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The Intersection of Culturally Responsive Pedagogy and Engineering Design in Secondary STEM (Research to Practice)

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Rationale

The purpose of this exploratory, mixed methods, multi-case study is to investigate teacher beliefs and sense of agency upon implementing new instructional practices. The research specifically focuses on teaching secondary science or mathematics 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 learning outcomes associated with STEM related careers [1]. This lack of exposure especially limits females and people of color, both of whom are already underrepresented in STEM fields [2], [3]. As such, while the need for improving the success rates in STEM coursework is pertinent across all racial and ethnic backgrounds, it is especially critical to address the needs of students from underrepresented and historically marginalized populations that are disproportionately less likely to pursue and persist through STEM-related degree programs [4].

Any reform regarding classroom methods must first begin with a shift in the instructional practices utilized by teachers. The beliefs and agentic behaviors of teachers matter because they are the guiding force behind instructional decisions and actions [5], [6], [7], [8]. There is a substantial amount of research on the topics of the engineering design process and culturally responsive teaching that supports the positive student outcomes associated with each pedagogical approach [9], [2], [10], [1]. However, as has been the case with other prominent instructional methodologies, the response, beliefs, and understanding teachers have about the techniques is largely overlooked [11]. This is problematic given that teachers are the most integral influencing factor in any type of curricular reform. Accordingly, the crux of this research is grounded in the value of examining secondary mathematics and science teachers' beliefs regarding the pedagogical constructs of the engineering design process (EDP) and culturally responsive pedagogy (CRP). Moreover, through the study of teachers' agentic behaviors, this research provides insights regarding the barrier teachers encounter along the way, and, how they self-regulate their own actions to overcome the challenges experienced.

This study is conducted through the guiding lens of Bandura's Social Cognitive Theory (SCT) and is driven by the assertion that individuals are capable of influencing decisions, functions, and behavior with intentionality [12], [13], [14]. Humans' beliefs are at the core of their agency which includes self-regulated behaviors that allow an individual to take the necessary actions to yield desired outcomes [14]. These agentic behaviors include intentionality and forethought which help guide the plans for action, as well as self-reactiveness and self-reflection which allows for one to persevere through challenges and self-examine their progress [13]. Acknowledging that an individual's sense of agency leads them to actively regulate their own experiences emphasizes the significance of exploring teacher agency and pedagogical beliefs.

Below is the overarching research question that informed the methodology, and is situated in the theoretical underpinnings of social cognitive theory [12], [13]:

> RQ. How, and in what ways, are secondary mathematics and science teachers' pedagogical beliefs and sense of agency related to the integration of the engineering design process and culturally responsive pedagogy in the classroom?

Knowledge Base for Research

The constructs of the culturally responsive pedagogy and engineering design process have each garnered national attention [1], [2] and multiple decades worth of research [8], [15], [2], [10], [16], [1], [17]. The findings from each body of literature urge educators and policymakers to integrate the instructional methods in K-12 instruction. Moreover, both philosophies of teaching are rooted in research-driven support for inclusion in STEM curricula [18], [19], [20]. Scholars have argued that the implications of immersion with STEM content include heightened student interest and improved academic achievement [21], [22]. Consequently, recent efforts in teacher development have encouraged the use of each approach in K-12 instruction [23], [24], [25], [7].

An essential feature of the engineering design process (EDP) includes identifying a problem, one that scholars suggest should emulate real-world challenges [26], [27], [28]. Yet, there is a dearth of literature on the need for framing those problems through a culturally responsive lens. Furthermore, research on both CRP and the EDP suggest that teachers are the most integral factor to any instructional reform [21], [29], [24], [30]. Nevertheless, there remains a gap in research on teachers' beliefs and agentic behaviors derived from the integration of the engineering design process (EDP) and, or culturally responsive pedagogy (CRP). Thus, the findings from this study aim to spark future investigations and discussions on the power of a culturally responsive engineering design approach to teaching, along with, the agency of teachers who are employing these practices. As such, this work also contributes to the literature on teacher agency, a developing and important field in the realm of teacher education research that is scarcely explored and reported [31], [32], [33].

