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Board 162: Engineering Education and Culturally Relevant Pedagogy in Pre-College: A Review and Synthesis of the Literature

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Engineering Education and Culturally Relevant Pedagogy in Middle School: A Review and Synthesis of the Literature

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Introduction

Engineering is a field that has significant impacts on daily life. For instance, engineering is used in water supply distribution, medicine, and manufacturing [1]. Engineers' roles are essential in the water supply process, designing sanitization systems for springs, cities, towns, and agriculture fields. This also includes water recycling for non-human uses. In medicine, engineers have contributed to several areas, such as the development of technologies that make human surgery precise and less invasive. Engineers have even developed health informatics for efficient medical care. Engineers have designed machines in industry and manufacturing that make useful items for everyday life, like cars, computers, refrigerators, etc. Many of these innovations have been spurred by advancements that rely on an occupational pipeline that is both robust and sufficiently diverse to support technological innovations worldwide. Despite our recognition that these pipelines are important, engineering education is challenged by the lack of demographic diversity that is ideal for supporting intellectual diversity [2], [3], [4], [5]. In the last census [6] reported that white men represented a significant proportion of science and engineering job holders. Some argue this is because learners lose interest—an idea that is consistent with National Science Foundation [7],[8] reports that underrepresented students are more interested in other non-science and engineering fields than science and engineering careers [7]. These data are essential to highlight because they show that engineering education must develop an academic strategy to enhance the diversity of students at middle school levels, where learners are actively making decisions about field interests and career goals [9]. To raise these diversity rates, some have argued that engineering education must start by including diverse students in engineering classes and provide social and cultural equity in engineering classes [10]. The result of all these academic strategies will support opportunity and diversity in engineering education that could drive innovation in science, technology, engineering, and math (STEM) fields [11] pipeline and create learning experiences that couch contexts in multicultural landscapes with their unique practices and priorities [12], [13].

Despite these calls, field diversity in engineering education is persistently homogenous. Furthermore, learning contexts are often decontextualized and thus remove learner culture and social concerns from learning experiences [10], therefore creating a disconnect between learners and the topic [14]. Moreover, this review shows less research on engineering education designs that expressly support diversity and inclusion—compared to other engineering fields. This has had a significant impact on engineering participation diversity. For instance, the College Board Advanced Placement program report showed that even though the percentage of Hispanic/Latino students represented 26% of enrollees in public schools [7], 19.7 % of enrollees were in engineering. Even though engineering education researchers have added knowledge to understand how schools could integrate more diversity, the gap is especially persistent in sociocultural watersheds such as borderland cities (i.e., cities where the population has diverse students or the majority of the population has underrepresented students in engineering education). The National Strategy Plan (2020-2025) developed for the National Academies of Science (NAS) has a cultural component in the three main goals of this plan [15]. The NAS recommends "Address[ing] critical societal and global issues; Improve[ing] public understanding and appreciation of science and the scientific method; Improve[ing] the culture and practice of science" [15, pg. 3-9]. Culturally Relevant Pedagogy (CRP) [16] is a framework that designs learning experiences and supports these efforts. However, we know very little about how CRP in engineering education is taken up in the literature, with whom the work is being conducted, and how. A review of the literature would provide essential insights into the state of the art of CRP and how the field might better focus and support efforts to strengthen the demographic and intellectual diversity needed to maintain field innovation. I am thus conducting a systematic review of the literature in order to understand what are the main features of engineering education in middle school with the CRP framework with whom the work is being conducted and how the research is being designed for their interventions.

The specific objective of this study is to enhance our understanding of how to support diverse students interested in engineering careers. The following questions guide this literature review: (1) How are culturally relevant pedagogies conceptualized in middle school engineering education? (2) With whom are culturally relevant pedagogies being enacted among middle school students? (3) How are culturally relevant pedagogies enacted with middle school engineering education? Insights gathered will inform middle school engineering education and practice.

Background

Engineering Education: Historical Perspectives and Contemporary Directions

In order to understand how today's engineering education has become a site of criticism concerning the aforementioned issues regarding diversity and inclusion, it is fundamental to understand the origins of contemporary engineering education. Engineering education was designed by the society for the Promotion of Engineering Education (SPEE). Along this trajectory, engineering education was focused only on college-level and professional issues [17]. The American Society of Engineering Education (ASEE) started redefining engineering education oriented to design and manufacturing. Over time, engineering education was taken up for pre-college setting—and integrated with science, technology, and mathematics to form the popularized acronym STEM. With the integration of STEM education in the 2000s, engineering education's primary goal was to support innovation and creativity in related fields. In this framing, organizations like the National Research Council (NRC) provided frameworks for how engineering education as a discipline might be implemented in pre-college settings. In 2012, in order to continue supporting STEM education in pre-college, the Next Generations Science Standards (NGSS) was integrated into science education, where engineering education cuts across disciplines, skills, and practices. It means that each discipline that composes STEM education has their-self evolution as an individual discipline too. As a result of these developments, there has been significant research to explore how engineering education might support learning outcomes, including concept mastery in a social context [18], literacy [15], and long-term engagement [15]. While these efforts are critical, far less attention has been placed on designing learning experiences that support diversity and inclusion. Given what we know about the trajectory of how contemporary engineering education was developed, it makes sense that those efforts marked important milestones in the field—in supporting innovation and occupational attainment. Nevertheless, we understand that intellectual diversity is critical to the field—after all, innovations in engineering are shaped and informed by diverse cultural needs, priorities, and values. This means engineering education is inextricably linked to society and culture, and therefore, engineering education must also be shaped consistently. Some research considers that "pre-college engineering education is still in its infancy" [19, p. 757]; also engineering education is a collaboration practice [18], [20]. For these reasons, I will review this discipline. In the next section, I will discuss one perspective on shaping learning experiences in relation to diverse cultures and use this perspective to understand opportunities for developing learning interventions that center culture as a guiding principle in contemporary engineering education.

