and the engineering design process felt “bold” and “daring.” Thus, it is important for teachers to feel safe and supported when implementing new instructional practices because they realize that they are taking risks with members of their team, and their students’ learning.

As was the case in the professional development endeavors discussed during the literature review (see, Estapa & Tank, 2017; Hynes, 2010; Nugent et al., 2010) teachers are often provided with a prescribed set of activities or curricular interventions to implement. One source of concern described by Hynes and Dos Santos (2007) included the teachers being focused on learning the materials and specifics of curriculum, versus engaging in pedagogical discussions. During the interviews, the teacher participants, involved in this dissertation research, inquired if they would receive time to work on writing additional lessons this summer much like they did last summer when they created the projects that are featured in this study. Thus, should teachers who are choosing to further their growth be provided with introduction to new instructional approaches, a key recommendation from this research is to allow them the time to plan for integration. They should also be able to develop lessons and projects under the guidance of experts who can provide helpful feedback. Furthermore, rather than teaching a completely new unit, the teachers, featured in this research, were able redesign a previously used project through incorporation of the EDP and CRP. This may have resulted in a sense of comfort during the implementation provided their familiarity with the course content and objectives covered during the original project. Teachers had a choice on which unit to reform and how to do so given their knowledge of the EDP and CRP. Teachers also used rubrics and lesson planning templates provided by the program for alignment of theory to practice. These lesson analysis tools provided teachers with an opportunity to self-reflect and self-evaluate their instruction, thus, shaping their core agentic behaviors.

Recommendations for Future Research

The crux of this research lies in valuing the beliefs and insights of teachers because they are the most critical component to any change in instructional practice. Much research has been conducted on exploring the value of each of the two pedagogical constructs, the engineering design process (EDP) and culturally responsive pedagogy (CRP). Some of these studies have involved teachers' beliefs (see, Siwatu, 2007; Yasar et al., 2006; Yoon et al, 2003). Nevertheless, there remains a shortage on investigating how teachers respond to the instructional practices upon enactment in their classes. This is problematic because beliefs and attitudes are dynamic and evolve through observations and experiences (Bandura, 1986). Therefore, the beliefs teachers have during their preservice years, or upon introduction to an approach, are not entirely representative of how teachers will describe the value of the instructional practices upon attempting them with their students. Moreover, examining these beliefs allows for the researcher to gain insights on which aspects of the pedagogical approaches are most appealing to teachers and which challenge them. Thus, the concepts that excite teachers can help researchers uncover strategies for introducing novel instructional practices. Accordingly, addressing the areas that cause hesitation in teachers can help strengthen the reform through targeted support.

Based on the findings from this research it would be wise for researchers to further explore how teachers' agency continues to develop as they further develop their sociopolitical consciousness. It would be worthwhile to investigate how the teachers' cultural competence and sociopolitical awareness translates to the types of projects they create for their students. One of the key barriers that teachers reported was the reluctance of their team members towards implementing the projects in their classes. Hence, another avenue for research should include examination of the methods and strategies used by teachers to successfully share new instructional practices with their colleagues and coach them through integration. This would help contribute towards the literature on teachers using their personal agency to build the capacity of their team's collective agency.

Furthermore, two of the teachers expressed turning to administrators or instructional specialists to advocate for value of adopting engineering-design and culturally responsive instruction. As such, research needs to be conducted on how administrative leaders can foster the drive and encourage the endeavors of teacher change agents at their school. Finally, provided the categories used to analyze teachers' agentic behavior, it would be valuable to investigate and classify the methods through which administrative leaders can identify change agents at their schools. Should principals and instructional leaders know what to look for, in terms of change agency, they will be able to recognize the teachers and capitalize on their skillset.

Conclusions

Much like any instructional or pedagogical intervention the teachers' buy-in, and beliefs surrounding the approaches will determine the fidelity with which the constructs are implemented. This research provided insights on how teachers, who are motivated to enact change, perceived the constructs of the engineering design process (EDP) and culturally responsive pedagogy (CRP) upon implementation. The teachers had no prior experience with the pedagogical approaches before entering the program. Moreover, since their introductory coursework on the topics, this iteration was their first-time adopting instruction inclusive of CRP and EDP. The insights and statements captured during this research are reflective of their initial reactions to the implementation. The author of this research acknowledges that the teacher participants' beliefs will likely evolve as they progress through the coursework and professional development. However, first impressions are of significance because experiences and observations have the power to influence agency towards future enactments. Additionally, the barriers these teachers encountered along the way, and, how they self-reacted to persevere through those challenges are also of importance. The findings can serve as lessons that will help strengthen the development of other teachers who are not as confident in their instructional abilities, or comfortable with parting from teacher-centered practices.

