Received: 22 June 2021 | Revised: 13 December 2022 | Accepted: 21 December 2022

DOI: 10.1002/jee.20507

JEE Journal of Engineering Education

RESEARCH ARTICLE

Civil engineering students as avoidant actors: Using culturally relevant problem-solving to increase critical action attitudes

Riley Drake[1] | **Cristina Poleacovschi**[2] | **Kasey M. Faust**[3] | **Arie True-Funk**[4] | **Jessica Kaminsky**[5]

[1]Department of Counseling, Rehabilitation, and Human Services, University of Wisconsin-Stout, Menomonie, Wisconsin, USA

[2]Department of Civil Construction & Environmental Engineering, Iowa State University, Ames, Iowa, USA

[3]Department of Civil, Architectural and Environmental Engineering, The University of Texas at Austin, Austin, Texas, USA

[4]Polk County Housing Trust Fund, Des Moines, Iowa, USA

[5]Civil and Environmental Engineering Department, University of Washington, Seattle, Washington, USA

Correspondence
Riley Drake, Department of Counseling, Rehabilitation, and Human Services, University of Wisconsin-Stout, 240F Heritage Hall, Menomonie, WI 54751, USA.
Email: draker@uwstout.edu

Abstract

Background: Civil engineers design systems that have the potential to impact existing oppressive societal conditions. Critical action—the ability to recognize and act against oppressive conditions—is an obligation for civil engineers committed to building a more just world.

Purpose/Hypothesis: History reveals that civil engineers often do not take critical action and accrediting bodies (e.g., ABET) have responded by creating requirements to consider social factors and contexts. Considering these endeavors, we ask: To what extent do civil engineering students demonstrate critical action attitudes when prompted by engineering problem-solving? In what ways does culturally relevant problem-solving influence critical action attitudes?

Design/Method: Employing transformative action as a theoretical framework, we assessed students' responses to a design question on three levels that perpetuate or disrupt oppression (avoidant, destructive, and critical action). The empirical study used qualitative and quantitative analysis to examine survey responses of 375 civil engineering undergraduate students across 12 US universities.

Results: The results showed that engineering students largely avoided discussing taking critical action, remaining focused on technical and nontechnical factors that evaded acknowledgement of sociopolitical factors. Nevertheless, when exposed to culturally relevant problem-solving, students showed a statistically significant increase in both critical and destructive action responses.

Conclusions: We posit that students' exposure to culturally relevant problem-solving can enhance students' critical action attitudes. The results call on the need for civil engineering educators to cultivate culturally relevant problem-solving in civil engineering curriculum.

KEYWORDS

critical theory, engineering curriculum, institutional change, multiculturalism

1 | INTRODUCTION

Civil engineering education primarily focuses on technical knowledge and sometimes neglects the social implications that result from engineering decisions. The Accreditation Board of Engineering and Technology (ABET) emphasizes the need to educate students who think holistically, and more recently drafted ABET standards explicitly mention considerations for diversity, equity, and inclusion (ABET Engineering Accreditation Commission, 2021). One of the ABET professional learning outcomes asks for engineering programs to educate engineers who think of "global, cultural, social, environmental, and economic factors" when making engineering decisions (ABET Engineering Accreditation Commission, 2021, p. 5). Civil engineers, specifically, are called to "enhance the quality of life for humanity" and "acknowledge the diverse historical, social, and cultural needs of the community, and incorporate these considerations in their work" (American Society of Civil Engineers, 2020).

Despite the increased efforts for engineers to address societal needs (Bucciarelli, 2008; Trbušić, 2014), civil engineering education has not often promoted students' understandings of social responsibility (Niles et al., 2020; Shuman et al., 2004; Shuman et al., 2005; Trbušić, 2014). Relatively absent from civil engineering education programs is the education and development of critical action (Trbušić, 2014), defined as the process of recognizing and taking action against oppressive conditions. As such, civil engineering students are rarely provided opportunities to demonstrate critical action (Jiménez et al., 2019) and may actually become more disengaged with social issues over the course of their education (Bielefeldt & Canney, 2016; Cech, 2014). Yet, students may develop critical action attitudes, or ways of thinking related to recognizing and acting against oppression, if given the opportunity to learn about such action from engineering educators, who are well positioned to cultivate critical thinking and attitudes demonstrative of critical action. Accordingly, in this research we ask: To what extent do civil engineering students demonstrate critical action attitudes when prompted by engineering problem-solving? In what ways does culturally relevant problem-solving (CRPS) influence critical action attitudes?

To answer these questions, we assess civil engineering students' critical action attitudes by revealing the levels of transformative action considered as they address an engineering design problem. The study also identifies the impact of culturally relevant curriculum for increasing students' critical action attitudes.