Culturally relevant pedagogy framework

Culturally relevant pedagogy (CRP) is a pedagogy that focuses on the influence of teachers' beliefs to design their pedagogy according to the students' needs. Gloria Ladson-Billings [16] argued that "culturally relevant pedagogy is an approach to teaching that relies on teachers as decision-makers and intellectuals who can translate and implement research and policy." [16, p. 4]. Ladson-Billings identifies three main pedagogy activities (i.e., competencies) teachers who work with underrepresented students must develop together in the class activities. CRP empowers the teachers' role as a designer in implementing policies and sociocultural research for developing three main competencies in classrooms. The first competence that CRP teachers have is student learning. Ladson-Billings redefined this term in 2021. She writes that it means how much the student grows in one scholarly period that begins in the fall and finishes in the spring-measuring this individual growth. CRP highlights this growth and avoids demerits of the standards test; CRP considers that standardized tests do not measure other meaningful learning that students could have acquired during the academic year. The second competence, Cultural Competence in the context of CRP, is the actions or activities teachers develop to help students gain awareness of their culture and other cultures. Ladson-Billings writes that teachers "would support students' understanding of their history [decolonizing the history], culture, customs, and language, and develop their fluency in the dominant culture" [schooling culture, traditional Anglo science curriculum]. Ideally, the students are *culturally competent* and experienced and consider themselves bicultural or multicultural [16]. Dr. Ladson-Billings mentions that this competency *of culturally competent* is the most misunderstood because other disciplines use these terms as awareness of the client's culture and use this knowledge to provide a better service to Black, Indigenous, and People of Color (BIPOC) [16]. However, CRP is more than using the students' culture. The teacher's *culturally competent* and produces students who can move, operate, dialogue, and be globally interconnected to other cultures and with respect and care for other persons around the world, including European American students [16]. The last competency is Sociopolitical/Critical Consciousness; the students must be able to identify a problematic situation related to them in the school context or student community context. Essentially, Ladson-Billings [16] mentions that this approach uses critical pedagogy devised by Freire. The student explores and researches the factors that generate the problematic situation and takes action to control or change these factors that are causing the effect, not disturbing or uncomfortable for doing so. Ladson-Billings suggests that as CRP teachers, we can take these situations to start exploring more significant ideas like critical theories related to the students' problems that they can bring to class [16]. In other words, the CRP teacher must provide students with pedagogy exercises to develop their cognitive skills for higher learning (like socio-political theories too). Pedagogy takes student problems into the schooling context or student's community context and uses them to start exploring social actions. This provides students with pedagogical strategies that let students develop skills of knowledge to have a high level of consciousness of their environment [16]. In other words, the teacher must guide students to develop the skill of researching and critiquing (critical theory: identify the cause-effect factors of the problem). At the same time, CRP has provided significant insight into teaching and learning across myriad fields such as computer science, language, and math. We know far less about it in engineering education. An insight here would inform both engineering education practice and, equally, how we might expand our conceptualization of CRP in fields that are production centric.

Research Methods

Data Collection and Analysis

For this review, I conducted research in order to identify published papers that include and/or conceptualize culturally relevant pedagogy [21] as a framework for engineering education in middle school. The research was implemented in two phases: (1) literature exploration (this was a pre-phase approach adapted from [4]; and (2) analysis guided by synthesis approaches used by [23]. The first pre-phase consisted of searching broadly if CRP was used in the STEM Education research literature. To accomplish this, I searched Google Scholar using relevant keywords (i.e., "culturally relevant pedagogies" + "STEM Education" + pre-college). Following, I assessed the extent to which articles addressed ideas related to my research inquiry (e.g., were the papers engaging with pre-college groups, were the papers using CRP as a guiding framework, etc.). Lastly, I limited my search to papers that were published within the last ten years because the scope of this research focuses on contemporary implementations of engineering education, and so research done prior to the last decade would not, in my definition, count as the state-of-the-field (i.e., contemporary pre-college education).

In step three of the exploration phase, I narrowed search terms to "Culturally relevant pedagogy" + "engineering education" + "middle school." Then, I used them to query the following publication databases, including: Education Full Text-H.W. Wilson (EBSCO), JSTOR database, Educational Resources Information Center ERIC, ProQuest, Engineering Village ELSEVIER, and Taylor & Francis Online. The first phase of my search result yielded 18 500 articles. In the second phase, applying criteria, as part of my exclusion criteria, I reject literature reviews, editorials, letters to the editor, book reviews, interviews, and book analyses. When I applied the exclusion criteria, my sample was reduced to twenty articles. As part of my inclusion criteria, the search included conference proceedings and papers that have the three keywords together and a second round of review on specific journals that published the selected papers. In general, the twenty selected articles represent the researchers' report applying CRP framework in engineering classes with middle school students. In third phase also included extracting the following data from each article: (a) publishing data such as publication year, authors' names, journals' names, and country or US' state when the study took place in the US; (b) if available, middle school learners' demographic information, including their gender and ethnicity; (c) engineering's academic program features. These data were collected in order to inform the following guiding questions: (1) How are culturally relevant pedagogies conceptualized in middle school engineering education? (2) With whom are culturally relevant pedagogies being enacted among middle school students? and (3) How are culturally relevant pedagogies enacted in middle school engineering education? See Figure 1.