The Engineering Design Process (EDP). The engineering design process (EDP) is a critical component of the work engineers do and how they approach societal problems. The National Center for Engineering and Technology Education [34] defined EDP as an approach encompassing identification of a problem and developing a model that is refined through data analysis to produce a solution consisting of social and technological elements [35], [34]. According to Katehi et al. [2], EDP is in essence, "the central activity of engineering" [2, pp. 56]. Wulf [17] explained that engineers regularly tackle problems through consideration of limitations and constraints (i.e., cost, time, materials, etc.) all the while still deriving solutions that cater to human wants and needs. Hence, EDP identifies a problem and works towards the design of a viable solution through an iterative set of practices [26]. Although the order of these practices may vary, the EDP encompasses a series of critical steps aimed at addressing a specific problem [36].

The process of engaging in engineering design is initiated by identification of a need or problem [26] often expressed through concerns of customers or clients [27]. Following this step, engineers explore similar, previously solved, problems, while being mindful of constraints and limitations. This research phase is critical because it allows engineers to acquire a deep understanding of how the problem being tackled relates to those previously resolved. The process of re-design and re-testing provides engineers with useful insights about the physical constraints and limitations of the problem or product. Furthermore, the practice of evaluation, which can take place at any point in the design, allows engineers to obtain feedback, as well as generate ideas for upcoming redesign procedures [27]. Therefore, the redesign stage is instrumental to the process as it allows engineers to refine the prototype through informed decisions based on data collected and feedback acquired during testing and evaluations [26].

The integration of engineering design has proven to connect mathematics and science content topics in meaningful ways [37]. Rooted in research is the notion that inclusion of EDP results in improved student achievement, along with, interest in the field of STEM [2]. However, according to Lee and Strobel [38], while preservice teacher preparation and in-service teacher professional development on scientific inquiry gained traction in STEM education reform, the engineering design process did not receive the same level of attention. Researchers believe that this discrepancy was a result of an already established foundation for the sciences in K-12 curricula [38]. Thus, scholars have asserted that in order to litigate the absence of teaching science and math content through the engineering design process, an increased emphasis must be placed on teacher preparation and professional development programs [29], [38], [39].

Culturally Responsive Pedagogy. Culturally responsive pedagogy (CRP), also referred to as culturally relevant pedagogy, is a pedagogical approach originally coined by Ladson-Billings [40], [41]. Ladson-Billings [41] explored the instructional practices used by teachers to effectively teach students of color in a way that builds on their lived experiences. CRP is a philosophy of teaching that asserts the need to use students' cultural identities, and experiences as resources for classroom instruction [40], [41]. The implications of tailoring instruction to reflect the culture of ethnically diverse students includes positive learning outcomes of underrepresented minority populations [42], [40], [41]. Cultural characteristics are inclusive of students' ethnic background and traditions. These traits include varying forms of learning styles, societal contributions, communications, and gender role socialization, all of which are influenced by cultural factors [9]. Culturally responsive teaching is "a pedagogy that empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes" [40, pp. 382]. Accordingly, teachers must move past the faulty ideology of a one-size-fits-all instructional approach, and, instead, adopt a methodology that envisions content through their students' cultural lens [21], [9], [43], [15]. The embodiment of CRP demands that teachers share content knowledge in meaningful ways, while also create avenues for students to challenge the systemic issues in society.

The Three Tenets of CRP. Gloria Ladson-Billings [40], [41] developed a model for culturally relevant pedagogy, that is supported on three fundamental pillars: academic achievement, cultural competence, and socio-political consciousness [40]. The first tenet asks instructors to foster an environment that is inclusive of the instructional practices intended to help students master the content. According to Ladson-Billings, the teachers who were able to effectively teach students of color, upheld a sense of responsibility towards preparing students to be academically successful [41]. She further explained that the embodiment of CRP "requires that teachers attend to students' academic needs, not merely make them feel good." [41, pp. 160]. In her later work, Ladson-Billings [44] explained that academic achievement does not equate to student achievement on high-stakes testing. Instead, she shared that her vision for the tenet entails learning that occurs through interactions with skilled teachers [44].

