An Exploration of the Role of Critical Consciousness in Pre-College Engineering Education (Other)

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Introduction

As the body of scholarship on pre-college engineering education (PCEE) research continues to grow, there remains a significant dearth of consideration of the influence sociopolitical context has on engineering teaching and learning in pre-college environments. Two prominent publications provide a comprehensive review of efforts to introduce engineering to students in grades ranging from pre-school through twelfth grade, *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* (National Academy of Engineering and National Research Council, 2009) and *Building Capacity for Teaching Engineering in K-12 Education* (National Academies of Sciences, Engineering, and Medicine, 2020). These publications do not represent the extent of literature on PCEE but they are significant beyond coming from leading national agencies regarding engineering education, practice, and policy. The former study offered general principles for P-12 engineering education based upon a review of curricula, professional development, and core engineering concepts and skills. The latter report came after the widespread implementation of the Next Generation Science Standards (NGSS Lead States, 2013) which include engineering concepts, and this report aimed to "consider the capacity of the US education system to meet current and anticipated needs for K–12 teachers of engineering" (NASEM, 2020, p. 1). Following such reports, the national discourse on P-12 engineering education has shifted from making the case for teaching engineering in P-12 education to the question of how to do so with excellence.

The literature on PCEE has expanded to include new frameworks (Moore et al., 2014), curricula (Chabalengula & Mumba, 2017), and standards for preparing teachers of engineering (Farmer et al., 2014); however, we suggest the social context of pre-college education needs more consideration for all students to be exposed to high quality PCEE. Though some scholars have engaged with the influences of identity (Charmaine Spruill et al., 2021; Wilson-Lopez & Acosta-Feliz, 2021) and culturally affirming teaching practices (Holly, Jr., 2021), the broader ecological circumstances experienced by a pre-college student may arguably be the most influential determinants on their preparation for post-secondary engineering education. Historical educational inequities like underfunding of urban schools (Kozol, 2012), lingering effects of racism and poverty (Milner, 2015), and a culture of ableism (Broderick & Lalvani, 2017) have long sustained disparate learning experiences for pre-college students. Furthermore, the expanding agenda to enrich Science, Technology, Engineering, and Mathematics (STEM) education is often proposed as a solution to educational inequities (Bullock, 2017). While we are encouraged by efforts to strengthen the PCEE infrastructure we propose more robust considerations are necessary to examine how these investments of resources will not deepen ongoing inequities, particularly as STEM courses suffer from an exclusionary culture (Carter et al., 2019; Nasir & Vakil, 2017).

In this paper, we will explore critical consciousness as a conceptual framework that can assist pre-college engineering educators in advancing equitable PCEE. Critical consciousness can help educators disavow perceptions, attitudes, behaviors/practices, and beliefs that justify

and reinforce inequities prominent in how pre-college students are educated about engineering. Additionally, critical consciousness can help educators in broadening their conception of engineering knowledge and its role in society, which supports the epistemic agency of their students (Carlone et al., 2021). These are important avenues for making engineering education more equitable for all students, particularly for those who have been excluded due to unjust social norms and deficit-oriented instructional practices. We present a review of scholarship on the concept of critical consciousness, including literature on it being applied in pre-college STEM education, and then we make an argument for this concept to be explored further in PCEE.

Background

The conception of what is now commonly referred to as critical consciousness can be traced to Frantz Fanon's profound autoethnographic work entitled *Black Skin, White Masks* (originally *Peau noire, masques blancs*). Fanon, a psychiatrist and intellectual, conceives of the term conscienciser to describe his efforts to raise the consciousness of his Black patients. Davis (2016) describes the way Fanon used his practice as a method of mental and social liberation:

> Fanon uses his conscienciser on his black Martinican patients to help them better understand the state of their psychosis—rooted ultimately in their oppression by French whites and their own battles with Du Boisian double-consciousness as black French colonial subjects—and counteract it with both awareness and education about the systems that impacted the ways in which they interacted with the white world and other black people. (p. 31)

Davis explains how Fanon identified the social structure of his patients as the root of their pathology, and he sought to raise their consciousness by helping them understand this social structure and pursue changing it. Fanon's location of the dysfunction within the society and not the individual is significant because he's writing in a colonized society, and in that context any display of dysfunction by the colonized people justifies their subjugation in the eyes of the colonizers. Moreover, Fanon's suggestion that the individual's condition could be resolved by consciousness raising is also significant as it asserts an individual's agency to resist and counteract externally oppressive social forces. This is not to suggest an individual can overturn a social structure, rather he is suggesting to dismantle an oppressive social structure one must first understand how it operates.