2 | TRANSFORMATIVE ACTION IN CIVIL ENGINEERING

The neutrality problem (Banks & Lachney, 2017) has been critiqued at length by engineering educators who are critically engaged (Catalano, 2006a, 2006b; Catalano & Baillie, 2006; Nieusma & Blue, 2012; Riley, 2008; Riley et al., 2015). Central to the neutrality problem is the common belief that engineering is apolitical (Banks & Lachney, 2017; Riley, 2008) reinforced by a decontextualized engineering education system (Breslin & Camacho, 2021). This is problematic as history is replete with examples of engineering as being political and not neutral (Riley, 2008). At times, civil engineers are situated within violent circumstances as a result of geopolitical conflict, and there are disputes over resources and materials, unfair allocation of benefits, and economic or authoritarian issues in projects (Banks & Lachney, 2017; Muscat et al., 2015). In another example, the U.S. Army Corps of Engineers' (USACE) involvement in the canal wall failures that caused colossal flooding during Hurricane Katrina (Banks & Lachney, 2017; Rogers et al., 2015) contributed to the death and displacement of nearly 1800 people (Knabb et al., 2011). Even when engineers are not in warzones or natural disasters, their choices are still political, never neutral. The inherently political nature of engineering is evident even when considering everyday design priorities. Take, for example, the design and construction of cars with seatbelts (Latour, 1992). The designers intentionally considered moral and ethical obligations during the design of the car. This example demonstrates social and political considerations inherent in engineering design (Cech, 2013).

The antithesis of apolitical stances or neutrality is critical action. The key to critical action is understanding the role of oppression and working to change unjust treatment. As a result of oppression, systemic inequities exist at the intersection of structural and institutional processes, practices, and outcomes (Jemal & Bussey, 2018). When engineers are unaware of oppression and do not act to combat oppressive ideologies and ways of acting, they may contribute to inequity. As such, it becomes important to evaluate whether civil engineering students engage in critical action. Toward this goal, we first ask: To what extent do civil engineering students demonstrate critical action attitudes when prompted by engineering problem-solving?

Critical action concerns the reflection upon and uprooting of oppression. Oppression in the form of systemic inequity is pervasive globally, historically manifesting in different, often violent ways. For example, Bangladesh (used as a case study for the engineering problem in this research) achieved independence in 1971, yet its colonization by Britain and Pakistan still contributes to numerous obstacles that impede the progress of the country (Huque, 2011).

Critical action theory categorizes different levels of action that contribute to or dismantle oppression and systemic inequities. One prominent framework that shows these levels is transformative action (TA) (Jemal & Bussey, 2018). This framework was derived from the inconsistency Jemal and Bussey (2018) saw in the way critical action was defined and challenges in its operationalization. TA is organized into hierarchical levels of action that perpetuate or disrupt oppression and systemic inequities (Jemal & Bussey, 2018). TA consists of three hierarchical levels: (1) destructive actions taken by people that directly perpetuate oppression and systemic inequities whether consciously or unconsciously; (2) avoidant actions or inactions that people choose to engage in by ignoring oppression that indirectly reinforce systemic inequities; and (3) critical actions taken by people to intentionally uproot oppression and systemic inequities. This study uses critical action theory as the framework to assess civil engineering students' attitudes related to oppression and inequities.

Destructive action consists of those direct actions that perpetuate inequities, whether knowingly or unknowingly. For example, the canal wall failures in New Orleans during Hurricane Katrina is an example of destructive action. De facto racial segregation pushed racially minoritized communities into sections of New Orleans that were subjected to frequent flooding (Colten, 2006). In these already vulnerable areas, protective engineering structures such as levees were built to standards that meant these marginalized communities continued to be at significantly higher risk (Morse, 2008; Rogers et al., 2015). While we do not intend to suggest malicious intent, this inequitable distribution of infrastructure services resulted in an entirely predictable disastrous impact to these communities during Hurricane Katrina. Although the literature states that there is no evidence that the USACE believed these technical choices increased flooding risk (Woolley & Shabman, 2008), one of the authors on this manuscript learned about the likely outcomes of a major hurricane hitting New Orleans as part of an undergraduate engineering class many years before Hurricane Katrina struck. Destructive action in this case directly contributed to and reinforced existing inequities.

The case of Hurricane Katrina also exemplifies avoidant action, which indicates passivity, or actions that avoid considering potential harm and indirectly perpetuate inequities. In this case, as in many others, flood control technical decisions were based on a cost–benefit analysis that explicitly ignored (in)justice. At the time of levee construction, USACE was legally mandated to ensure that the cost of any flood control project was less than the related public benefit, which was measured by the value of the protected property (refer to Flood Control Act of 1936; Morse, 2008). This approach meant that expensive properties, owned disproportionately by wealthy and White individuals, qualified for more protection than lower cost properties. Avoidant action was taken in this case and, like the inequitable distribution of infrastructure services described above as destructive action, resulted in the same outcome: an inadequate levee wall. Avoidant action indirectly reinforced existing systemic inequities.