According to the findings, the most central and pervasive factor impacting the teachers' beliefs and agency was the reaction their students provided towards the project. The teacher participants reported heightened student engagement, interest in content, and improved academic performance. Teachers were encouraged by these positive student outcomes, and, felt driven to continue in their journey towards future implementation.

They used their students' reaction as a benchmark to assess this own success with the incorporation of EDP and CRP. Furthermore, upon implementation, the teachers felt empowered in their ability to convince others to utilize CRP and EDP because they were now equipped with the positive feedback garnered from student experiences. Thus, framing the introduction of instructional practices through the lens of student outcomes is an important take-away for teacher educators.

Another key implication derived from this research is the connectivity between the engineering design process (EDP) and culturally responsive pedagogy (CRP). Specifically, teacher participants, having experienced the two constructs simultaneously, were convinced that the EDP was most beneficial and worthwhile to use when it is immersed in their students' cultural context. The teachers acknowledged the value of each approach and shared their willingness to use CRP on its own. However, based upon the outcomes experienced through the synergistic enactment of the EDP and CRP, the teachers felt compelled to frame each engineering design challenge around a problem that was culturally responsive towards their students. Provided the power of teacher buy-in, this finding is of critical importance to teacher educators in the fields of teacher development, STEM education, engineering education, and CRP.

Finally, professional development providers, and, policy makers are urged to place teachers at the forefront of any conversation that is charged with producing reform. Researchers are advised to examine the ways in which teachers perceive, react, and define, instructional approaches that are deemed impactful. Involving willing teachers as active contributors to the field, as opposed to, passive recipients of instructional initiatives, can help cultivate teachers' change agency. Accordingly, this research underscores the importance of empowering teachers with professional development that is shaped and informed by their beliefs and experiences. It is imperative to acknowledge and foster the power of teacher change agents who, if given the opportunity, will transform traditionalistic approaches, not only in their classrooms, but, throughout our educational system.

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APPENDICIES

Appendix A

Recruitment Letter

Dear Master Teacher Fellows,

I am writing to let you know about an opportunity to participate in a research study about the integration of engineering design and culturally responsive pedagogy in secondary math and science instruction. This study will investigate teacher perceptions and beliefs regarding the implementation, as well as, barriers and catalysts encountered along the way by select teachers enrolled in the University of Houston – Leadership through Equity and Advocacy Development program (also referred to as LEAD Houston).

Should you agree to participate in this study, your responses on the CRSTE and CRTOE surveys (emailed to you by Dr. Andrea Burridge) will also be utilized which contain demographic information.

The approximate duration of time will vary, but, is expected to be about 3-4 hours.

- Design, Engineering, Technology (DET) Survey, 45 minutes, once
- Reflective Journal Prompts, 60 minutes, once
- Semi-Structured Focus Group Interview, 60 minutes, once

Should you be willing to participate in this study please complete the following form indicating your interest:

➔ https://forms.office.com/Pages/ResponsePage.aspx?id=vboLF_CikEytSw6PDwxCWcmwj6nJExlCt40LPRGNtsZUM0hVMDZLWlo0VUYzUkk3MFdXUFNQRU
RLSi4u

Upon completion of the form you will be contacted by the Co-PI, Mariam Manuel, mamanuel@uh.edu to discuss your participation.

What happens if I do not want to be in this research?

You can choose not to take part in the research and it will not be held against you. Choosing not to take part will involve no penalty or loss of benefit to which you are otherwise entitled.

If you are a student, a decision to take part or not, or to withdraw from the research will have no effect on your grades or standing with the University of Houston.

What happens if I say yes, but I change my mind later?

You can leave the research at any time it will not be held against you.

If you stop being in the research, already collected data will be removed from the study record.

Is there any way being in this study could be bad for me?

There are no foreseeable risks related to the procedures conducted as part of this study. If you choose to take part and undergo a negative event you feel is related to the study, please inform your study team.

Will I get anything for being in this study?

Participants will not receive compensation for being in the study.

Will being in this study help me in any way?

We cannot promise any benefits to you or others from your taking part in this research. However, you may be exposed to information that may help you in the future.

What happens to the information collected for the research?

The following procedures and safeguards guide research staff in the protection of privacy and confidential information of study participants.