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

The third tenet of CRP aims to develop the socio-political and critical consciousness of students [41]. Teachers who integrate CRP in their classrooms, cultivate opportunities for students to engage in academic discourse and activities that challenge the power dynamics within their communities. Hence, students are empowered to question the social inequities they may have personally experienced or witnessed. This tenet also suggests that teachers develop their own socio-political consciousness. However, scholars in the field of CRP have acknowledged that teachers often struggle with doing so, therefore, only implement the first two tenets [45].

Methodology

The participating teachers for this study were recruited from a National Science Foundation (NSF) funded, five-year, fellowship program, Leadership through Equity and Advocacy Development (LEAD) Houston, at the University of Houston. The cohort of 15 teachers engaged in a master's degree in STEM education and four subsequent years of professional development. The five teachers selected from the cohort shared plans for incorporating CRP and EDP during the upcoming school year. This research utilized an exploratory, comparative multi-case study design [46] that employed mixed methods of data collection [47]. Each participant comprised an individual bounded case [48] and the data collected was triangulated and analyzed within and across each case. The participating teachers submitted reflective journal entries regarding their perceptions and beliefs about the implementation process, shared philosophy of teaching statements, and were interviewed individually. Member checking through synthesis of analyzed findings [48] was facilitated as an additional and final data source. The member checking process allowed the participants to clarify statements, provide additional insights, and corroborate the researcher's interpretations. Saldaña's [49] coding techniques were utilized to identify emerging themes through qualitative analysis. Next, the thematic codes were analyzed to identify meta-patterns across cases. The findings from the qualitative data were combined with quantitative results derived from the Design, Engineering, and Technology (DET) survey, and the Culturally Responsive Teaching Outcome Expectancy (CRTOE) survey [7], [50]. During cross-case analysis, the descriptive statistics acquired from the quantitative instruments helped corroborate the insights regarding teachers' beliefs and agentic behaviors.

The author utilized a comparative multiple case study design [46], [51] using an embedded mixed methods approach [47], 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 [51]. These cases represented experiences of the select secondary math and science teachers enrolled in a STEM Master's program at a University of Houston. This exploratory, comparative, multiple-case study addressed the following primary research question, followed by 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 (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. 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 1c. 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 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.

Table1 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 Qualitative: Reflective Journals; Interviews	Descriptive Analysis Three rounds of content Analysis: first cycle (In Vivo), second cycle (In Vivo and Values), and third cycle (pattern) coding methods
Barriers encountered during implementation of EDP and CRP	Quantitative: DET survey Qualitative: Reflective Journals; Interviews; Member Checking	Descriptive Analysis 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

Case Selection. The 14-month graduate coursework is part of the five-year LEAD Houston fellowship commitment. 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 PI team on the grant 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. In addition to the number of participants and requirements enforced for enrollment by the program, each case study is also bounded [48] 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 an 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.

Delimitations of the Study. Due to the bounded nature associated with case studies [52] 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 STEM teacher fellowship program, LEAD Houston. 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's 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. 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 the geographical area used in this study. Moreover, it is important to the note that these findings are reflective of teachers who sought and earned enrollment in a highly competitive 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 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 [53]. 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.

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 [54]. In the context of teacher education, reflective journaling strengthens relationships between the instructor and trainee [55], and improves the learning process of teaching candidates [56]. According to Farabaugh [57], 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 [58].

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 [59]. Furthermore, unlike the generalizations caused by only using surveys, interviews yield insights into human behavior and perceptions [60]. Thus, Crotty [61] 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 [62]. 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 2.

Table 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 [62]

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 includes a sample of the interview questions with cells marked to indicate which construct of the research is being addressed through each question [63]. The next phase of the framework suggests that the researcher construct an inquiry-driven conversation with the interviewees. Maxwell [64] 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" [64, pp. 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 [65]. 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 [62], [66], [67], [68].

The third phase ensures that reliability and trustworthiness of the interview protocol is strengthened by obtaining feedback. This was provided by an additional mixed-methods researcher who is involved with the NSF grant that funds the fellowship. For the fourth and final phase, a pilot interview was conducted with an educator not associated with the fellowship grant only in an effort to "try out" the research questions and instrument [69]. This is an integral phase in the protocol because as explained by Merriam [68] the "best way to tell whether the order of your questions works or not is to try it out in a pilot interview" [68, pp. 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 [62] 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" [62, pp. 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 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		

INTERVIEW QUESTION	**BACKGROUND INFORMATION**	**TEACHER AGENCY**	**TEACHER BELIEFS**
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 description*>			
Q3a. How do you define EDP in your classroom context?			X
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	
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 [62]

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 [70]. 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 [71] 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 Birt, Scott, Cavers, Campbell, and Walter [72], "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" [72, pp. 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 [72], [70].