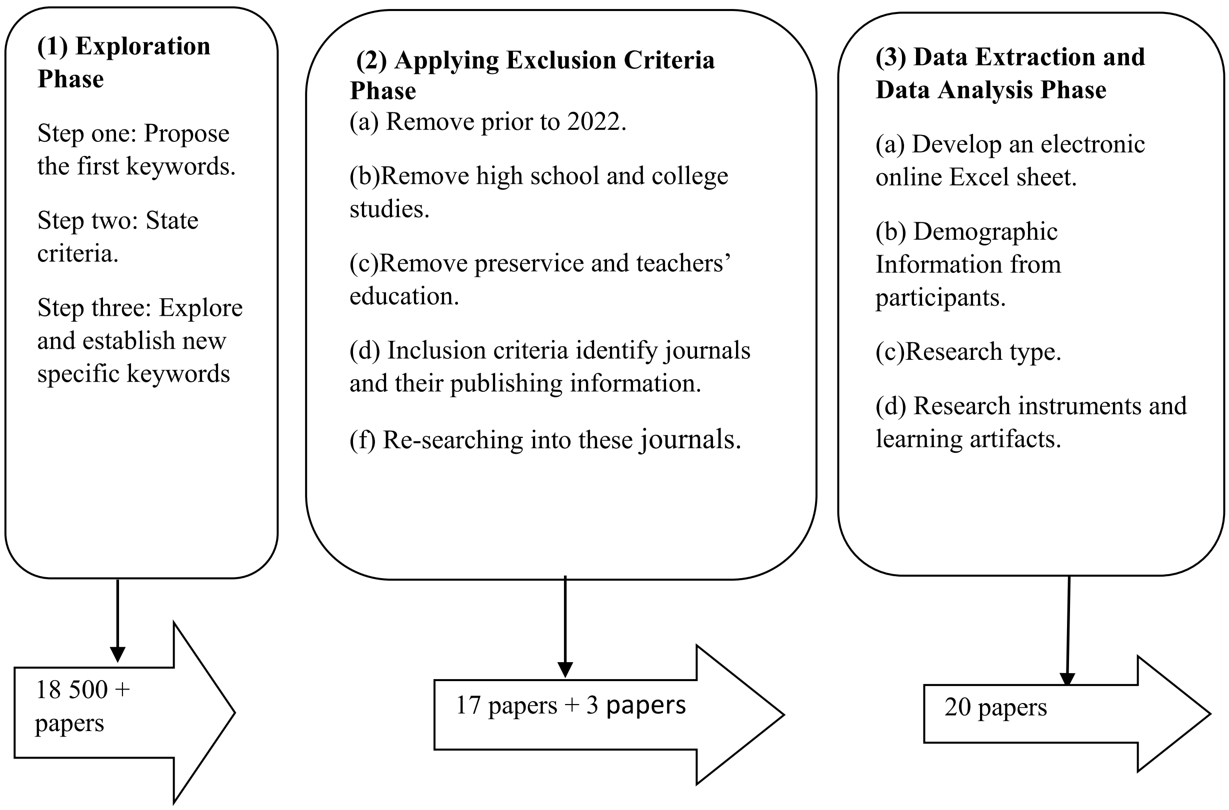

Figure 1. Phases of the systematic literature review method

Analysis and Synthesis

My analysis begins with a description of the characteristics of data sources, such as publications based on the keywords CRP, Engineering Education, and Middle School; 20 articles were found in the database. These articles were published in journals summarized in Table 1.

Table 1
Frequency and promotion of research in journals in the last ten years.

	Journal Title	# Of articles
1	Cultural Studies of Science Education	1
2	Current Issues in Middle-Level Education	1
3	EURASIA Journal of Mathematics, Science, and Technology	1
4	International Journal of Engineering Education	1
5	International Journal of STEM education	1
6	Journal of Science Education and Technology	1
7	Journal of American Males in Education	1
8	Journal of Pre-College Engineering Education Research	1
9	Roeper Review	1
10	Science and Children	1
11	Science and Scope	1

12	The Journal of STEM Outreach	1
3	Conference Proceedings and Virtual: IEEE, ASEE (2019, 2021)	7
1	Thesis from Louisiana State University	1
	Total	**20**

Findings

An analysis of the 20 articles selected for the literature review is provided in this section. The following sections describe the trends of this literature review in terms of the different areas examined within it, including the conceptualization of CRP, demographic information about the participants, research types, and fields of knowledge. For this reason, the analysis and synthesis of engineering education and culturally relevant pedagogy in middle school papers generated the following categories: (a) How do researchers conceptualize CRP? (b) Participants' demographic information? (c) what was the learning context in middle school engineering education? (d) What are the research type's trends?

Conceptualization of Culturally Relevant Pedagogy

I decided to categorize or group the literature into two main groups. The first group was published between 2010 and before 2016, and the second group after 2016 and 2021. The first group of articles used the words culturally relevant pedagogy AND engineering education AND middle school, although none of them conceptualized the CRP framework. Even though these articles pursue the same goal that Ladson-Billings [21] defined in her CRP framework, her framework was not used to design the final curriculum. For example, Henderson [24] reviewed several summer camp curriculums. The data collected by Henderson's research were incorporated to design a new curriculum. Henderson's curriculum was conceptualized in human constructivism learning theory, and cognitive and social behavioral theories [24] and he developed a curriculum to integrate engineering concepts for Black American students. The research concluded that integrating students' culture into engineering summer camps helps Black Americans to develop a significant understanding of the engineer's role. The integration of significant cultural activities increases students' interest in engineering topics. For example, students were exposed to Black Americans' contributions to science and American history. Another article presented a strategy to develop a better understanding of the role of engineering women. Bowles et al. [25] studied the impact of a full-day intervention on Black American female middle school students and their mothers. They were interested in gathering data about the impact of this one-day intervention on students' motivation. The design of this intervention consisted of middle school students listening to the experience of professional women in engineering. The research was conducted to encourage Black American women engineers to participate as professional speakers and mentors and to motivate Black American girls to pursue engineering. The design of this research was based on the knowledge that students of color have a conflict about developing an identity in an engineering career. This is because it is not a social tradition. This conflict of cultural context was studied [21] but she was not mentioned in this publication.

As a final point in this discussion, I would like to mention the research that was conducted by Kern [45] was completely CRP, it developed the three CRP's competence, but it did not use any sociocultural theory. Kern [26] designed, planned, and developed a curriculum and class intervention based on the interest in using Native American students' background knowledge about the traditional construction of fish weirs. Through this pedagogy strategy, the teacher could connect students to culturally significant practices. This curriculum also had the goal of developing community involvement and social activism [26].

The only research I found that was developed outside of the U.S. was from Malaysia. The study used a curriculum from the Museum of Science of Boston to design their informal settings activities. Shahali [27] called the projects a real-world problem because they addressed engineering-based problems in the context of the local community. Their findings showed a positive increase in the interest of students in studying STEM careers based on their geographical context in order to measure motivation. The local cultural community has a positive impact on students' interests. This article highlights the design of hands-on learning activities with applications in the real world. This is the understanding of research about culturally relevant activities.

