Development of a Critical Consciousness Instrument for Civil Engineers

ABSTRACT

Engineering students in the U.S. commonly receive instruction concerning a limited subset of what constitutes social responsibility. Indeed, research reveals that students fail to recognize and analyze real inequity challenges as they arise in engineering contexts. This is troubling as history is filled with examples of engineering projects that have exacerbated inequality—particularly along racial and social class lines. To address these issues, engineering programs need to be able to assess and measure progress in students' critical consciousness. Towards this goal, this study describes the development of a Critical Consciousness Scale for Civil Engineering Education (CCSCEE). Critical consciousness centers on how people understand and analyze how power and oppression operate to inform what steps they take to work towards more just, equitable relations. The CCSCEE instrument provides a way to assist engineering instructors in assessing if students are becoming more socially aware engineers. Additionally, CCSCEE provides an alternative and reflective way to help students learn and achieve ABET's professional learning outcomes. The paper provides an overview of the four domains/constructs for CCSCE including obliviousness (no awareness of inequalities), deficit-minded (awareness of inequalities but finding them as justifiable), misguided (awareness of inequalities but actions taken have unintended negative consequences), and critically consciousness (awareness of inequalities and actions takes are focused on root causes and expertise of those impacted by inequalities). The CCSCE will be tested with undergraduate civil engineering students during the summer and fall of 2020.

INTRODUCTION.

The Accreditation Board for Engineering and Technology's (ABET, 2016) professional learning outcomes emphasize the non-technical knowledge and skills that engineering students need to learn both inside and outside the classroom (ABET, 2016). The professional learning outcomes focus on the social aspects of engineering including social awareness, effective communication, and critical thinking that promotes inclusivity and equity. Previous research reveals that engineering students fail to recognize and analyze real ethical challenges as they arise in engineering contexts (Lynch and Kline 2000; Nicholls et al. 2007; Sax 2004; Shuman et al. 2004a) and that engineers as professionals have historically engaged in a culture of oppression (Riley 2008). As a result, we see increasing calls from diverse institutions (e.g. NAE, ABET) for implementing more sustainable engineering practices (Davidson, Matthews, Hendrickson, Bridges, Allenby, Crittenden & Austin, 2007) including assuring that engineers become more socially aware and empathetic (Walther, Miller, & Sochacka, 2017).

Previous researchers have created and studied critical consciousness (CC) curriculum in engineering with the goal to develop engineers' critical thinking. The CC curriculum included designing engineering problems and solutions beyond the Western context (Baillie and Armstrong 2013; Riley 2003, 2008). Regardless of these efforts, there are numerous challenges to assure that engineers become more critically conscious. In part, some of the challenges relate to assessment of students' understanding of CC that would aid engineering programs in their efforts to capture progress on their current efforts. To address this issue, we propose designing a critical consciousness assessment for engineering – Critical Consciousness Scale for Civil Engineering Education (CCSCEE). The CCSCEE is informed by critical pedagogy and was developed with the

goal of nurturing students' ability to think and act in critical ways. Critical pedagogy is rooted in critical theory, which examines how power operates at the individual and structural levels through the distribution of resources that marginalize particular social groups. A critical pedagogic approach requires content and methods that are explicitly attentive to these issues (Darder et al. 2008). Critical pedagogy also assumes a sociocultural theory of learning, which situates all learners as co-constructors of knowledge within specific historical and situational contexts. In this framework, even technical knowledge such as principles of engineering are never apolitical or ahistorical; they cannot be divorced from questions of social, cultural, and economic power (John-Steiner & Mahn 1996). As such, learners do not come to understand principles of engineering in a vacuum, but rather in relation to their real-world applications and their own social positions (Bonk & Kim 1998). As a result, it is expected the pedagogy will contribute to improving social consciousness and professional responsibility regarding how engineering work affects people.

THEORETICAL FRAMEWORK

The National Academy for Engineering increasingly calls for engineers to become more aware of community needs created through engineering work (Litchfield, Javernick-Will, & Maul, 2016; NAE, 2004). To address this need, the ABET professional learning outcomes focused both technical and professional learning outcomes. The professional learning outcomes are designed and continually updated to help set goals and achievable outcomes for engineering students such as awareness of environmental and social issues and other factors aligning with critical consciousness. The critical consciousness instrument described in this paper was rooted in an embrace of critical theory. Critical theorists focus on analyzing systems and structures that allow for inequality to exist in order to disrupt them (Giroux, 1983). In education, applying critical theory means reimagining the form and content of curriculum and instruction so that it works towards justice and liberation; in other words, critical pedagogy. While there are many critical pedagogical traditions, many in the past fifty years have been influenced by scholar activist Paolo Freire, who criticized and questioned the way educational content was being delivered to adults who were learning literacy skills. Freire (1970) critiqued the practice of banking education, where students passively receive educational content in the pursuit of predetermined knowledge, and encouraged instead a problem-posing education rooted in learners' lived experiences. This has led to multiple models of social justice education that prepare students to develop a critical consciousness helping them to understand and act in ways that deepen justice. For the purposes of this project, a more just world is one that recognizes diverse identities and redistributes resources (Fraser, 1996) in ways that challenge the capitalist myth of an individualistic meritocracy, deepen democracy, and enhance human flourishing (Wheeler-Bell, 2014). Hackman (2005) identifies five "essential components" of this approach to education: (a) content mastery that includes exposure to both hegemonic and counter-hegemonic resources; (b) critical analysis tools that allow students to question such information; (c) social change tools that help prevent students from becoming hopeless or complacent by engaging them in action; (d) self-reflection tools for both students and teachers to make sense of their lives within this framework; and (e) an awareness of multicultural group dynamics that affects how social justice teachers approach the previous four dynamics within a diverse groups of students.