The more popular version of consciousness raising comes from Paulo Freire's legendary text entitled *Pedagogy of the Oppressed* (originally *Pedagogia do Oprimido*). Freire, an educator and philosopher, translated the consciousness raising concept as conscientização in his prominent work on critical pedagogy as he was exiled from his home country. Freire spent time teaching poor rural workers in Chile where he aimed to provide a truly liberating education, he describes conscientização as "learning to perceive social, political and economic contradictions, and to take action against the oppressive elements of reality" (Freire, 1968, p. 36). Freire adds specificity to the problematic social structure referenced by Fanon by naming its domains, and retains the core principle of necessitating counteraction against the social structure. More importantly he asserts oppressive social class structures produce ideological hegemony which

causes a fear of freedom for the oppressed. In other words, Freire, like Fanon, emphasizes the psychological harm that results from a society that compels its marginalized citizens to believe their inferior social position is natural or justified in some way.

Freire's notion of conscientização, more commonly known as critical consciousness, is perhaps more popular because it is explicitly connected to pedagogy. Specifically, Dr. Gloria Ladson-Billings embeds it as a core tenet of her formulation of culturally relevant pedagogy as she prescribes "students must develop a critical consciousness through which they challenge the status quo of the current social order" (Ladson-Billings, 1995a, p. 160). Scholars in education have longed provided analysis of social structures by correlating factors of racial identity (Hammond, 2014; Hrabowski et al., 1998) and socioeconomic status with likelihood for academic success (Economic Policy Institute, 2017), but little is known about how these factors influence PCEE. In a recent special issue focused on PCEE research, Martin & Wendell (2021) discuss the dominant narrative driving initiatives for equity in engineering education:

> In this problematic view, advancing equity revolves around a two-step process of diversifying participation, which itself entails (a) getting diverse learners ''into the room,'' perhaps by building excitement or by rooting out barriers to participation, and then (b) remediating their deficiencies so that they can be full participants. (p. 43)

This narrative follows the tradition of unjust societies to locate the problem of inequity within the disenfranchised individuals and not the social system. Therefore, the solution is thought to be fixing the students and not the social conditions that created any shortcomings displayed in their academic performance. Alternatively, we suggest pre-college engineering educators should be trained on how to counteract the consequences of inequitable education systems in their pedagogy. This begins with first understanding the mechanisms that created and sustain educational inequity and we consider this literature review an initial step to cultivating such consciousness among pre-college engineering educators.

Literature Review Approach

Despite the age of Fanon's and Freire's works, the literature on critical consciousness (CC) has only begun to expand substantially within the last ten years. Research studies that explore the effect of critical consciousness span disciplines of philosophy, media, and linguistics among others, demonstrating the widespread appeal to disrupting the status quo. In our search we considered the pre-college educational context to be the primary interest area, and then STEM education contexts were of interest since there is a lot of correlation in culture and content between engineering and the other STEM disciplines at the pre-college level. Our objective in this literature review was to gain a foundational sense of how educational researchers operationalized CC and articulated its usefulness for educating students in STEM learning settings. We used SCOPUS as our primary literature search database, beginning with keyword searches that used a combination of terms covering P-12 (e.g., secondary, elementary, informal), CC (e.g., social inequity, oppression), and STEM (e.g., mathematics) simultaneously. After yielding a small number of articles we removed the STEM focus, this process provided us 19 articles, though two were not relevant. We figured exploring the examination of CC outside of STEM courses would provide a more expansive operationalization of the concept since

analyzing the social and political aspects of STEM education is growing but still lags substantially behind other disciplines. Then we determined we would also like to see how CC has been examined at the collegiate level, so we searched for articles retaining the CC terms but combining them with terms representing post-secondary education and the specific discipline engineering. This process provided us with 13 more articles. After surveying the list of 32 articles we selected 19 that we were most interested in reading. As we read these papers we sought to identify three features: 1) how are the authors defining CC, 2) what theoretical frameworks are they using, and 3) what benefits to student learning were presented. In the next section we present themes we identified across multiple papers.

Findings

The findings below discuss cross-cutting themes that came out of our review of the literature, we will highlight nine papers which had the strongest representation of the themes we found.