Lastly, critical action, wherein action is taken intentionally to uproot inequities, is the highest level of TA. Flood control projects in New Orleans could have disrupted inequities by seeking to prioritize the safety of those vulnerable communities pushed to the outskirts of the city (Colten, 2006), which would have required higher cost projects to protect communities that are at lower elevations. We acknowledge that the cost–benefit policies legally constrained USACE actions, but also recognize that these institutional rules may be changed. Indeed, the Water Resources Development Act of 2020 has recently made a broader equity analysis possible for the USACE, although hurdles remain. In the case of Hurricane Katrina, when we acknowledge that living in lower elevation areas of New Orleans equates to higher flood risk as well as the racially charged historic reasons for settlement patterns, or even by simply recognizing all homes as equally valuable despite sale price, the extreme limitations of using property value as the sole metric of harm become readily apparent. Critical engineering action in this case means uprooting the impacts of historical and institutional inequities through infrastructure practice.

3 | CIVIL ENGINEERING EDUCATION FOR CRITICAL ACTION

This example and numerous others (Riley, 2008) exemplify the need for educating engineers who are critically conscious. Unfortunately, civil engineering undergraduate programs have historically focused instruction on technical, traditional problem-solving and often neglect social responsibility (Beder, 1999; Bucciarelli, 2008; Conlon, 2008; Trbušić, 2014; Zandvoort, 2008). In past research, civil engineering education frequently failed to foster critical action

(Trbušić, 2014). In fact, one study showed that civil engineering students' concern related to the welfare of the public decreased over the course of their engineering education (Cech, 2014). Some attribute this to the focus on technicality (Cech, 2014; Conlon, 2008) and neutrality (Banks & Lachney, 2017; Riley, 2008) as the dominant curriculum (Baillie & Armstrong, 2013; Leydens & Lucena, 2017; Niles et al., 2020). Others discussed the need to require ethics courses (Herkert, 2011). Accordingly, recent ABET professional learning outcomes ask civil engineering programs to act with social implications in mind. Specifically, Outcomes 2 and 4 ask for civil engineering students to show an understanding of how their engineering decisions affect society. Outcome 5 asks for civil engineering students to create an inclusive environment. Considering these recent efforts to promote critical action, it becomes important to assess whether civil engineering students demonstrate critical action attitudes in their engineering work. This research addresses these goals by adopting a critical action theory as the framework to assess civil engineering students' attitudes related to oppression and inequities.

Previous research from education has shown that culturally relevant pedagogy (CRP) (Ladson-Billings, 1995, 2014) including CRPS increases students' critical action (Grimberg & Gummer, 2013). A CRPS approach assures that engineering problems are embedded in their social context (Herron & Barta, 2009). Specifically, a CRPS approach would emphasize that engineering decisions need to be taken with deep understanding and reflection of the people involved and impacted by these decisions and the institutional and cultural practices enacted in that context. While the CRPS approach has been largely encouraged as the means to assure inclusion of minoritized, historically excluded students who may be interested in problems that present details about social context (Castaneda & Mejia, 2018), the approach is promising for all students as it stimulates their understanding of privilege and oppression (Grimberg & Gummer, 2013). However, despite previous research advocating for CRPS in civil engineering (Castaneda & Mejia, 2018), there is a dearth of empirical evidence regarding the efficacy of CRPS in civil engineering. To address this gap, we ask: In what ways does CRPS influence critical action attitudes?

4 | THEORETICAL FRAMEWORK FOR CRPS

CRPS is rooted in CRP. CRP was initially developed by Gloria Ladson Billings (1995) to assure that the perspectives of marginalized students are incorporated into the curriculum and that they are learning in an inclusive environment. To do so, CRP adopts pedagogical approaches that reflect the experiences of diverse students in the classroom (Ladson-Billings, 1995, 2014). A curriculum that includes students' varied languages and cultures is often a more relevant curriculum. For example, science instructors who taught scientific concepts (e.g., accelerated motion) to American Indian students using relevant Indigenous knowledge about arrow making and throwing found that their culturally relevant instruction led to increased academic performance (e.g., test scores) (Grimberg & Gummer, 2013). Another important benefit of CRP includes enhancing the critical consciousness of all students, especially those of the dominant groups (Grimberg & Gummer, 2013). By engaging all students in taking action against issues that impact marginalized communities, everyone stands to experience humanization (Freire, 1970).

One important aspect of incorporating CRP in the classroom is the inclusion of issues of oppression and privilege in curriculum (Ladson-Billings, 1999). In civil engineering, such curriculum is almost absent as the majority of problem-solving focuses on technical decisions without consideration of the social context (Cech, 2014). However, as history shows, engineering problems do not exist absent from their social context. CRPS is one methodology to increase critical action as it lets students identify the close links between scientific and engineering problems and social context (Herron & Barta, 2009). For example, according to CRPS, scientific and engineering problems would emphasize more details about the people (e.g., geography, age, gender, history, income, etc.) who are directly or indirectly impacted by engineering decisions. While there has been some research on the benefits of CRPS, this research has been limited to mathematics and has focused on the effects of CRPS on academic performance (Herron & Barta, 2009). Specifically, the study evaluated the benefits of students solving mathematical problems that reflected students' personal experiences (Herron & Barta, 2009).