- All interviews and focus groups will be audio and videotaped. Recordings will be transferred from the transmitting medium to the computers of the assigned staff only, secured with a password. Recordings will be coded so that no personally identifiable information is visible.
- The records of this study will be stored securely and kept confidential. Authorized persons from the University of Houston, members of the Institutional Review Board, and study sponsors, have the legal right to review your research records and will protect the confidentiality of those records to the extent permitted by law. All publications will exclude any information that will make it possible to identify you as a subject. Throughout the study, the researchers will notify you of new information that may become available and that might affect your decision to remain in the study.
- All data and materials, including recordings, will be kept for at least three years after the completion of the study.
- If you consent, the data resulting from your participation will be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate you with it, or with your participation in any study.
- This research is funded in part by the National Science Foundation who has the right to review research records

What else do I need to know?

The results of this study may be published in scientific journals, professional publications, or educational presentations; however, no individual subject will be identified.

Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, you should talk to the research team by contacting Paige Evans at 713-743-3993 or pkevans@central.uh.edu.

This research has been reviewed and approved by the University of Houston Institutional Review Board (IRB). You may also talk to them at (713) 743-9204 or cphs@central.uh.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research subject.
- You want to get information or provide input about this research.

Appendix B

Interest Form

https://forms.office.com/Pages/ResponsePage.aspx?id=vboLF_CikEytSw6PDwxCWcmwj6nJExlCt40LPRGNtsZUM0hVMDZLWlo0VUYzUkk3MFdXUFNQRURLSi4u

Interest Form for Engineering Education Case Study

Required

1.Please enter your name (Last Name, First Name):

2.What school are you currently teaching for?

3.What subject do you currently teach?

4.Did you take the Fundamentals of Engineering Course during the summer semester of 2018 with Professor Mariam Manuel?

Yes

No

5.Do you plan to utilize the final project that required you to develop a lesson inclusive of engineering design practices and culturally responsive instruction?

6.If so, when do you plan to implement in your classroom? Please include specific date(s) or estimated time frame.

Appendix C

Reflection Journal Prompts

Dear Master Teacher Fellows,
Thank you for agreeing to participate in this research that will help inform future practices and STEM education reform.
Please answer the following questions about your experience upon implementing the engineering design and CRP infused project in your classroom.
If you have any questions at all, please contact: Mariam Manuel, mamanuel@uh.edu

1. Describe your lesson/project. Discuss how it included the engineering design process and what components made it culturally relevant to your students

2. How was this lesson/project different than the previously used version that did not was not inclusive of the engineering design process or culturally responsiveness?

3. What benefits to students do you expect to see or have seen through this activity that is inclusive of engineering design and culturally responsiveness?

4. On a scale of 1 to 5, with 1 being the lowest and 5 being the highest, consider how would you rate your success on the integration of engineering design and culturally responsiveness in your lesson. Please explain.

5. What challenges or catalysts did you personally encounter when implementing this lesson/project?

6. Did anyone else in your team or department also implement this lesson/project?
7. 6a. If not, why do you think that is?
8. 6b. If so, discuss the process of collaborating with your team members and what challenges or catalysts did you encounter along the way.

9. Please discuss how and why you entered the field of teaching:

10. Please describe your philosophy of teaching:

11. In your own words, please define/explain the Engineering Design Process:

12. In your own words, please define/explain the Culturally Responsive Pedagogy (also referred to as culturally relevant teaching):

Appendix D

Interview Protocol

Introduction of Study (to Participant):
I want to thank you for agreeing to meet with me today and for being willing to participate in the interview aspect of my study.
As I have mentioned to you before, my study seeks to examine teacher beliefs and agency upon implementation of the engineering design process and culturally responsive pedagogy in secondary math and science. Through this research also seeks to understand the types of barriers and catalysts encountered along the way and the teacher's self-reflections.
Our interview today will last approximately one hour and will be recorded for audio. I will be asking you questions about your overall experience and perceptions upon implementing a project that incorporated both engineering design process and culturally responsive pedagogy.
Before we begin the interview, do you have any questions?

Interview Protocol Matrix (adapted from Castillo-Montoya, 2016)

INTERVIEW QUESTION	BACKGROUND INFORMATION	RQ 1 TEACHER AGENCY	RQ 2 PEDAGOGICAL BELIEFS	RQ 3 PERCEIVED SUCCESS	RQ 4 BARRIERS/ CATALYSTS
Transition Statement: *I'd like to begin the interview by first asking you some questions regarding your school and/or district.*					
Q1. Can you describe your school setting for me? (Which can include (provide examples for teacher here)	X				
Q2. How long have you been teaching at this school/district? (Does this include the same teaching assignment, which may include same/different grade level, course, school building, etc.)	X				
Transition Statement: *Great. Next, I'd like to discuss your perceptions about the constructs of* <u>*engineering design process*</u> *(which I will abbreviate as EDP) and* <u>*culturally responsive pedagogy*</u> *(which I will abbreviate as CRP).*					
In your reflection journal you described how you used EDP to augment your project by *::insert what respondent said here::* **Q3a. How do you define EDP in your classroom context?** **Q3b. How did the infusion of EDP change this project?** **Q3c. Do you see room for infusing EDP pedagogy in other curricular projects you are currently using?**		X	X		
In the reflection journal, you described how you used CRP to augment your project *by::insert what respondent said here::*		X	X		