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. [50] 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 [73]. 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 [50]. 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." [50, pp. 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 [74] 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. [74, pp. 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 [7]. As is true for the theoretical foundation of this research, Siwatu [7] was also guided by Bandura's [75], [12] 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" [7, pp. 1088]. Siwatu [7] 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 in-service teachers' culturally responsive teaching self-efficacy and outcome expectancy beliefs. The development of the CRTSE and CRTOE would allow for these needed inquiries [7, pp. 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 [51] utilized a mixed methods concurrent triangulation design [66], [76], 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" [77, pp. 122], thus, achieving a deeper understanding of the topic or problem. The convergent model of triangulation design [78] allows 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 [66].

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 [47]. 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 [49] 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 [49] 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 [49] 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" [49, pp.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 [79], [49]. 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" [49, pp. 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 [80], [49].

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.

Summary of Findings

The summary of findings begins with an introduction of the demographics of the teacher participants, followed by quantitative results from the surveys utilized in this research. All participating teacher names were changed to pseudonyms. The descriptive statistics derived from the quantitative instruments served to provide additional insight regarding teacher beliefs during the cross-case analysis. Included next is a discussion on the meta-patterns identified through analysis of thematic codes across the cases. Saldaña's [49] coding techniques were utilized for qualitative analysis to identify emerging themes in each case.

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. 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 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 5 shows the combinations of gender and race/ethnicity included in this study.

Table 5 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 6 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 6 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 [7] 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." [7, pp. 1090]. Therefore, high scores on the CRTOE scale reflect greater beliefs associated with positive outcomes that result from culturally responsive instruction. Table 7 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 [7] 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 7 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 [50].

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 [74].

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. 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 8 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 8 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

Pedagogical Beliefs about CRP and EDP. Through partaking in reflective journals and individual interviews, teachers shared their definitions of culturally responsive pedagogy (CRP) and the engineering design process (EDP). The definitions provided remained consistent within each individual's data sources and were also common in language across the participants. Teachers explained the EDP as an iterative cycle encompassing the following steps: identifying a problem, brainstorming solutions, designing prototypes, and redesigning to address the problem at hand [2], [69], [50]. CRP was defined by teachers as am approach centered on students' cultural backgrounds, lived experiences all of which contribute to students' funds of knowledge which are then integrated into instructional content lessons [21], [81], [7], [30]. The common language and description of the constructs are expected provided that the teachers shared their introduction to the pedagogical approaches through the graduate-level coursework as part of their master's degree program. Still, upon completion of summer courses, each teacher returned to their individual school/district and implemented the CRP and EDP to fit their content curricula. In doing so, teachers experienced varying levels of support from team members and administrators at their schools. Hence, capturing their beliefs upon implementation of the pedagogical constructs was critical because they reflect each participants' definitions shaped through personal experience.

According to the findings, the most critical and pervasive factor influencing teachers' beliefs and agency was the reaction of their students towards the projects infused with CRP and EDP. The teacher participants reported heightened interest in content, student engagement, and improved academic performance. Teachers felt encouraged by the positive learning outcomes and were driven to continue future implementation. They viewed their students' reaction as a benchmark to assess this own effectiveness with the enactment of EDP and CRP. Moreover, upon successful implementation and receiving positive student feedback, the teachers felt empowered in their capacity to advocate for others to use CRP and EDP. As such an important take-away for teacher educators is framing the introduction of instructional practices through the lens of student outcomes.