We posit that a similar approach can be adopted to increase critical action attitudes in civil engineering. CRPS in civil engineering requires inclusion of material that emphasizes social context including social inequities, privilege, and oppression when describing engineering problems. The more we can infuse possibilities for students to recognize and take action against oppression into engineering problem-solving, the more students can understand that their position as an engineer is always political. We test the efficacy of such an approach using an experimental design with CRPS. In the experimental design, a group of engineering students was exposed to problem-solving where social context was mentioned, while another group of students were exposed to traditional problem-solving relying solely on technical aspects.

5 | METHODS

5.1 | Positionality

As researchers and educators who aim to build critical reflexivity for critical action among students in higher education, we attempt to practice reflexivity here. While our identities and interests intersect to inform our lived experiences and ways we see the world, we attempt to cull from our wholeness and briefly describe where we are situated relative to this study.

Riley, a White, cisgender woman, is an Assistant Professor of School Counseling with critical lines of inquiry in social and cultural studies of education. While engineering education is built upon engineering standards and practices that are beyond the scope of Riley's expertise, oppression exists in the cracks of the foundation of higher education across disciplines, making her professional background relevant to this study. Further, as a White woman, she is aware of the ways that whiteness has been weaponized against people of color, particularly in fields dominated by white bodies such as engineering, and attempted to approach this study being mindful of the ways in which she might inadvertently reinforce whiteness in data analysis and interpretation, as well as how those findings are conveyed.

Cristina, a White, cisgender, immigrant woman, is an Assistant Professor in Civil, Construction and Environmental Engineering. Her research focuses on social justice and designing housing and infrastructure that best addresses the need of marginalized people. She is passionate about changing current approaches in engineering education toward a curriculum that acknowledges the political nature of engineering decisions and educates reflexive engineers.

Kasey, a White, cisgender woman, is an Associate Professor of Civil, Architectural, and Environmental Engineering. Her background as an educator in engineering is relevant to this study, and her research focuses on improving the delivery of safe, reliable, and equitable infrastructure services. Infrastructure performance is shaped by each unique operating environment that includes the human capital, regulations, social needs, cultural and local norms, and the wider institutional context. It is her belief that it is necessary to understand this situational context of infrastructure to shape the efficacy of services and in failing to do so, communities receive asymmetric harms and benefits. Further, Kasey believes we must teach our students the macroethical considerations of infrastructure projects. These beliefs have shaped how she approached this research.

Arie, a White, cisgender, queer woman, is a Social Science Analyst with the Public Science Collaborative at Iowa State University. While her expertise lies within the social sciences, her background as a researcher of vulnerable populations is relevant to this study. As a White woman from a marginalized community, Arie understands how White culture causes harm to people of color. She examined her own biases and attempted to minimize the effect on the study.

Jessica, a White, cisgender woman, is an Associate Professor of Civil and Environmental Engineering. Her engineering work centers on socially sustainable civil infrastructure, which eliminates unfreedoms that reduce human choice and agency (Kaminsky, 2021). Because of this, she believes that humanitarian motivations are important to the work of many other engineers, too. Further, her time in engineering has led her to see that there are important sociodemographic differences (e.g., gender, race, class, etc.) in the experiences of being and becoming an engineer. These beliefs shaped this research project.

5.2 | Data collection

Data collection for this study took place from January 2019 to June 2019. Prior to full deployment, the survey questions were workshopped by a group of five engineering and engineering education faculty including two civil engineering faculty members, one women, gender, and sexuality studies faculty member, one industrial engineer faculty member, one electrical engineer faculty member, and one postdoctoral scholar with a PhD in learning sciences. Next, they were tested with students using cognitive interviewing methods (Willis, 2004). In this process, four undergraduate engineering students from two different universities, all of whom were civil engineering students, sequentially took a pilot version of the survey, providing both their answers and reflections on their thoughts and question interpretations as

TABLE 1 Demographic characteristics of the respondents based on the intervention ($n = 375$).

Demographic characteristics	Number of students	Relative frequency	No context (%)	Mississippi (%)	Bangladesh (%)
Political leaning					
Very liberal	27	7.3	44.4	22.2	33.3
Liberal/very liberal	1	0.2			
Liberal	71	19.3	32.4	26.8	40.8
Moderate liberal					
Moderate	132	35.9	34.1	31.8	34.1
Moderate conservative	1	0.3	0.0	100.0	0.0
Conservative	77	20.8	32.5	41.6	26.0
Very conservative	15	3.7	40.0	33.3	26.7
Prefer not to respond	18	4.9	27.8	22.2	50.0
Race					
White	279	81.9	35.1	31.0	33.9
Asian	49	14.2	29.8	36.2	34.0
Black or African American	6	1.2	50.0	25.0	25.0
Prefer not to respond	10	2.7	22.2	44.4	33.3
Language spoken					
English only	273	92.7	35.6	31.8	32.6
Spanish only	11	3.5	1.1	1.5	1.1
Chinese only	12	3.8	0.7	1.5	1.9
Gender					
Man	252	68.5	34.5	30.6	34.9
Woman	100	27.2	31.0	36.0	33.0
Prefer not to respond	3	0.8	33.3	33.3	33.3
Sex					
Male	251	69.0	34.3	31.1	34.7
Female	104	28.0	30.8	34.6	34.6
Prefer not to respond	2	0.8	50.0	0	50.0
Class					
First year	5	1.4	40.0	20.0	40.0
Sophomore	33	9.0	18.2	45.5	36.4
Junior	137	37.2	34.3	34.3	31.4
Senior	179	48.6	35.2	28.5	36.3
Major					
Architectural	17	6.1	52.9	17.6	29.4
Environmental	11	3.9	18.2	36.3	45.4
Civil	179	64.0	31.8	31.3	36.9
Civil and environmental	61	21.9	39.3	26.2	34.4
Construction	11	3.9	45.4	36.4	18.2
Family income					
<19,999	6	1.6	66.7	0.0	33.3
$20,000–$34,999	15	4.1	20.0	40.0	40.0
$35,000–$49,999	22	6.0	27.3	40.9	31.8