Interview Question	Background Information	RQ 1 Teacher Agency	RQ 2 Pedagogical Beliefs	RQ 3 Perceived Success	RQ 4 Barriers/ Catalysts
Q4a. How do you define CRP in your classroom context? **Q4b. How did the infusion of CRP change this project?** **Q4c. Do you see room for infusing CRP pedagogy in other curricular projects you are currently using?**					
Q5. What connection/s have you made between EDP and CRP? Please describe the connections you see or lack thereof.			X		
Q6. Between EDP and CRP, do you feel one is more conducive to fitting in with your classroom context* and/or instruction? ***Please explain your reasoning.*** ****students taught, being math or science, years of teaching, etc.***			X	X	
In the reflection journal you shared your personal teaching philosophy as *::insert what respondent said here::* **Q7. How does the inclusion of EDP and CRP pedagogical practices fit into with your personal teaching philosophy?** ***Please explain your reasoning.***		X	X	X	
Transition Statement: *Now, I would like to discuss your overall experience with the implementation of this project in your classroom.*					
Q8a. How would you describe your experience implementing this project in your classroom(s)?		X		X	

INTERVIEW QUESTION	BACKGROUND INFORMATION	RQ 1 TEACHER AGENCY	RQ 2 PEDAGOGICAL BELIEFS	RQ 3 PERCEIVED SUCCESS	RQ 4 BARRIERS/ CATALYSTS
Q8b. What factors made project implementation easier? **Q8c. What factors made project implementation challenging?**					X
Q9. Do you see yourself using this project in the future? If so, what would you change?		X		X	X
Q10. Do see yourself using different projects with CRP and EDP infused? **If so, why? If not, why not?**		X	X		X
Transition Statement*: In one of the last segments of this interview, I'd like to discuss your content team/PLC.*					
Q11a. How would you describe the nature of collaboration in your team/PLC? **Q11b. In your opinion, are they open to trying new ideas?**	X				X
Based on your reflection journal response, you had shared this project with your team/PLC saying*::insert what respondent said here::* **Q12. How did they respond? What was their feedback?** **Q12a. How did you incorporate or refute their feedback?** **(Did you make any changes or compromises for your team?)** **If so, how did these changes modify the project from its original intended design?**		X			X
OR					

INTERVIEW QUESTION	BACKGROUND INFORMATION	RQ 1 TEACHER AGENCY	RQ 2 PEDAGOGICAL BELIEFS	RQ 3 PERCEIVED SUCCESS	RQ 4 BARRIERS/ CATALYSTS
Based on your reflection journal response, you mentioned that you did not use this project as a team/PLC saying*::insert what respondent said here::* **Q12a. How do you think they would have responded? Q12b. In your opinion, what would have to change for your team/PLC members to use this project?**		X			X
Transition Statement: *Finally, I'd like to conclude with some big picture questions.*					
Q13. For you professionally, what was the biggest takeaway* from this experience? Note: this can include a curricular or pedagogical takeaway, as well as, takeaways related to collaboration or leadership		X	X	X	X
Q14. How do you see your role with regards to integrating EDP and CRP in your content?		X		X	
Q15. Is there anything else about this experience (the project) that you would like to share with me?					

Thank you for your time and thoughtful comments. As a follow up, I will reach out to you with the results/findings based on your responses for a check of interpretation. This process is called member checking and is used by researchers to help improve the accuracy, credibility, and validity of the study.

If any questions (or other questions) arise at any point in this study, you can feel free to ask them at any time. I would be more than happy to answer your questions.

Appendix E

NVivo Codebook

Statements coded In Vivo
Absolutely, yeah
adding substance
all students
All students should have the opportunity to learn what they need to be successful, with an adult by their sides who cares, and enjoy the process!
also had some pretty impactful teachers growing up,
Any chance that I have to incorporate the engineered design process, I'm going to jump on that as well.
barriers
brainstorming
building, testing, analyzing their results,
But I really see where they - their engagement with their academics is going to increase through using engineering process and ERP with that.
CER
changed a lot
collaboration
community support
CRP
CRP and EDP

Statements coded In Vivo
CRP) is teaching that acknowledges, celebrates, and promotes the student's culture in the classroom.
CRP, being so open ended and expansive,
EDP
edp and crp
EDP is a process that promotes engagement, critical thinking, problem-solving, creativity, and communication.
21st century skills
empathy
engagement
engineering design process is definitely a messy process, but it's kind of confined
finding resources
focus on diversity
forethought
forethought (2)
getting their input into it.
I also believe that we should always strive to better our craft.
I kind of feel like I've crossed this line where I know that my students can be successful and I know that all of the other students can be successful, and so I feel obligated. I feel like I owe it to the students to ensure that they're getting more experi
I know that my quiet students, that's -- I would say I had more of all of my students in this activity than I did in any other unit. I could tell that they were all in on it. I think it was because they had buy in, they felt empowered.