Theme 1—Focus on Social Relations

The articles had different foci in terms of whose critical consciousness was being explored (e.g., teacher, student) and at which level of society the study was located (e.g., classroom, institutional), but a common focus was on social relations. Specifically, the nature of the relationship between teachers and students. Banda & Flowers (2018) examined the ways Latinas in navigated the climate of their undergraduate engineering programs. Interestingly, this study highlighted the importance of how who is absent from a context is just as important as who is present. The participants in this study discussed their desire to see more Latinx, and even Black American, students in their courses. The Latinas articulated the social comfort of being able to relate to someone with the same racial/ethnic identity and how that would have improved their educational experience. On the other hand, the predominance of male students led to many experiences of sexism during their academic pursuit. One student stated the need to assert herself within classroom discussions to ensure her perspective was heard and valued, and her perceptiveness of the core issue as not her but how males viewed her is notable. The authors recommended discussions at multiple levels to address the issues Latinas in engineering endure: a) dialogue amongst faculty, staff, and students within institutions, b) dialogue with Latinas about the complexities of the engineering workforce, and c) dialogue with national leaders to advocate for increased Latina participation in STEM.

Another article, Johnson & Elliott (2020), proposed a model that begins with faculty-student interactions and expands to the departmental level. The authors state, "this model requires professors think critically about culture and power; we will argue this is key to transforming departments" (p. 3). This framing of the role of faculty suggests the proposed change faculty experience will not end within their classrooms, rather faculty are encouraged to spread their learning and practice of critical consciousness to the broader community norms. Though this article is not a research study, the authors report data from qualitative research and program evaluation they conducted over a 15-year period. When discussing critical consciousness, the authors share a scenario from their dataset about faculty in a mathematics department that agreed to avoid criticizing students in the presence of other students. The authors

state "by changing how they talked about students, these faculty began to think differently about their students" (p. 6). The authors locate the cultural issues that marginalize students characterized as "underrepresented" is within the culture of science itself, which they suggest allows faculty to create new departmental cultures.

A third representative paper that is focused on social relations offers a considerably different depiction of what is possible when implementing CC to alter teacher-student interactions. Gómez & Cammarota (2021) investigated how Mexican American high schoolers' CC developed over time after taking a university social justice course. In this case, CC was not just a part of the course but central to the learning outcomes. The authors state, "this article reports on a radical pedagogical approach to social justice education rarely implemented in university settings in which students and instructors share in the responsibility of co-constructing knowledge" (p. 2). This framing of the teacher-student relationship has implications on the roles of teacher and students within the learning setting, as well as, on the content and epistemic outcomes of the learning experience. The authors state Chicanx and Latinx youth increased their engagement and self-efficacy when given the space to "interrogate and resist the white supremacist world in which they find themselves" (p. 3). The authors centered their course within a framework of critical pedagogy, exhibiting the tenets of equitable relationships, empowerment, radical love, and critical hope. The researchers mention one of the most prominent themes from their interviews with students was the importance of the relationship students were able to form with their instructor during the course, the classroom culture increased their sense of comfort which led to deeper engagement.

Theme 2—Use of Critical Theoretical Frameworks

Freire's book, *Pedagogy of the Oppressed*, is considered to be an example of critical pedagogy which scholars interested in CC tend to model in their instructional practice. We noticed that many researchers also used a "critical" framing as a lens to interpret the findings of their critical pedagogical practice. Huffling & Scott (2021) use the theoretical framework of critical environmental agency (CEA), this theory builds upon the critical science agency framework and environmental literacy research. CEA suggests a) the particularities of people's lived experiences should be considered in environmental education and that will broaden educational practices, and b) environmental education is a benefit to people because it provides knowledge and skills that will further their development of CEA. CEA includes five principles, here we include the principle and the definition provided by the authors. 1) Knowledge means to gain a deep understanding of the sciences that inform environmental education and the processes, skills, and modes of inquiry associated with the sciences. 2) Identity implies people identify themselves as experts in one or more realms associated with EE. 3) Place means to gain a deep understanding of place, leading to a critical consciousness of place. 4) Action is when people strengthen their sense of place and demonstrate behaviors, actions, and/or individual and/or collective agency to consider, discuss and/or act on environmental issues. 5) Vision is when people use EE as a foundation for change, such that their identity develops, their position in the world advances, and/or they alter the world towards what they envision as more just (Table 1, p. 5). The study took place during a professional development opportunity for middle and high school science teachers. The authors created this framework to shift the identities of the teachers toward enacting agency in how information about the environment is used to educate students,

specifically encouraging a deeper engagement with the historical background of a place and its socioecological aspects.