The research that Stevens et al. developed was designed to have a better understanding of Native American students learning in context using the iSTEM program. In this case, Stevens et al. [28] frame the design of the study in the FoK framework. Additionally, the researchers understand the phenomenon of negotiation that students have to perform between students' FoK and the academic FoK [28]. The academic activities were designed to let students explore community knowledge around specific engineering topics. In addition, they also explored how these engineering topics have related to their community or how these engineering concepts have been managed for their community historically. Stevens et al. argue that the orientation of the questions and arrangement of the questions in open classes allows students to negotiate community knowledge and institutional knowledge. It is CRP's cultural competency goal. Another element of intervention in this research is mentoring local professional engineers. Mentors were trained in STEM programs, and their performance and influence on students' motivation were evaluated as well. The professional development and capacitation of the mentors that take place during the beginning of the iSTEM program is the exact requirement that Ladson-Billings mentions as a key to developing and applying her CRP [16].

Furthermore, the scientists were interested in collecting data from this first group of students before 2016. This project was to observe how local culture and students' culture influence their conceptual change among underrepresented students in the engineering professions. Ladson-Billings [21] identified cultural activities as relevant for African American, Latino, and Native American students and woman students. She included underrepresented students in all minority populations and women who have been historically marginalized from many intellectual activities [21] due to the way women continue to be defined in the traditional way. This first group was more interested in the following field of knowledge: Design curriculum [24], [29], Learning Environments [26],[27], [29], Students' knowledge [25] [26] and student's motivation [25], [27], [28], and the studies that are interested in understanding the student's conceptual change about what an Engineer does [25], [27].

The second group is composed of the last fourteen articles; these studies are characterized by declaring the CRP theoretical framework plus the engineering education AND middle school. These groups of publishing articles were interested in three main areas of knowledge. Most of this research focused on understanding the "Designing Learning context" and the "Designing Curriculum". The second interest for researchers was to investigate what are the students' prior knowledge about engineering roles or duties. After 2016 the design research to understand the students' motivation and how the students' conceptual change was less than in other areas of research about engineering education and CRP.

In general, I found seven different projects and one of them generated seven articles using the same project. This project was called Virginia Tech Partnering with Educators and Engineering in Rural Schools (VT PEERS). This project was designed to cover all the CPR's goals. To have success, the research integrates social community agents like local industry, community, and the local university. Additionally, three school districts (e.g., teachers and administrators, scholar's programs, standards tests, curricula) and science teachers in a regular class with engineering-focused and culturally relevant Engineering concepts were related [49]. This project VT PEERS was developed for the Appalachian rural population that resided within four states of the U.S. The goal for this four years project was to build a collaboration between the scholar administration, local industry, local community, and literature, a big project that was funded by the National Science Foundation for four years. The population that was targeted by this study was Appalachian students. The first article establishes all the relations systems over which this group of researchers is going to inquire, and it highlights the integration of culturally relevant curriculum and science standards can increase Appalachian students' motivation to enroll in engineering careers [30]. The following publishing study reports that the project wants to develop cultural competence and focus on societal challenges more than Appalachian students' culture. The researchers want to develop community engagement through local industry and local mentors [31]. This publishing study is culturally relevant and synonymous with real-world learning activities [31]. For this study, the research identifies the societal challenges in local engineering life and agricultural life science and uses this context as a real-world learning activity. For including culturally relevant pedagogy activities, this study reports using the Model-Eliciting Activities (MEAs) to address local problems; the curriculum's design provides students context to learn Engineering roles and tasks [31]. As they mention, the conceptualization of this project uses several frameworks to design the project. Just one published paper mentioned the Ladson-Billings' framework [16]. Other papers cited themselves when using the culturally relevant framework [32].

Gloria Ladson-Billings includes women in the same group of underrepresented students; she mentions African American, Latino students, Asian Americans, females, and males [16], [33]. Young et al. [33] use CRP to motivate girls of color. She explains that CRP lets him design activities to have a better understanding because these activities develop deep connections between students and cultural context [33]. Young mentions that the lack of continuity in the women population can be to the culture of the community. Then one reason to use CRP is to promote sociopolitical consciousness, so then students can evolve into STEM careers [33]. The integration of CRP in the study is through the role of the mentorships and develops another cultural context around the girls, plus encouraging them to participate in activities outside of the school. It means that CRP designed several activities outside of the school in order to let women of color motivate in a different community context [33]. There is other research that is interested in the importance of gender in engineering education [34]. Even though this study does not mention the CRP theoretical framework, one of the researchers is an expert in CRP. The design of the engineering activity lets students express them-self through oral communication and lets them organize themselves to solve the engineering challenge. However, this study does not mention CRP as a part of its framework. The only connection is the interest of the research expertise in CRP and the focus on women as an underrepresented student population in engineering education research, letting them use their cultural language and cultural background. Maybe the CRP helps researchers understand why women perform better in engineering classes but choose other careers. One of the findings of this research was that in a mixed group, the men were more aggressive in some moments when managing the situation. Then the research focuses on the students' culture that they bring to class and how they manage in engineering class. On the other hand, one article identified some misunderstandings about applying the CRP in engineering classes [36]. CRP is for developing students' competence that lets them negotiate different cultures at the same time without conflict. Also, at the same time, they increase their self-esteem in any professional role and help others to develop their sociocultural competence in their community. This last competence is Freire's dream; it is the goal of critical education that is a democratic education [35]. In this direction, Keratithamkul [36] highlights that teachers must be careful when they use culture in context [36]. When Ladson-Billings focuses on students' culture to help them negotiate democratically and consciously with the school culture, the professional role culture, the family culture, and most recently, there are a group of researchers that are talking about Culturally Sustaining Pedagogy [37] to continue with the critical social competence after school. Here is interesting research that uses students' language. The main component of CRP is the culturally respective teaching practices that are an important element of CRP. With the role of CRT practices, the students can trust and feel free to express their process of understanding [38] then the students start enjoying learning new concepts. However, also, they started writing poetry and sharing their learning and comprehension of their phenomena [38] then, for this research, they created a learning context for expressing their ideas and sharing their learning processes. In other words, letting students bring their culture into class developed an enjoyable environment for learning. Another study that is about CRP comes from ethnography. This research is about Black Americans who have been done by male Black Students. CRP framework helps students face the challenges of everyday life in contexts of different cultures. This everyday challenge is especially true when the school culture is not the most appropriate for studying. Occasionally, school culture can be crowded in classes, and sometimes there are too many rules that students must negotiate between this culture and their own [39]. For Holly [39], engineering education can unintentionally perpetuate the erroneous tradition of racial roles in the academic professions. A career in engineering or an engineering education that provides the correct framework can be expected to evolve and expand engineering education to a wide variety of students so as to challenge the next generation [39] while at the same time developing a more humanistic career in engineering. Also, Holly [39] agreed to continue to work with CRP and expand it to the Culturally sustainable pedagogy designed by [37]. The CRP framework is essential for Holly to teach black students and understand the complex context they face. It also helps them to understand the professional role they will play in the future. Other research is considering ways to develop critical social frameworks that let teachers continue the evolution or transformation of the CRP framework. For example [40], developed the sociotransformative constructionism (sTc) framework. As he mentioned, he took the concepts of CRP and CRT. Rodriguez [40] designed his research by merging socio-critic frameworks [40]. His study used the Rodriguez method of teaching and reporting students' experiences with engineering concepts. Additionally, it examined the social function of the concepts and the needs that these concepts addressed in his study. See Table 2. In summary, the researchers were exploring more in developing cultural competence (seventeen articles) and were less interested in developing sociopolitical competence (see Figure 2).