(Continues)

TABLE 1 (Continued)

Demographic characteristics	Number of students	Relative frequency	No context (%)	Mississippi (%)	Bangladesh (%)
$50,000–$74,999	53	14.4	37.7	28.3	34.0
$75,000–$99,999	34	9.2	23.5	29.4	47.1
>$100,000	138	37.5	37.7	31.9	30.4
Prefer not to answer	49	13.3	26.5	40.8	32.7

they did so. These responses were reviewed between each of the four students to determine if question modifications were needed. Wording modifications were incorporated after the first student; subsequent responses did not indicate the need for further modifications. The demographic questions were the last questions of the survey. Race, ethnicity, and family income questions used US census categories. Gender and sexuality questions were developed in consultation with faculty from the University of Washington's Department of Gender, Women, and Sexuality Studies.

The survey was administered in one session in civil engineering courses, some construction engineering courses, as well as a few capstone designs and one structures class during regular course meetings. The selected courses were a mix of required and elective courses. While all students were juniors or seniors, the courses were taken at different points in students' course sequencing. For example, in one case, the selected course was taken in the first term, students took coursework from the civil engineering department. In another, the selected course was in the last term of students' senior year.

Students had the option to exclude their responses from the research project. In addition, most classes had an attendance optional policy, so some students did not attend the course session in which we collected data. Ultimately, the data analyzed here include 375 responses, which is 53.2% of the 705 students enrolled in the courses in which we collected data. Of these 375 students, seven did not provide an answer in response to this prompt, although they responded to other parts of the survey (such as answering demographic questions, etc.). The full survey is available from Jessica upon request.

Data collection occurred at 12 major universities across the United States after receiving research with human subjects approvals. All of the universities are classified as "Doctoral Universities: Very High Research Activity" (The Carnegie Classification of Institutions of Higher Education, 2021). The 12 universities are a convenience sample where we were granted access to students. We requested access through a combination of professional networks or messages to professors of relevant courses. All 12 are doctoral granting universities with accredited civil engineering programs. Further, some of those institutions required diversity, humanities, or social science courses. Refer to Table A1 in Appendix A for those institutions with related requirements.

We also sought and achieved a geographic distribution across the United States. In all but two universities we collected data from a single course in a single session; in those two we collected data from several sections of a single course. Class enrollment ranged from 15 to 105 students, with a median of 43 students. In one case, the faculty member leading the course provided only an estimated enrollment. Refer to Table B1 in Appendix B for gender and race demographics of the respondents in each program.

Participants ($n = 375$) are situated in regions across the United States, with students from the North, South, Midwest, and Rocky Mountain areas. Students averaged 21 years of age, and ages ranged from 18 to 35 years old. Students spanned classes with 1% first year, 9% sophomores, 37% juniors, and 49% seniors. Twenty-nine percent of students identified as female, while 68% of students identified as male and 0.5% of students preferred not to respond. Students' engineering majors were predominantly civil engineering (50%) and civil and environmental (24%); thus, we describe students as civil engineering students for brevity in this piece. Refer to Table C1 in Appendix C for majors across institutions and their ABET accreditation status.

The majority of participants (75%) were White including Middle Eastern, 13% of students were Asian (including Indian subcontinent and Philippines), 1.6% were Black or African American (including African and Caribbean), and 2.6% of students preferred not to respond. Table 1 presents some sample sociodemographics including political leaning, race, language spoken, gender, sex, class, major, and income.

The survey included one open-ended question to capture CRPS versus traditional problem-solving. The open-ended question asked students to think of their decision-making with regard to an engineering problem. There were three

TABLE 2 Percentage of participants within contexts ($n = 375$).