Statements coded In Vivo
I really love hands-on experiences myself and I think we don’t do enough of that in schools anymore.
I reflect on the lessons, experiences, and interactions often. My goal is to be the best teacher I can be today, and even better tomorrow.
I think the level of engagement was higher more consistently throughout the project due to the hands-on aspect (engineering) and the fact that all students could access the project (CRT).
I think, were really engaged and it was a group of kids that might not have always been completely 100 percent bought in to the activity that we were doing.
I was able to improve the lesson and modify it to ensure that this group of students were successful.
I would consider the integration to be a 4 or 5.
I would definitely introduce the tech tool prior to the engineering lesson next time. I also struggled with the time frame.
I’m actually writing ~~[0~39~32]~~curriculum as well later this year for my district
I'm just all in on it. I can't go back now.
I'm learning.
I'm ready to do professional development in that area and continue the conversations in our PLCs, for sure.
I'm really trying to consider how is it culturally relevant, and how can I improve it~
improve
improvement
intentionality
involving students

Statements coded In Vivo
it really helped having the lesson plan draft written in the summer (with our engineering course).
It was night and day.
it's messy
knowing now that I didn't have the engineering experience in my educational experience, I think that's all I was missing.
materials cost
more of an opportunity to connect CRP to every unit, then there is with engineering design process
more time
most important parts to CRP is identifying and incorporating students' funds of knowledge. Funds of knowledge consider and validate students' varied experiences that lead to knowledge outside of the school setting. By
my academic students are fully capable of everything that any other student in the school is capable of
No one on my team implemented this project with fidelity.
open ended
open-ended for students
power of PD
pride in students
problem that is relevant to the student
problem that students might have
relatiblity

Statements coded In Vivo
relevance
reluctant
replicate
representation
run out of time
scale up
self reactiveness
self reflection
self-reactiveness
self-role
skills that promote 21st century learning and jobs.
So having that experience and having this opportunity to study the value of CRP helps me to just kind of realize, that's a must.
some of my lower-achieving students, they just kind of went bananas with this.
Student Advocacy
student driven
student centered.
student-generated problem
Students were engaged
student engagement
student involvement

Statements coded In Vivo
student ownership
student performance
students have more buy-in
surpise at results
surprised at results
The Engineering Design Process (EDP) is a cycle that engineers and students work through to solve problems
The more I can provide those opportunities to the students, the better.
their thinking was visible to me
they are exposed to all different kinds of people and countries and experiences that have contributed to the achievements in science.
They built some really great insulating packages, I guess, and they looked amazing, and they were so proud of them that they were taking them to the cafeteria to show everybody.
think along the way my parents were trying to get me to understand that I did have a little engineer in me.
Those teachers did not make any effort to get to know me or the funds of knowledge that I brought into the classroom.
very traditional idea
very, very different
we have this unique opportunity to appreciate and empower so many different students, and we have an opportunity to get them to appreciate each other and learn to work with each other.

Statements coded In Vivo
We need to know our students. We need to know what they bring and how we can connect what they bring to the classroom, so that they feel like a valued student in the classroom.
When they asked a very pointed question in the classroom, and had in mind a very specific answer, I wasn't able to provide that answer due to my background and my experiences; and therefore, I think I was labeled as not a great student.
When we look at how something is working and how we can fix it, that's a skill that engineers use and I had some stake in the claim for that.
When we started the design process with a problem that was relevant to the students' lives, that kind of lent itself automatically to being culturally responsive.