The goal of this approach is to help students develop a critical consciousness. Critical consciousness (CC) is a Freirean concept (conscientizacao) that focuses on understanding how oppression operates (Freire, 1973). Scholars drawing on Freire's (1973) work see CC as, "describ[ing] how oppressed or marginalized people learn to critically analyze their social conditions and act to change them." (p. 44, Watts, Diemer, & Voight, 2011) but can be extended

to all people positioned within oppressive systems to critically analyze and act. CC has two main components: critical action and critical reflection. Diemer, Rapa, Park, & Perry, (2017) describe critical reflection as identifying structural constraints producing social inequalities along a variety of intersecting axes (e.g., racial, gender, economic, etc.). Critical action is about sociopolitical change and looks at the individual and/or collective efforts needed to disrupt oppressive systems. Critical pedagogues operate with the belief that education ought to equip students with the knowledge and skills to develop their critical consciousness in order to build a better world.

Critical pedagogical approaches rooted in traditions of social justice education described above have been implemented in engineering with varying degrees of success. At a fundamental level, scholars such as Riley (2008) have discussed the difficulty in implementing basic critical thinking skills in engineering classes, identifying several challenges to this work such as the culture of the engineering profession which does not encourage the questioning of authority that is foundational to critical theory. Kabo, Day, & Baillie, (2009) discussed the implementation of a course titled "Engineering and social justice: critical theories of technological practices" at Queen's University in Canada. The class was a seminar and had two instructors present at all times. Researchers noted that seeing the instructors, who were open minded and critiqued and disagreed with each other in class, was beneficial to the students in the class. In terms of how class was organized, the students discussed issues after they were introduced and had an open discussion for students to agree, disagree, and talk with each other. The class was deemed successful as students began to slowly change how they thought. For example, one student mentioned that the class encouraged them to think beyond binary terms with solutions and to acknowledge that sometimes there is no right answer. Transformations such as these are evidence that engineering students can develop critical thinking as a result of practices rooted in critical pedagogical approaches.

Researchers such as Castaneda (2019) and Castaneda & Mejia (2018) have most recently begun conversations to incorporate CC into the classroom with the aid of culturally relevant pedagogy (Ladson-Billings, 1995). Castaneda & Mejia's work (2018) discusses how culturally relevant pedagogy has not been implemented or explored widely in the engineering curriculum and how it can be beneficial for underrepresented students. Castaneda's (2019) continues the conversation about CC by sharing results from a sophomore-level engineering statics course, focused on students' awareness of their environments. The paper explored barriers within the engineering curriculum and everyday life, and encouraged students to develop the abilities to see inequalities and think of ways to implement action. This research contributes to the existing efforts on implementing CC in civil engineering by designing an instrument to capture students' CC. The instrument can be further used in education to capture how different curriculum and other educational interventions are achieving their intended CC outcomes.

CCSCEE DESIGN

Given the complexities inherent in creating a critical consciousness instrument that aligned with the engineering field, our approach to developing an assessment tool required a departure from common scale development approaches, wherein item pools are developed widely and then trimmed following iterative administration and evaluation of item characteristics. Rather, we began the development process following principles of backward design (Bowen, 2017; Wiggins & McTighe, 2005). Backward design is most often applied to curriculum development but the three-stage approach also provides a systematic rationale for developing our assessment of student acquisition of critical consciousness capabilities. The first step in backward design requires

identification of the desired result; in our case, the desired result is reflected in each stage of critical consciousness. Starting with one outcome (or facet of an outcome), the second step of backward design requires identification or determination of what evidence demonstrates that the outcome has occurred. For example, if we view consideration of impacts on individuals outside the specific engineering project as the desired outcome, indicating a need to obtain information from those individuals in order to make informed decisions about a project would provide evidence that students have developed the intended skill. Finally, the last step of our backward design approach takes the acceptable evidence that each outcome has been achieved and formulates that evidence into response options tied to specific engineering project scenarios.