Table 2
Summary of Culturally Relevant Pedagogy's Competence

	Year of Publication 2010-2016						Year of Publication 2018-2021													
#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
C1		√	√		√	√	√		√		√	√	√			√	√	√	√	√
C2	√	√	√	√	√				√	√	√	√	√	√	√	√	√	√	√	√
C3								√				√	√	√					√	√

Note: # = Identification article number. C1=Academic Achievement Competence. C2= Cultural Competence. C3= Sociopolitical Competence.

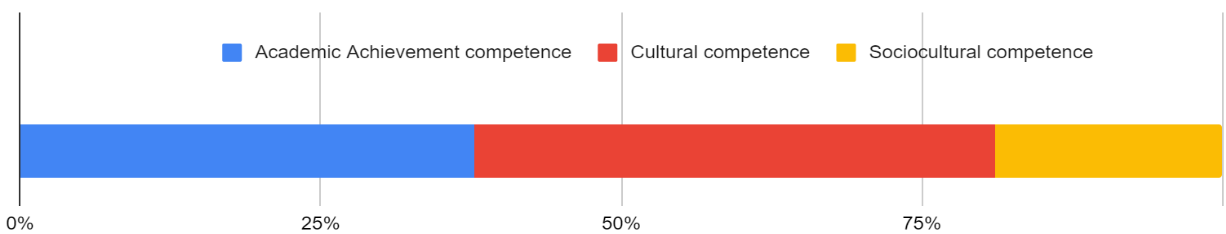

Figure 2. CRP's Competence

The Participants' Demographic Characteristics

Ethnicity

Among the studies (60%) reported students' ethnic composition involved students diverse. From this data, eight studies reported that these studies involved African American students, three of them consisted of all African American students, and in only two, they were the majority. Asian American students were involved in four studies, and they represented less than 18.1%. Native American were involved in two studies (100% and 57 %). The Latin American students were involved in four studies; three of them represented between (13.6 %, 12 %, and 5.7 %) and one study reported a majority of Latino Americans, but this study did not provide accurate information [29]. In summary, even though diverse students have a representation by the philosophy of CRP, African American students have the majority of representation in these studies. Latino American and Native American students were less represented among the students in middle schools. This data serves as a confirmation that more research is needed in engineering education for Latino American students.

Gender

The middle school student population was sampled in different ways across the studies. The vast majority of papers examined in this review did not report on gender (n=12); in 60% of the remaining papers, four reported on interventions with homogenous gender groups (n=4), two studies reported 100% females and two studies for 100% male [41], [39] and four reported on interventions with mixed gender groups where female were 59.5% [27], 71% [28], 33% [34], and 33.3% [38]. The rest of the published papers integrated both genders but needed to specify this information. Despite the fact that engineering education has traditionally been designed for male students, we can see that there are few researchers that are interested in middle school female students in the context of engineering education. In general, see Figure 3.

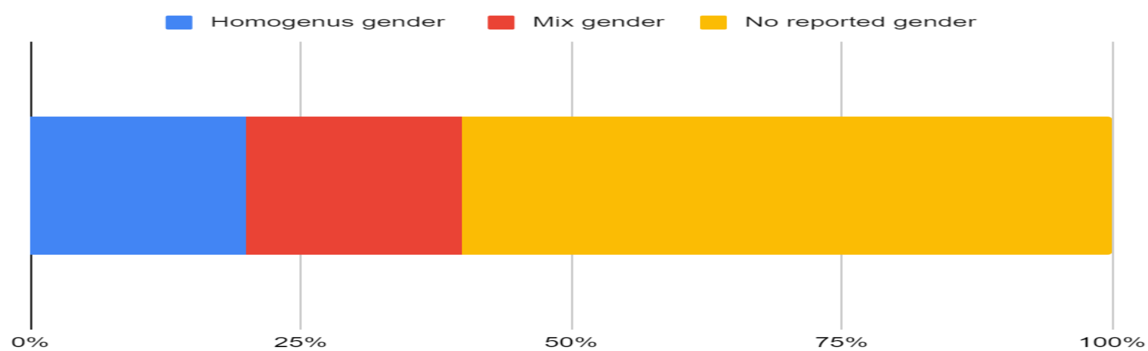

Figure 3. Gender information

Learning Context

Investigations were divided into two main categories: school time and out-of-school time. During the regular school year, researchers conducted their studies during the school day. Only two of the research projects integrated these two modalities during the regular school year [30], [28]. Another type of research context in the summertime was the study presented by Henderson [24]. Research during the summer also helped to study a specific population of middle school students which was lower income. This was because it was probable that their parents could not afford the cost of summer camps or vacations. During the two months of summer break, these underrepresented middle school students interrupt their education [42]. Another interesting learning context process that research has studied is the tutoring and role support [25], [41], [43], studies designed to establish a dialogue between students and professional engineers through the intervention of a woman or a man of color as a professional engineer. The research found support in different colleges of engineering that provide the student in engineering careers with tutoring students or professional engineers to provide motivating speech to specific URM population [25], [28], [39],[44]. In general, the literature shows that learning contexts were informal or out-school settings (see Figure 4).