	Percentage of participants
Bangladesh	34.93
Mississippi	32.27
No context	32.80

versions of this engineering problem; each student saw just one version. Two versions of the survey were based on traditional problem-solving and included the no context and the Mississippi versions. The no context version asked: "As an engineer, what factors would you take into account in designing and constructing a retaining wall system for flood protection?" The Mississippi version asked: "Over the summer, the Midwest experienced massive flooding of the Mississippi River, causing significant losses for industry and the national economy. As an engineer, what factors would you take into account in designing and constructing a retaining wall system for the Mississippi?" One version of the survey was based on CRPS and included the Bangladesh example, asking: "Over the summer, Bangladesh experienced massive flooding of the Ganges River, displacing over 300,000 people, most of whom are below the global poverty line of $1.25 USD/day income. As an engineer, what factors would you take into account in designing and constructing a retaining wall system for the Ganges?" The content of the no context and Mississippi version is driven by previous literature evaluating engineering students' attitudes toward social issues and capturing a wide range of students' design skills when provided with a design problem lacking context (Kilgore et al., 2007). The no context and Mississippi versions are considered traditional because they do not discuss any details about the social context (e.g., people, culture). The Bangladesh version has been created by the research team to address the issue of overreliance on engineering problems that are not culturally relevant such as the no context and Mississippi problems. Accordingly, the Bangladesh version was created to incorporate social issues—experiences of global economic inequities and poverty reduction in a low-income nation.

After the students saw one of these three questions and brainstormed factors, they were asked to expand upon their answers with the following prompt: "One useful way to improve infrastructure design and construction is to think beyond technical factors. You may or may not have already included these in your retaining wall answer. Regardless, please try to explain at least five relevant non-technical factors, and how these might influence the retaining wall design and/or construction."

Paper surveys were distributed as students entered the classroom and the three versions were sequentially handed out (e.g., versions no context, Mississippi, and Bangladesh, then repeated as each student entered) assuring that an equal number of students received one of the three scenarios (Table 2).

Preliminary directions were provided regarding the study by the instructor. The instructor mentioned that the survey seeks to assess students' design thinking based on different types of engineering problems. Students completed the survey by hand, taking between 45 and 60 minutes depending on the length of the class period. Following the session, all student responses were mailed to the lead investigator, who filtered out those in which students opted out of participating in the research. Surveys were transcribed and imported into Dedoose (SocioCultural Research Consultants, Los Angeles, CA, 2021).

5.3 | Data analysis

We adopted a mixed methods approach for this project, acknowledging both the promise and risks of this approach (Dainty, 2008; Lamont & Swidler, 2014; Sykes et al., 2018). We believed open-ended qualitative responses would allow us to explore the destructive, avoidant, or critical ways in which students responded to design questions. Such attitudes can be both explicit and subtle, requiring an inductive and detailed analysis of the language used (Glaser & Strauss, 2017). To be more confident in the differences we observed, we quantified the qualitative coding (Chi, 1997).

Following Pawley (2017), we hoped to be able to perform an analysis disaggregated by demographic groups. We note our analysis is gender disaggregated to cisgender males and females. Because of the small numbers in the engineering discipline as a whole, and therefore our sample, we are not able to present results for other genders and racial and ethnic groups. However, we provide these and other demographics from the sample in order to make visible this limitation of our work and call for future work using methods that can gather more diverse knowledge.

5.4 | Qualitative analysis

The question was coded using Dedoose, a software for analyzing qualitative data. After reviewing the data, we developed a coding framework for the three TA levels. Destructive action attitudes included three sub-codes based on excerpts showing perpetuated oppression and systemic inequities. Examples of destructive action attitudes included assumptions about community inferiority and desire for community exploitation. Avoidant action attitudes included 31 sub-codes based on excerpts showing avoiding or neglecting oppression and systemic inequities. Examples of avoidant action attitudes included project considerations such as project cost and schedule and project team motivation. Critical action attitudes included five sub-codes based on excerpts seeking to explicitly disrupt oppression and systemic inequities. Examples of critical action attitudes included assuring that the retaining wall did not increase inequities and increasing local opportunities for the community. Refer to Table 4 for a thorough explanation of the coding framework. The coding framework was developed using a combination of deductive and inductive coding. The TA levels provided the framework for the three main macro-codes. Based on the framework, the researchers identified sub-codes inductively based on main and repeating themes in the data. Between 0 and 43 excerpts were coded to each student's response, with a median of 10 per student. The reliability check was performed with the help of a second coder. The first coder is Riley, who, at the time, was a PhD student in social and cultural studies of education with 2 years of experience in qualitative coding. The second coder was a PhD student in sociology with 2 years of experience in qualitative coding. The second coder identified 200 random excerpts and verified whether the codes aligned with the coding framework. The agreement rate was 95%. Below we present a participant's full survey response with codes inserted in parentheses and italicized:

> Skill of workforce (*avoidant: project considerations, project competency*): construction workers there may not have the same ability as American's (*destructive: community inferiority*). Money to pay (*avoidant: project considerations, project financial considerations*): a smaller/poorer population may not be able to afford the best design (*critical: sociopolitical awareness*). Language barrier: communicating in general will be a different problem all together (*avoidant: community considerations, community engagement*). Quantity of workforce: are there enough employees to support a project[?] (*avoidant: project considerations, project logistics*). Transportation to/from site (*avoidant: project considerations, project logistics*): after flood damage, it could be difficult to have safe site access (*avoidant: project considerations, project safety*).