Chávez-Moreno (2021) offers a specific nuance for CC that hones in on racism as a point of consciousness raising within the broader social structure, she calls this framework critical racial consciousness (CRC). This added specificity, Chávez-Moreno explains, is due to the ways the United States' social norms evade any real engagement with race. While CRC is explained as an outgrowth of Freire's notion of CC, Ladson-Billings' (1995b) culturally relevant pedagogy, and tenets of dual-language bilingual education (Cervantes-Soon et al., 2017), it is not very clear what propositional underpinnings are being added to formulate CRC. Nevertheless, the implementation of CRC by teachers is described as "a way to detect dehumanizing ideologies, improve outcomes, and/or provide educational equity to Latinxs" (p. 19). This use of a critical framework also aligned with the use of critical ethnography to study how white supremacy was present in the policies of a secondary-level dual-language program. This approach lead to the following takeaways: 1) Teachers viewed Spanish speaking students as privileged because Spanish is regarded as very important in terms of teaching, while simultaneously not allowing the students to have autonomy in their learning; 2) Justice, or societal issues, were not examined nor addressed in the context of these students' learning; 3) The prominence of meritocratic ideologies led to many students being placed in remedial classes; and 4) Viewing intelligence as a genetic factor was used to rationalize differences in achievement. The author stated using this theoretical framework provided insight as to why even teachers that are motivated by social justice still use racist ideologies regarding language to explain disparate educational outcomes.

Schindel (2016) makes use of critical pedagogy of place (CPP) to study urban high school youths' civic engagement in relation to environmental science curricula. This article describes a learning context where a teacher made explicit connections between the curricula content within the classroom and the local context that existed outside the classroom. Using a project focused on restoration of a park, the author demonstrated how students gained a deeper understanding of ecology with a certain place while also gaining insight as to how the ways humans interact with the environment producing the consequences being analyzed. In this article, CPP is described as a combination of:

> "critical pedagogy with place-based education, potentially providing educators with a powerful framework for engaging youth in learning and action that can transform youth's ways of living in places and challenge dominant ways of thinking and practices that have led to unsustainable and exploitative relationships among people and with the planet" (p. 814-815)

This framing of CPP suggests students are being trained on how to analyze the impact of the social structure on their learning, their interactions with others, and the planet. This explicit connection between student learning and "unsustainable and exploitative relationships…with the planet" make clear the author's desire for students to problematize power dynamics and environmental inequities they experience. The author suggests using CPP revealed instances of students cultivating CC even though CC was not a central feature of the class curriculum. For example, the author states, "youth expressed understandings of place that were both dynamic and relational by recognizing the relationships between species and their habits and by situating these

relationships with cultural and sociopolitical contexts" (p. 829). This was a display of how student used their scientific understandings to analyze social contexts. Another example is the way the framework highlighted students challenge of dominant ways of thinking. After spending time in the course, students began to reframe the narrative of their community as defeated due to urban deindustrialization to articulating the opportunity for transformation. The author describes these manifestations of hope as evidence of student exhibiting critical consciousness.

Theme 3—Connecting Discipline to Social Change

As we read papers we noticed a difference between researchers that were investigating how CC can prompt change within a discipline, and researchers that were investigating how CC could stimulate thought about how the discipline itself could be used to bring about change. The latter scenario generated this theme due to its commonality across the papers we read, whether art or engineering, the study was focused on how the technical knowledge of the discipline could help address some social issue. Ibrahim et al. (2021) describe how many of the skills that are promoted to be of benefit to youth whose critical consciousness is engaged, are present within socially engaged arts programming and general arts programming. These skills include, but are not limited to, perspective-taking, empathy, and maintaining positive cross-racial relationships. This study took place over two years and included two cohorts of students, totaling over 2,500 students, during the study researchers explored a connection between youths' participation in arts programming and their ability to display critical reflection. The authors explain they found increased participation in arts programming led to growth in critical reflection and action, what Freire calls critical praxis, for non-white youth.

In another representative paper, Castaneda & Mejia (2018) mention "civil engineers are positioned within society to create solutions that have long-lasting environmental and social consequences, both positive and negative, to local and regional environments and communities" (p. 3). The authors describe the influence civil engineering has on society but acknowledge the impact of civil engineering has included negative outcomes, and resolving these harmful consequences or preventing new products that reproduce the same harms is how the authors explain the potential contribution of developing CC. The authors argue there is a need for engineering curriculum to make explicit connections between cognitive processes, technical knowledge, and social responsibility in the lesson materials. They also suggest the standards of the Accreditation Board for Engineering (ABET) provide a pathway to assist civil engineering educators to implement a focus on CC because there is overlap between ABET student learning outcomes and the traits of heightened CC (as defined within culturally relevant pedagogy). Social change is encouraged by implementing project-based work in civil engineering curricula so that students use their technical knowledge to reframe engineering problems in a way that highlights and addresses the social, political, and economic impact of engineering solutions. Specifically, students would learn new perspectives from community stakeholders and professional engineers which may help them notice their own prejudices and faculty could assist with challenging these conceptions while developing new knowledge, skills, and language.