Using the framework of backwards design and aspects of the ABET outcomes (e.g., public health, safety, and global, cultural, environmental, and economic factors), the researchers with expertise in civil engineering, critical theory, measurement design, and education met weekly to develop the CCSEE, a multiple-choice assessment that included scenarios that students may encounter as civil engineers. In the assessment students are asked which choice best represents how they would approach the scenario presented. The choices of the approaches each represent one of the four indicators of critical consciousness that represent differing awareness of inequities and actions to address them. These include 1) *obliviousness*, no awareness of inequalities, 2) *deficit-minded*, awareness of inequalities but finding them as justifiable, 3) *misguided,* awareness of inequalities but actions taken have unintended negative consequences, and 4) *critically consciousness*, awareness of inequalities and actions takes are focused on root causes and expertise of those impacted by inequalities. The CCSCEE was designed to assess student's CC thoughts and abilities based on a certain set of criteria. One of the first things we had to do was to decide conceptually what to capture, as this is an important aspect of scale development (Clark & Watson, 1995). Critical pedagogy and critical consciousness helped to conceptualize what we wanted to assess within students and helped to develop the scale.

After conceptualization occurs, then comes the process of creating an item pool. For the CCSCEE scale, this was composed of creating questions and responses, based on critical pedagogy and with a goal of reaching critical consciousness. This resulted in us creating 27 questions and responses. CCSCEE with these criteria have yet to be widely implemented in undergraduate engineering education to analyze students' understanding of engineering and the decisions they may make in future projects. The preliminary instrument developed in this case is a CCSCEE scale that is measurable and commonly not assessed or possibly even addressed in most engineering classes, yet are vital to our building an ethical and inclusive engineering standard. Below is the CCSCEE scale centered on four domains/constructs: obliviousness, deficit-minded, misguided, and critically consciousness.

Table 1: CCSCEE Scale

Scale	**Description**
Obliviousness	There is no malice or bigotry, just no awareness or recognition of inequalities.

Deficit-minded	There is awareness of inequalities, but they are seen as justifiable and/or "normal" and attributed to misinformed, even bigoted, perceptions of deficits within communities.
Misguided	There is awareness of inequalities and a sense that they are bad, but the actions taken as a result have unintended negative consequences that could have been mitigated with better attribution of the problem and coordination with those most impacted by the inequality.
Critically Consciousness	There is awareness of inequalities and a sense that they are bad, and actions taken are focused on root causes with coordination to leverage resources and expertise in solidarity with those most impacted by the inequality.

Using the scale domains/constructs as a framework, we designed case questionnaires. Each case is situated in a real-world engineering context, and each response item is aligned to each scale domain. For example,

Figure 1: CCSCEE Assessment Item. Currently choices are aligned to the scale in Table 1.

A construction company has been hired to build a big box store in a rural community and you are the project manager for the construction project. Fifty percent of the construction workers on the project are native Spanish speakers from Mexico, Guatemala, and El Salvador. Many of them are not yet proficient in English. How will construction safety requirements be communicated?

a. An English and Spanish language OSHA poster is posted in the common area. In addition, a memo written in English needs to be sent out to all employees explaining the construction safety requirements in detail. The safety requirements will ensure that all workers comply with safety standards. *(Obliviousness: no awareness of the workers who are native Spanish speakers and who are not proficient in English)*
b. An English and Spanish language OSHA poster is posted in the common area. A memo written in English needs to be sent out to all employees explaining the construction safety requirements in detail. A cover letter in English is added to the memo instructing employees that translation of any materials is their responsibility and failure to understand the standards makes the workers liable for any injury incurred. *(Deficit-minded: disregards native Spanish speakers and views it as a deficit in an English-only environment)*
c. An English and Spanish OSHA poster is posted in the common area. A memo written in English and Spanish needs to be sent that communicates the safety requirements. *(Misguided: understanding spoken language is not the same as understanding written language)*
d. An English and Spanish language OSHA poster is posted in the common area. A memo needs to be sent asking for a meeting, where translators both in English and Spanish

will be present, to discuss safety and language barriers. *(Critically Consciousness: provides an avenue for both the native Spanish speakers and English speakers to communicate and understand the safety requirements through the use of translators)*

DISCUSSION

This research proposed a CCSCEE scale and a CCSCEE assessment to capture individual student CC and growth. This assessment improves upon the current existing CC scales which are more generic and not contextual to engineering education. In addition, the shortened nature of the CCSCEE scale instrument will both reduce resource allocation to assessment and can be more easily incorporated into rigorous research designs that include multiple assessments. Development of such a tool would allow extensive research into the effectiveness of curriculum and instructional developments aimed at increasing student's critical thinking and critical consciousness learning and skills. Overall, the research addresses the need to build shorter, but valid and reliable measures of CC skills and contribute to the extended efforts across the engineering disciplines to systematically examine learning outcomes at the student level. Building and testing CCSCEE scale will directly impact engineering education scholarship since it facilitates examining the role of diverse interventions of interest on professional skills in engineering programs.

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