5.5 | Statistical inferencing

Hypothesis tests were conducted to explore the statistical relationships between paired variables—here, being the (1) TA levels (destructive action, avoidant action, and critical action attitudes) and either (2a) CRPS presented (No context, Mississippi, and Bangladesh) or (2b) demographics of the respondent. Chi-square tests were used unless the frequency was too low in the observed value, in which case Fisher's exact tests were conducted. Each respondent received a version of CRPS or traditional problem-solving (e.g., No context, Mississippi, and Bangladesh). Each response could be coded to more than one TA, multiple times. However, the frequency used in the hypothesis test was converted to binary to indicate a presence (or lack thereof) of a TA level. For instance, did Respondent-X have at least one destructive action attitude coded to their response? If the answer was yes, it was assigned 1; if the answer was no, it was assigned 0. Twenty-three students were classified into critical action attitudes category, 110 were classified into destructive action attitudes category, and 368 students were classified into avoidant action attitudes category. The TA levels were paired with their respective self-identified demographics. Beyond assessing for association between CRPS and TA, we tested for associations between CRPS and demographic variables including self-identified gender, class standing (e.g., first year, senior), university, income, first-generation students, race, sexual orientation, number of languages spoken, and age (refer to Table 1 for additional details on the sample).

TABLE 3 Word count median and range across context.

	Median	Min	Max
Bangladesh	31	0	142
No context	32	1	135
Mississippi	32	0	159

To avoid the bias inherent in relative respondent verbosity, we counted and analyzed the number of students who responded to each of the three scenarios. The response length for the three scenarios was similar. Table 3 presents the median, minimum, and maximum number of words for each scenario.

6 | RESULTS

6.1 | Qualitative results

Table 4 presents the TA levels, sub-codes corresponding to each TA level, the number of excerpts for the TA levels and sub-codes, and the relative frequency for each TA level and sub-codes. The results in the table are based on all student responses including students who responded to CRPS and traditional problem-solving.

Approximately 4.75% of the excerpts ($n = 196$) reflected destructive action attitudes. Given that engineering educational programming often does not attempt to disrupt destructive ideologies (Trbušić, 2014), it is not surprising that some students indicated that they would engage in destructive action attitudes. Factors coded to destructive action attitudes were identified across the three problems but particularly in response to the Bangladesh context. Across contexts, we identified marginalizing assumptions about communities. In the Bangladesh example, factors coded to destructive action attitudes may reflect some students' beliefs—whether conscious or unconscious—that the poor Bangladesh community was somehow inferior. These were visible through students' assumptions regarding the community. One such assumption included assumption of criminality indicated by concern about construction equipment being stolen ("In an area below poverty line, equipment might be more likely to get stolen"). Assumptions of criminality outline meritocracy beliefs where poverty becomes rationalized through people's inherent qualities (e.g., they are thieves). This assumption is destructive because it reinforces inequities through stereotyping. Similarly, a student who received the Mississippi problem responded with an assumption of criminality ("Will it improve people's lives or only promote more dangerous or damaging behavior?"). Students also assumed that local engineering decisions will fail ("Design failures look really bad"). In this particular response, the student was concerned with their own reputation. They also perceived local decisions to be unreliable and local skills to be less complex ("Less complex methods if hire locals that are previously untrained"). Here, while hiring locals for the construction of a project may appear to at least align with community considerations, the assumptions undergirding this decision demonstrate a belief in the inferiority of local methods or skills alongside an assumption that workers who may not be "formally" trained in westernized methods of construction are "untrained." Finally, respondents who received the no context and Mississippi problems also demonstrated assumptions indicating beliefs in community inferiority. A respondent who received the no context problem questioned the idea of building a retaining wall for a "tiny" town ("is it worth building a huge retaining wall to save a tiny town built below sea level"). This example of a destructive action attitude indicates that the student devalues "tiny" communities. The student compared the utility of saving a community to that of building a large retaining wall. There are two destructive action attitudes in this student's logic. The student questions the idea of saving a community at the expense of building a wall. They, thus, view the engineering project as superior to people's lives. Additionally, the student rationalizes their decision by questioning the need to develop engineering projects whenever such projects impact a small, and therefore less important, community. Further, as this student's description of this community as "tiny" is not reflective of the literal size of a community, this descriptor may instead imply an assumption of the inferiority of smaller communities.

Approximately 90.40% of excerpts ($n = 3733$) demonstrated avoidant action attitudes. Avoidant action attitudes constituted the vast majority of the excerpts. Avoidant action attitudes were reflected in generic social and technical aspects (or those directly related to the physical design and construction of the project) regarding project considerations ($n = 986$), community consideration ($n = 608$), infrastructure considerations ($n = 264$), and environmental

TABLE 4 Transformative action levels across codes.