Our third representative paper is a study in post-secondary biomedical engineering, Catalano (2016) discusses an activity embedded in a required course that is designed to assist students' development of CC. The activity is called a compassion practicum, and compassion is

explained as giving "rise to an active desire to alleviate another's suffering" (p. 5). The author proposes focusing attention on compassion can be used as a mechanism to stimulate CC along the path to social change. Therefore, the compassion practicum instructed students to complete one of two tasks: 1) identify suffering of others (whether human species or some other species) and take some action designed as a response to the identified suffering, or 2) examine the ethical considerations regarding the use of animals in biomedical research. The first option seemed more correlated since there is some action required to address the identified social issues, projects within this category included tutoring juvenile inmates or elementary students, preparing meals for residents of homeless shelters or immigrant families, and mentoring underclassmen studying biomedical engineering. The author's findings focused more on students' reflections and demonstrations of compassionate commentary rather than the actions students had taken and the resulting effects. In general, students felt that both projects encourage critical thinking and the material from class was thought provoking.

Conclusions and Implications

Critical consciousness motivates individuals to identify unjust aspects of society and work against them, without such direct-action pre-college engineering education will embrace many of the same inequities prominent in pre-college education more broadly. We reviewed literature to explore how the concept of CC has been operationalized and studied in STEM education with pre-college contexts, though we included literature on non-STEM learning experiences and even some post-secondary engineering courses. Our initial takeaway from this review is the minimal number of papers that examine CC within engineering across pre-college education. We consider this significant because the amount of investment in broadening participation in engineering through pre-college outreach and educational initiatives continues to expand, and CC presents itself as a useful concept to better understand why these efforts have not been successful in transforming the quality of experiences and statistical representation of people groups that have been marginalized in engineering throughout history. Notwithstanding, we noticed some encouraging activities taking place with researchers and educators that are studying CC in pre-college contexts and some collegiate engineering courses.

The three themes we have discussed in this review are both descriptive and prescriptive for educators that desire to cultivate CC in themselves, their students, and their broader educational context. This literature is helpful in dispelling any notion that complex issues like social structures and inequities are too difficult to engage with pre-college students. In some of the studies we saw that youth, particularly those with non-white identities, experienced an enhanced learning experience due to content focused on developing CC. Similarly, we see that education infused with CC development can be effective in engineering education, despite the dominance of ideologies that neglect the influence of social and political contexts. In fact, many scholars argued the absence of focus on CC contributes to the harmful consequences of engineering study and practice. From a researcher positionality, it was insightful to recognize the significance of aligning a critical theoretical framework with the research focus on CC. The lens we apply in our research practice is essential in supporting or inhibiting our ability to identify the possibilities, barriers, and limitations of educational practice focused on developing CC within engineering. As we considered this theme we pondered the necessity of the researcher to have a

critical disposition in order to effectively analyze the effects of consciousness raising on teachers, students, and institutional settings. This is something we desire to explore further.

On the other hand, we still see opportunities expand upon the breadth and depth of future studies regarding CC in engineering, specifically those in pre-college contexts. These studies tended to address social issues at a generic level, meaning teachers and students were encouraged to examine the issues that are symptomatic of inequities in social power rather than scrutinize the underlying values and beliefs that sustain their presence. We see opportunities to identify how conceptions of race, gender, and ability have shaped scientific thought and engineering practice throughout history. Additionally, there remains a need to critically evaluate claims about the science of human difference and analyze the complex relationships among engineering, technology, and ethical responsibility in current social contexts in which engineering is practiced. Lastly, we would like to see more attention and detail given to presenting the correctives or solutions students and faculty devise to advance equity and address systemic disenfranchisement. Given the extent of harm our inequitable social structure continues to cause, we need time and space to move beyond purely theoretical problem solving. Future studies can examine what happens when people test their proposed interventions, what do students learn from such experiences and how does it alter their understanding of engineering study and practice. We are grateful for this scholarship giving us a foundation to build upon, and we are inspired to take this work further within PCEE.

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