Appendix F

Qualtrics Survey Questions

https://educttu.az1.qualtrics.com/jfe/form/SV_e4nVJI6nuu16wSh

The purpose of the survey is to collect data from select teachers enrolled in the University of Houston – Leadership through Equity and Advocacy Development (UH-LEAD) program on their perceived success regarding implementation of engineering design, and culturally responsive pedagogy in mathematics and science instruction. The survey is divided into two sections: Culturally Responsive Teaching Outcome Expectations Survey (Section I) and Design, Technology, and Engineering (DET) Survey (Section II). The estimated time to complete the survey is 45 minutes. Thank you for participating in this survey and providing your thoughtful responses. If you have any questions or concerns, you may contact the Mariam Manuel: mamanuel@uh.edu The estimated time to complete the survey is 45 minutes. Thank you for participating in this survey and providing your thoughtful responses. If you have any questions or concerns, you may contact the Mariam Manuel: mamanuel@uh.edu
Participant Demographic Profile (Check all boxes that apply)
Name (Last, First): ____________________________________ Unique Identifier (used for CRSTE and CRTOE surveys): ____________________ Gender: ☐ female ☐ male Ethnicity: ☐ African American ☐ American Indian ☐ Asian American ☐ Hispanic ☐ White ☐ Other Grade level: ☐ Middle School ☐ High School Content area(s) you currently to teach: ☐ Math ☐ Science ☐ Other _________ (mark all that apply)

SECTION I: CULTURALLY RESPONSIVE OUTCOME EXPECTANCY INVENTORY ITEMS

For each of the following items, please read the questions carefully and answer thoughtfully by rating the probability that the behavior stated will lead to the specified outcomes. Please indicate your rating for each statement using the scale provided below. The scale ranges from 0 (entirely certain) to 100 (entirely certain). Please note that you may adjust the scale bar to select any number values between 0 and 100:

Entirely Uncertain Entirely Certain
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

1. A positive teacher-student relationship can be established by building a sense of trust in my students.
2. Incorporating a variety of teaching methods will help my students to be successful.
3. Students will be successful when instruction is adapted to meet their needs.
4. Developing a community of learners when my class consists of students from diverse cultural backgrounds will promote positive interactions between students.
5. Acknowledging the ways that the school culture is different from my students' home culture will minimize the likelihood of discipline problems.
6. Understanding the communication preferences of my students will decrease the likelihood of student-teacher communication problems.
7. Connecting my students' prior knowledge with new incoming information will lead to deeper learning.
8. Matching instruction to the students' learning preferences will enhance their learning.
9. Revising instructional material to include a better representation of the students' cultural group will foster positive self-images.
10. Providing English Language Learners with visual aids will enhance their understanding of assignments.
11. Students will develop an appreciation for their culture when they are taught about the contributions their culture has made over time.
12. Conveying the message that parents are an important part of the classroom will increase parent participation.
13. The likelihood of student-teacher misunderstandings decreases when my students' cultural background is understood.
14. Changing the structure of the classroom so that it is compatible with my students' home culture will increase their motivation to come to class.

15. Establishing positive home-school relations will increase parental involvement.
16. Student attendance will increase when a personal relationship between the teacher and students has been developed.
17. Assessing student learning using a variety of assessment procedures will provide a better picture of what they have learned.
18. Using my students' interests when designing instruction will increase their motivation to learn.
19. Simplifying the language used during the presentation will enhance English Language Learners' comprehension of the lesson.
20. The frequency that students' abilities are misdiagnosed will decrease when their standardized test scores are interpreted with caution.
21. Encouraging students to use their native language will help to maintain students' cultural identity.
22. Students' self-esteem can be enhanced when their cultural background is valued by the teacher.
23. Helping students from diverse cultural backgrounds succeed in school will increase their confidence in their academic ability.
24. Students' academic achievement will increase when they are provided with unbiased access to the necessary learning resources.
25. Using culturally familiar examples will make learning new concepts easier.
26. When students see themselves in the pictures that are displayed in the classroom, they develop a positive self-identity.

Section II: DET SURVEY

Please keep in mind that the Design, Engineering, and Technology (DET) is inclusive of the following general engineering design characteristics:

1. Identify a problem or a need to improve on current technology;
2. Propose a problem solution;
3. Identify the costs and benefits of solutions;
4. Select the best solution from among several proposed choices by comparing a given solution to the criteria it was designed to meet;
5. Implement a solution by building a model or a simulation; and
6. Communicate the problem, the process, and the solution in various ways

Please read the questions carefully and answer thoughtfully by indicating your response: Strongly disagree, Disagree, Neutral, Agree, or Strongly Agree.