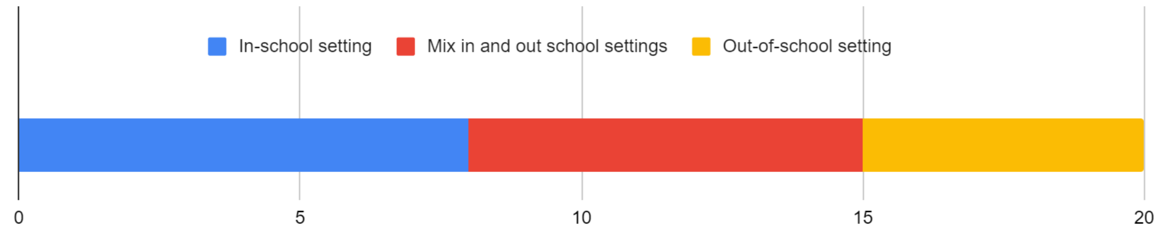

Figure 4. Learning context

Where did the studies develop?

The following table lists the U.S. states that have participated in research using the keywords that this study has defined. By analyzing this table, we can determine where the studies are located in terms of their inquiry development. The majority of the studies (15 out of 20) were conducted in non-borderland states. The review on this category shows that Virginia has six research studies on rural students, while Minneapolis has two. One study was conducted in North Carolina, Idaho, Indianapolis, Iowa, Georgia, and Michigan, and three states, Arizona, Idaho, Minnesota, New Mexico, and Texas studies were conducted in borderland states, but not one was conducted in borderland cities (e.g., El Paso/ Mexico). There is also a study from Malaysia, a country in Southeast Asia. A total of twelve states have conducted studies related to CRP and engineering in diverse students, and two countries, the USA and Malaysia, are presented in Table 3. This table shows that only fifteen states have resources and researchers that are contributing their findings to the body of knowledge.

Table 3
Research States Involve(d)

Study State	Study Country	Study State
Arizona	USA	1
Georgia	USA	1
Idaho	USA	1
Indiana	USA	1
Iowa	USA	1
Louisiana	USA	1
Malaysia	Malaysia	1
Maryland	USA	1
Michigan	USA	1
Minnesota	USA	2
New Mexico	USA	1
North Caroline	USA	1
Texas	USA	1
Virginia	USA	6
North Tennessee is collaboration to Virginia	USA	
Easter Kentucky is collaboration to Virginia	USA	
Total: 15 U.S. States	2 Countries	20 articles

Note: North Tennessee and Easter Kentucky do not were counted because they are included in the articles with Virginia states.

Research Type's Trends

Literature reviews are analyzed according to research types; this literature review covers the following research qualitative (Ql), quantitative (Qn), and mixed-method (MM) research are the three types of empirical research, see Table 4. Ten researchers in this literature adopted a Ql approach, and their studies focused on pre and post-interviewing. Additionally, the researchers used recorded video in class, recorded audio from interviews, students' artifacts like drawings developed in class, written papers, and observation field notes. Only one study's approach employed a Qn design [27]. Shahali's study [27] was designed with a quasi-experimental design (QE) and pre-and post-survey. Five researchers employed MM. Two studies used the well-known Draw and Engineer Test (DAET) to get data from students and their conceptions of engineers' tasks [25], [45]. Bowles's team analyzed exit surveys and requests for survey satisfaction. Other MM practices included pre- and post-structured interviews about students' beliefs [28]. Research artifacts included in MM are an open-ended survey and a close-ended survey; this method is employed by [41], along with a correlation t-test. Also, they analyzed semi-structured interviews, pre-semi-structured interviews, and post-semi-structured interviews. Young et al. presented a position paper [33]. Lesko et al. [30], and Kern [26] presented a description of engineering curricula for class.

Table 4
Research Type

Empirical research		**Total**
	Qualitative research	10
	Quantitative	1
	Mix-methods	6
Position Paper		1
Review Curricula		2

Engineering Disciplines

There are three research projects that clearly stated the engineering disciplines that they were focusing on. They situated their research using Civil Engineering [24], both Industrial Engineering and Biochemical Engineering [25], and both Electrical Engineering and Robotic Engineering lab activities [38]. The remaining articles did not report specific engineering disciplines. The summary of all this data is in Table 6. In this literature review, I found seven articles that are related to a four years-research-project called "Partnering with Educators and Engineers in Rural School", or PEERS. PEERS is a four-years-study-project. They started to identify the student conception of engineering and then support different activities involving several social and economic factors like community belief and local industry activity [43], [45]. The papers of this review focused on the following specific fields: Engineering activities, careers, components, support, work, practice, design, process, workforce, manufacturing facilities, industry-community, career pathways, and local engineering plant. There were few researchers in the studies of engineering education that took a sociocultural perspective prior to recent years [34]. Grohs' research [44] used the words: students' self-efficacy in engineering, hands-on engineering activities [44], middle, grade level engineering learning experiences, learning interaction, student conceptions of engineering changes, educators/pre-college engineering education, and Matusovich et at. [46] integrated civil engineering with social aspects [46]. It was not until 2021 that Holly [39] wrote that the following words more clearly signify the tendency of engineering and CRP like engineering educators; these include pre-college engineering education, engineering student, the engineering community, pre-college engineering learning experience, engineering teaching, engineering learning interaction, to learn engineering, engineering habits of mind, engineering ecosystems, conceptions of engineering, multidimensional of engineering, sociotransformative engineering, engineering identity, the ways traditional engineering instruction, engineering instructional to be socially transformative if done well, engineering literacy, the ways the techno centricity of engineering. Throughout this review, I identified only four articles that mention six engineering professions: civil engineering, industrial engineering, biochemical engineering, computer engineering, manufacturing, and industry. Out of all these disciplines, only one article has been written about "biochemical engineering." This is a discipline combining three different scientific disciplines: biology, chemistry, and engineering [25]. Engineering has important implications in several other academic disciplines, including synthetic biology, which combines engineering with computer and biology knowledge, or biomedical engineering. Using this analysis, it is identified that there is not enough research concerning new engineering careers [47], [48], which is necessary in order to address the challenges mentioned above [49].