The Engineering Design Process (EDP). The definitions teachers provided for EDP were consistent with those rooted in literature [34], [50]. The teachers described the steps which include defining the problem [82], researching solutions, identifying constraints, building prototypes, testing, redesigning, and communicating solutions [83]. 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 [84]. 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 [85]. This process of failing and moving forward is productive as students and engineers learn and obtain data through trial [84]. Petroski [86] 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. [86, pp. 45]

Thus, the experiences acquired through the EDP encourage students and teachers to embody a growth mindset, defined by Ricci [87] 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" [87, pp. 3]. Growth mindset has proven to yield positive student learning outcomes through enhanced academic performance in the [88]. The EDP cultivates a growth mindset through student engagement with "test to failure experimentation" [84, pp. 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 [89], [90]:

> 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 [89]

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 [90].

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 [34]. Furthermore, the iterative nature of EDP naturally allowed for the incorporation of scientific reasoning and mathematical problem- solving [22], [88]. 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, [43], [91], [41], [10]. 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 and Boutte [24]. 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 [24]. 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.

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 [92]. 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 considering the cultural and linguistic background of students, and, therefore, provide culturally responsive instruction [21], [81], [93], [30].

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 [40] 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 [40] involves the development of critical consciousness which fosters the cultivation of an individual's sociopolitical awareness through cultural, social, and political engagement [94]. CRP empowers students to identify and tackle the injustices and inequities that impact their lives, and represent the experiences of disenfranchised populations [95]. Consequently, social justice has gained traction as an integral component of culturally responsive instruction, especially in the field of mathematics [95], [81], [93]. 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, [93] to the use of quantitative analysis to challenge a school district's decision for closing a neighborhood school, see [96]. 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 [21].

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 and Zavala [21]. 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 manifested 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 and Irvine [91] 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 [97], [98]. This quality allows individuals to foster sensitivity towards other cultures and approach situations by bearing others' perspectives and experiences in mind [99]. McAlister and Irvine [91] 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. [91, pp. 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 [100]. Furthermore, the findings suggest that emphatic teachers are likely to design and value instruction that fosters a sense of service in students.

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). A key implication derived from this research is the connectivity between the engineering design process (EDP) and culturally responsive pedagogy (CRP) yielding a Culturally Responsive Engineering Design Process (CREDP). A significant pattern and finding that emerged from this research is that upon enactment in unison, teachers perceived a powerful and natural relationship between the two pedagogical constructs. Moreover, an important aspect of this finding was that while teachers were able to conceive implementing CRP in the absence of the EDP, they were unable to do so in reverse. In other words, the value that teachers placed on implementing engineering design with a culturally responsive lens was so strong that they were unable to commit to or visualize the implementation of EDP without CRP. Teachers explained that through combined enactment they were able to reap the benefits of both constructs simultaneously.

Castaneda and Mejia [101] have connected the three tenets of CRP as defined by Ladson-Billing [40] with the standards established by the Accreditation Board for Engineering and Technology (ABET) for a civil engineering program. Similarly, this research provides a framework that couples each of the three tenets of CRP with the iterative steps commonly found in prominent versions of EDP as used in K-12 curricula. See Table 9 [74].

Table 9 The EDP in relation to the three tenets of CRP

Steps in EDP	Tenets of CRP
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
Create a protype	Tenet I: Upholding high expectations for all students
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 [40], [41] 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. [44, pp. 34].

As such, a teacher embodying CRP will need to approach students through an asset-based philosophy [102]. 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 [103], [28]. 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 [40]. 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 [44] 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." [44, pp. 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 [45], [104]. Additionally, teachers often struggle with this concept of CRP because they are lacking in their own sociopolitical consciousness [45]. 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-Gutierrez [96], 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.

Teacher participants, having implemented the two constructs simultaneously through classroom projects, were convinced that engineering design was most beneficial and worthwhile to use when it is immersed in their students' cultural context. All participating teachers acknowledged the value of each construct and were willing to embody CRP on its own, and as a pivotal facet impacting instructional and curricular decisions. Nevertheless, based upon the positive outcomes experienced through the synergistic enactment of the CRP and EDP, the teachers felt compelled to frame each engineering design challenge around a problem that was culturally responsive towards their students. Based on the findings from this study, formalizing the relationship between the two constructs and adopting a culturally responsive engineering design process (CREDP) has the potential to yield greater teacher buy-in which is essential for all curricular reform efforts [31].

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 [100], [91]. 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.

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 [7], [50], [73]. 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 [12]. 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.

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.

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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