Factor 1: Importance of DET		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	I would like to be able to teach my students to understand the use and impact of DET.	1	2	3	4	5
2	I would like to be able to teach my students to understand the science underlying DET.	1	2	3	4	5
3	I would like to be able to teach my students to understand the design process.	1	2	3	4	5
4	I would like to teach my students to understand the types of problems to which DET can be applied	1	2	3	4	5
5	My motivation for teaching science is to promote an understanding of how DET affects society.	1	2	3	4	5
6	I am interested in learning more about DET through in-service education.	1	2	3	4	5
7	I would like to be able to teach students to understand the process of communicating technical information.	1	2	3	4	5
8	My motivation for teaching science is to prepare young people for the world of work.	1	2	3	4	5

9	My motivation for teaching science is to promote an enjoyment of learning.	1	2	3	4	5
10	I believe DET should be integrated into the K-12 Curriculum.	1	2	3	4	
11	I am interested in learning more about DET through workshops.	1	2	3	4	5
12	I am interested in learning more about DET through college courses.	1	2	3	4	5
13	In a science curriculum, it is important to include the use of engineering in developing new technologies.	1	2	3	4	5
14	I am interested in learning more about DET through peer teaching.	1	2	3	4	5
15	My motivation for teaching science is to help students develop an understanding of the technical world.	1	2	3	4	5
16	My motivation for teaching science is to educate scientists, engineers and technologists for industry.	1	2	3	4	5
17	In a science curriculum, it is important to include planning of a project.	1	2	3	4	5
18	How important should pre-service education be for teaching DET?	1	2	3	4	5
19	DET has positive consequences for society.	1	2	3	4	5
Factor 4: Barriers in Integrating DET		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
20	Barrier in integrating DET – lack of teacher knowledge.	1	2	3	4	5
21	Barrier in integrating DET – lack of training.	1	2	3	4	5
22	Barrier in integrating DET – lack of time for teachers to learn about DET.	1	2	3	4	5
23	Barrier in integrating DET – lack of administrative support.	1	2	3	4	5
24	Most people feel that minority students can do well in DET.	1	2	3	4	5
25	Most people feel that female students can do well in DET.	1	2	3	4	5

Appendix G

Member Checking Questionnaire

(Sent Via Email)

Dear Teacher,

Attached you find a portion of Chapter IV which includes the findings regarding your specific case as well as the cross-case analysis that compares the emergent themes from your data with that of other participants to identify meta-patterns. Your pseudonym, utilized to protect your identity, is <Insert Pseudonym>.

Please note that each participant is only receiving their case and overall cross-case analysis, as such, your individual findings are currently shared only with you.

As explained during the interview, the purpose of member checking is to allow you the opportunity to corroborate the findings and add or clarify anything you see fit.

Upon reviewing your case and cross-case findings please answer the following questions. You can respond via email or through a separate document.

> **Question 1.** Do the findings match your experience?
>
> **Question 2.** Do you want to change anything? If so, feel free to share it in this response or make edits via track changes in the document.
>
> **Question 3.** Do you want to add anything?

Lastly, thank you so much for taking the time participate in this research and for completing this last step which will help ensure I report your story as accurately as possible. I am so grateful for time and participation.

Mariam

Mariam Manuel
Instructional Assistant Professor | Science Master Teacher
UNIVERSITY of HOUSTON | **Natural Sciences and Mathematics** | ***teach*HOUSTON**
mamanuel@uh.edu | (713) 743-3429 | 304E Farish Hall | *teach*HOUSTON.uh.edu

Appendix H

IRB Approval

Oct 16, 2018 10:57 AM CDT

Jessica Gottlieb
Curriculum and Instruction CI

Re: IRB2018-731 Integration of Engineering Practices and Culturally Responsive Pedagogy in STEM instruction

Findings: *Good luck with your study.*

Dear Dr. Jessica Gottlieb, Mariam Manuel:

A Texas Tech University IRB reviewer has approved the proposal referenced above for an Institutional Authorization Agreement (IAA). The IAA has been fully executed and the investigators are now authorized to engage in research as outlined in the approved protocol. The IAA is effective beginning October 16, 2018.

Please notify the IRB of record and Texas Tech of any reportable events, modifications, renewals, and closures. Any change to your protocol requires a Modification Submission to the IRB of record for review and approval prior to implementation. Then submit a modification in Cayuse IRB to Texas Tech and attach the approved modification letter. Should a subject be harmed or a deviation occur from either the approved protocol or federal regulations (45 CFR 46), please complete an Incident Submission form at Texas Tech and contact the IRB of record. Once your research is completed, please use a Closure Submission to terminate this protocol at Texas Tech.

Your study may be selected for a Post-Approval Review (PAR). A PAR investigator may contact you to observe your data collection procedures, including the consent process. You will be notified if your study has been chosen for a PAR.