Researchers' Topics Interests

The articles of this literature can group into five main categories. The Learning environment was the category that the research was interested in. It means that fourteen research papers developed their study around this topic. The second category that researchers were interested in was curriculum; in this category, twelve studies developed a curriculum for this study. The third category that researchers were interested Students' prior knowledge and scaffolding, and the last category, researchers were interested in deeper conceptual understanding; this category has four studies. (1) Curriculum: These studies focus on developing or designing a curriculum for Engineering content while simultaneously integrating Culturally Relevant Pedagogy. The second group (2) Learning Environments, is interested in designing a better learning context for young middle students. (3) The third group of study focuses on identifying the students' beliefs about the Engineering profession or their understanding of the role of engineers. (4) The fourth group leads to the study of how to engage students using their cultural framework, and (5) the fifth group is a study of deepening conceptual understanding of how the CRP intervention ultimately generates changes in students' conceptualizations of engineering careers or engineering roles. See Table 5 and the summary in Figure 5. The outcomes of the studies focus the majority on learning environments and less on deepening conceptual students' change. One of my criticisms is that there are very few studies that explore engineering concepts and very few studies that discuss non-traditional engineering careers (just one). The fact that more research is being conducted on CRP in the field of engineering education is encouraging; however, there still needs to be more interest in the student's background knowledge.

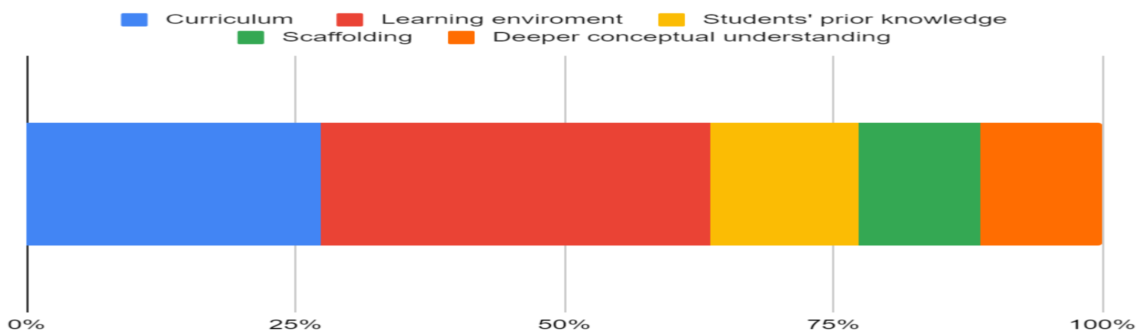

Figure 5. Fields of Knowledge

Table 5

Trends in Engineering Education and CRP's Research Topics

Year of Publication 2010-2016							Year of Publication 2018-2021													
#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
C	√		√	√				√	√			√	√		√	√		√	√	√
LE	√		√	√	√	√	√	√	√	√	√		√	√	√	√		√		
S'PK	√	√							√	√				√			√	√		
DCU					√							√					√		√	
Scff		√		√	√			√	√							√				

Note: Curriculum (C), Learning Environments (LE), Students' prior knowledge (S'PK), Deeper Conceptual Understanding (DCU), Scaffolding (Scff)

Discussion

The Conceptualization of CRP

As part of this literature review, I examined using the CRP framework in Engineering starting in 2010. From 2010 to 2016, I observed that researchers used the term culturally relevant pedagogy but did not use Ladson-Billings' CRP framework. The articles before 2018 define CRP just as a way of teaching specific students. This published research only included Black American students as samples of their study and integrated students' cultures to develop better communication [24]. Another element of CRP that the research was using was the implementation of Black-American engineering students or professionals as tutors or mentors. In this way, the students could feel motivated to study engineering careers and could have a concept change about the identity of being an engineer [25]. Another important requirement that the CRP framework requires is the integration of local community knowledge or local community culture into the school curriculum. The research develops a curriculum with these elements in order to motivate students; however, Ladson-Billings mentioned that integration of students' cultures is to learn how to negotiate and integrate both cultures into their life. In this case, almost all the studies misunderstand this CRP's goal. In 2018, the research added CRP and cited Ladson-Billings. Their conceptualization of CRP in these studies justifies the importance of studying not only underrepresented students but also studying diverse students' populations and using the community's local culture of the engineering industry to identify students' ideas or beliefs about engineering roles and to know more about local engineers. This study has identified that the conceptualization of this CRP's framework was partially complete. CRP requires the integration of the community into the academic curriculum to develop the competence of sociopolitical consciousness [16]. In 2018, a big 4-year project was created. This project generated six articles that focused on the study of rural Appalachian students. Using their previous knowledge, researchers, together with a university in Virginia, developed an engineering curriculum integrating local context to engineering topics and local industry to motivate students. This PEERS project was framing its project with CRP, only missing the sociopolitical competence. Considering this CRP 's goal, only a few research projects were focused on developing this competence [41], [39], [40]. But still, one of my observations is that sociopolitical competence is incomplete as the integration of critical thinking is not developed. Holly writes and highlights that teachers must be careful in introducing culture into the classroom and compare the different student's cultures or different contexts to highlight science or technology as they can fall into racial comparison, which can lead to themes of racial supremacy [39]. Sociocultural competence is into critical theory (e.g., equally, dialogue and comprehension of the resources that people have). Even though the literature that I reviewed focused on developing this sociopolitical competence, they misunderstand this goal.