Sincerely,

Scott Burris, Ph.D.
Chair Texas Tech University Institutional Review Board Professor,
Department of Agricultural Education and Communications
Human Research Protection Program
357 Administration Building
Lubbock, Texas 79409-1075
T 806.742.2064
www.hrpp.ttu.edu

Apr 3, 2019 1:25 PM CDT

Jessica Gottlieb
Curriculum and Instruction CI

Re: IRB2018-731 Integration of Engineering Practices and Culturally Responsive Pedagogy in STEM instruction

Findings: *Renewal Approved.*
Expiration Date: *October 29, 2019*

Dear Dr. Jessica Gottlieb, Mariam Manuel:

A Texas Tech University IRB reviewer has approved a renewal for the protocol indicated above within the expedited category of:

The renewal is effective from April 3, 2019 and will expire on October 29, 2019. This expiration date must appear on your consent document.

The research must follow Texas Tech University's Operating Procedures, the Belmont Report, and 45 CFR 46. If changes to the approved protocol occur, a **Modification Submission** must be reviewed and approved by the IRB before implementation.

A goal of the IRB is to prevent negative occurrences during any research study. However, despite our best intent, unforeseen circumstances or events may arise during the research. If a deviation, unanticipated problem or adverse event happens during your research, please notify the Texas Tech University, Human Research Protection Program as soon as possible (45 CFR 46). We will ask for a complete explanation of the event and for you to submit an **Incident Submission** in Cayuse IRB.

Your study may be selected for a Post-Approval Monitoring (PAM). You will be notified if your study has been chosen for a PAM. A PAM investigator may request to observe your data collection procedures, including the consent process.

Once your research is complete and no identifiable data remains, please use a **Closure Submission** to archive this study. IRBs that remain active are subject to audit by the IRB.

Sincerely,

Scott Burris, Ph.D.
Chair Texas Tech University Institutional Review Board
Professor, Department of Agricultural Education and Communications
Human Research Protection Program

Updated April 19, 2016

UT Centralized IRB Review

Site Investigators Pre-Notification Letter - Intent to Submit for Centralized Review

Information for the Overall Principal Investigator – In addition to submitting an application to your institution's IRB (designated the "Reviewing IRB"), an "Intent to Submit for Centralized Review" form must be submitted to the IRB office at each participating institution.

Information for the Site Principal Investigator - The purpose of this form is to request centralized review at your institution (designated the "Relying Institution"). This request will be considered by your institution and a decision made on a case-by-case basis. The IRB office from your institution will forward the final decision to the Reviewing IRB.

If your institution agrees to Centralized IRB Review, you will be required to submit additional materials in accordance with local policy. The review of local issues by your institution is a separate process from the IRB approval being sought by the Overall PI. Reminder: you are not authorized to initiate research at your institution until both processes are completed: 1) the study is approved by the Reviewing IRB and an *approval* letter is issued, and 2) the local policy issues have been resolved and an *activation* letter has been issued by your institution.

Study Title:	STUDY00000652: UH-LEAD, NSF DUE-1759454

1. Name and Address of Site Principal Investigator (PI):

Site PI's Name (Last Name, First Name, MI): Mariam Manuel (Co-PI), Jessica Gottlieb (PI for TTU)

Department: Curriculum and Instruction, College of Education

PI's Telephone#: 806-834-5341 (JG) 281-639-3766 (MM) PI's Cell or Pager Number:

PI's e-mail address: jessica.gottlieb@ttu.edu, mariam.manuel@ttu.edu PI's FAX Number:

2. Name of the Overall Principal Investigator (PI):

Overall PI's Name (Last Name, First Name, MI): Paige Evans

Institution: University of Houston

3. Which Texas Participating Institution will serve as the Reviewing IRB?		
Select only one		
☐ UT at Arlington (UTA)	☐ UT HSC at Houston (UTHealth)	☐ Angelo State University (ASU TTU)
☐ UT Austin (UT Austin)	☐ UT Medical Branch (UTMB)	☐ Rice University (Rice)
☐ UT at Dallas (UTD)	☐ UT HSC at San Antonio (UTHSCSA)	☐ The Texas A&M University (TAMU)
☐ UT at El Paso (UTEP)	☐ UT MD Anderson (UTMDACC)	☐ The University of North Texas (UNT)
☐ UT Permian Basin (UTPB)	☐ UT Health Science Center Tyler (UTHSCT)	☐ The University of North Texas Health Science Center (UNT HSC)
☐ UT Rio Grande Valley (UTRGV)	☐ Baylor College of Medicine (BCM)	☑ The University of Houston (UH)
☐ UT San Antonio (UTSA)	☐ Texas Tech Univ (Texas Tech)	☐ The Methodist Hospital System (Methodist)
☐ UT Tyler (UTT)	☐ Texas Tech Univ, Health Sciences Center (Texas Tech HSC)	☐
☐ UT Southwestern Medical Center (UTSW)	☐ Texas Tech HSC El Paso (Texas Tech HSC El Paso)	☐