Opportunities for Increased Demographic Diversity

The literature shows that researchers were focused on Black-American students that are below on middle school level. Of all studies, only three were reported and interested in focusing on gender issue experiences. Black American women in engineering [25], [33], [34]. It is not clear whether gender issues were particularly important to researchers in fifteen studies since no information is provided regarding the gender of the students. In contrast, the other studies only reported on the effects of Black American students when they comprised 100 percent of the student group [39], [41]. Additionally, most of the research was conducted on African American students in fifteen states of the United States; however, only five of these states border another country. Two articles described work with Latino populations, but the cities selected for research were not located on the borderland with Mexico. Students from Latino backgrounds need to study engineering more for educational purposes. The same reflection is for Native American and Asian American students. To summarize, there are not enough studies in engineering education with the perspective of gender in diverse students.

CRP in Formal and Informal Settings: Opportunities to Examine

The literature shows that most of the studies were developed after the school cycle 11 studies. Only the project PEERS was implemented as a class intervention. Another two studies [34], [36] out of 20 were able to develop during class time. I would like to highlight that some of the research developed either in the summer or outside of the school cycle because they considered that this modality would let researchers incorporate variables that schools would not like (tolerance, safety choice, emotions, and other variables of gender) [33], [50]. The study that was implemented in the summertime mentioned that at this time, the curriculum could implement innovative approaches to engineering topics unlike traditional studies [24]. Using this modality led to diverse students engaging in school topics and maintaining high self-esteem of academic motivation before coming back to school. Also, the implementation of summer camps allowed researchers to integrate different experiences of learning [38]. The analysis of learning context, informal or formal just, was limited to the space where the DS receiver engineering activities or classes, also there are pedagogy realities [51] that must be necessarily integrated to design learning experiences for DS

CRP Learning Outcomes and Learner Success in Engineering Education

The literature reflects the interest of some researchers in education to consider the CRP framework as a tool to design learning environments for engineering content. The researchers have found that the CRP is the perfect framework for designing learning environments due to the fact that society and the school can have a better dialogue. It means that the CRP framework has opened the door to integrating two different points of view where both these cultures can compromise. As a consequence of this dialogue then, the students feel that engineering roles are something that they can develop. Inquiry about the relationship between DS's language and identity as an engineer can help in understanding how DS is learning or negotiating new identities [52] in science classes. The consequence of this dialogue or negotiation is the researchers' interest in the curriculum design for DS because, thanks to CRP's framework, now the researchers understand that the traditional curriculum is lacking in meaning for DS. The other research topics, such as students' prior knowledge, how students are scaffolding, and how to measure the students' concept change when the CRP's framework is present, but in fewer published articles for DS I saw in the literature that the comprehension of the CRP's framework on engineering education is applied partially to underrepresented students; therefore, it is necessary to conduct more studies about the influence of CRP's framework on Latino American students. This is because the U.S. shares a long border with México. This borderland is a melting pot of two cultures where American students not only have to negotiate with these two cultures but also with academic and school cultures. CRP's framework mentions that as teachers, we can use this cultural context to engage students and let them develop their creativity to establish channels of communication that are more meaningful in the areas that we need to develop, such as engineering. Research has shown that students' experience of engineering roles in their community can lead to conceptual change. This awareness is very important for DS because CRP's framework allows students to enjoy their identity at the same time as they develop a new local engineering identity. The outcome of this research is the increased motivation and interest of this population, which is not traditionally represented in engineering profiles. Finally, CRP's framework primarily determined the factors that Black-American students need to achieve academic success. This framework identified the importance of the feeling of belonging to an academic class, a professional role, and a local community. Further, the results of this literature review identified the importance of developing qualitative research to understand more about engineering roles and how underrepresented students perceive these roles and prepare diverse students to innovate or create new engineering disciplines that are more important in our contemporary times.

Conclusion

It is evident that the main interests of the researchers lie within the category of Learning environment, followed by Curriculum design, and at almost the same time, students' prior knowledge, scaffolding, and deeper conceptual understanding are also important. It is evident from this last category that fewer researchers have been interested in developing pedagogical strategies for teaching or designing strategies for learning engineering concepts. Most research endeavored to understand how CRP might benefit African American students in engineering education. My interest is in developing research with diverse students living in borderland cities in the United States. Generally, the researchers found that diverse or underrepresented students accepted all the CRP strategies and were motivated to pursue engineering careers. Moreover, there is a lack of research regarding new engineering careers since we are preparing students for future challenges, many of which are common to the engineering profession. As a result of the analysis of these articles, I can conclude that contemporary engineering education still needs to be researched with sociocultural frameworks. CRP was created to emphasize the importance of developing other channels of communication where diverse students can communicate and use their cultural knowledge, comprehension, and understanding in engineering classes too. In this literature review, I noticed that CRP's framework was used to design learning contexts for Black-American students, even though Ladson-Billing always included all underrepresented students. Ladson-Billings mentions Native American, Indigenous, Latino, and female students as an underrepresented population, but still, there are few studies that research that consider women and diverse students in engineering education. Also, there are few articles that consider middle school students and CRP (20 articles) in engineering education. Middle school students, according to Ladson-Billings [16], are the perfect population where CRP can help not only to create a more effective way of dialogue through youth students' culture but also to take care of other thought sociopolitical competence. Ladson-Billings mention that studies in middle school students are essential because these middle school students just start defining the profession they want to be and the cultural identity to follow. Developing academic or professional identity is a process that teachers must consider in science classes [52] at the same time that pedagogies realities are present in science [51] classes. Additionally, engineering education in middle school takes place in social practice [19]. There is few research investigating middle school students' conceptions of engineering [11] and less research about Latino American or diverse students and CRP. One of the findings of this literature review is that researchers are considering incorporating different forms of cultural expression into engineering education can help to increase the interest of diverse students in engineering careers, but only one study mentioned new engineering disciplines. This literature review shows a gap in the literature about engineering education and Latino students in borderland cities. As a result of the literature review and findings related to engineering disciplines, it may continue to be necessary to study diverse students in new engineering disciplines in order to increase the index of integrating diverse students into the engineering workforce. As well as contributing to the creation and innovation of engineering fields, this will also contribute to the development of scientific citizenship literacy.

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