Codes and sub-codes	Definition	Example quotes	Relative frequency (%)	Excerpt count
Destructive level	Actions taken by people that perpetuate oppression and systemic inequities whether consciously or unconsciously		4.75%	$n = 196$
Community inferiority	How deficit orientations about the community are projected by the project team	Less complex methods if hire locals that are previously untrained	0.46%	$n = 19$
Company profits	How the company will benefit from the project	Publicity for company	0.29%	$n = 12$
Community exploitation	How community is exploited by the project and/or project stakeholders	This could be an opportunity and shine a spotlight on a major project and how it could help impoverished communities.	0.12%	$n = 5$
Avoidant	The inaction that people choose to engage in by ignoring oppression and systemic inequities		90.40%	$n = 3733$
Community considerations	How the community will be impacted by the process and outcome of the project		14.74%	$n = 608$
Community impact	How the community will be impacted by the project	What impacts will it have on their lives?	4.92%	$n = 203$
Community engagement	How the community is engaged in and with the project, and how knowledge is considered	Community support—ensure they are involved throughout the processes	3.13%	$n = 129$
Access to community needs	How the community will access what they need during and after project	Access to water: there needs to be a way through, over, or around the wall so the community can access water for drinking, sanitation, and recreation.	0.73%	$n = 30$
Community cultural values	How the project team considers the culture of the community	In line with cultured beliefs? Local architecture Different cultural norms	0.70%	$n = 29$
Community perception of aesthetics	How the project looks or appears to the community	How it looks people will be upset if it is ugly	0.65%	$n = 27$
Community sustainability	How the community will sustain itself	Harm to the community if wall breaks upon completion	0.32%	$n = 13$
Community safety	How the community will be kept safe during and after the project	If wall malfunctions during project, will homes/people near probably be harmed?	0.19%	$n = 8$
Community funds of knowledge	How the funds of knowledge of the community are considered	Local expertise	0.10%	$n = 4$
Environmental considerations	How the environment will be impacted by the project during and/or after the completion of the project		5.14%	$n = 212$
Wildlife impacts	How the wildlife will be impacted by the project during and/or after the completion of the project	Construction disturbance to surrounding environment	1.24%	$n = 51$
Natural systems impacts	How the soil will be impacted by the project during and/or after the completion of the project	Public wants to minimize environmental disturbance from construction/erosion	0.34%	$n = 14$

TABLE 4 (Continued)

Codes and sub-codes	Definition	Example quotes	Relative frequency (%)	Excerpt count
Global considerations	How global issues are considered	Global concerns	0.24%	$n = 10$
Infrastructure considerations	Anything related directly to the infrastructure itself as opposed to the project team or community		6.40%	$n = 264$
Infrastructure aesthetics	How the project looks	How the project looks (general)	3.13%	$n = 129$
Infrastructure design	How the infrastructure is designed	Design of wall	1.99%	$n = 82$
Infrastructure sustainability	How the project will be sustained	Maintenance—Consumer should have a rough idea about the operation and maintenance	1.28%	$n = 53$
Owner considerations	How the needs or desires of the owner are considered	Owner's wishes	0.78%	$n = 32$
Infrastructure uses	How the infrastructure will be used	Multiple uses?	0.17%	$n = 7$
Infrastructure financial considerations	How the project should be funded and/or general considerations of costs associated with project	Cost to taxpayers or investors	0.07%	$n = 3$
Project considerations	How the project team will engage in the process and outcome of the project		23.90%	$n = 986$
Project logistics	How team will work on the project	How will workers enter the site?	6.33%	$n = 261$
Project financial considerations	How the project will be budgeted for and/or funded	Budget of the project	4.17%	$n = 172$
Project schedule	How the project will be scheduled, including timeline, setbacks, etc.	Timeline	4.17%	$n = 172$
Project competency	How competent the project team is	Team members have skills to complete?	3.10%	$n = 128$
Project materials/ technical needs	Note of the technical and/or material needs of the project that do not include an explicit consideration of the community's well-being	Available labor force-need to know what can be purchased and acquired for the construction	2.08%	$n = 86$
Law and contracts	Note of any local, state, national or international policies, laws, or regulations that are related to the project	An international law that relates	1.58%	$n = 65$
Project safety	How all people will be safe during and after the project	What risks are involved with the construction?	1.26%	$n = 52$
Project cost	How the project cost will evolve	Cost of project, needs as arise	0.92%	$n = 38$
Project ethical considerations	How the project team uses ethics on the project	Ethics of contractor/sub-contractors	0.48%	$n = 20$

(Continues)

TABLE 4 (Continued)

Codes and sub-codes	Definition	Example quotes	Relative frequency (%)	Excerpt count
Team motivation	How the team is motivated to work on and complete the project	Motivations of the people working the project	0.12%	$n = 5$
Critical	The actions taken by people to intentionally uproot oppression and systemic inequities		4.04%	$n = 167$
Community economy	How the project team can create financial well-being and/or revenue for the community	Can we employ the area? Can we pour more money in the area?	1.82%	$n = 75$
Sociopolitical action	How the community's oppression is recognized as sociopolitical and acted upon by the project team to lessen oppression/bring about justice	Are we making sure that we are hiring women/small businesses? Are we hiring people with disabilities?	1.82%	$n = 75$
Power considerations	How power is used to influence processes and outcomes related to the project and community	Politics—Is this project supported by those in power?	1.19%	$n = 49$
Sociopolitical awareness	How the community's oppression is recognized by the project team	Are poorer communities more likely to have insufficient defenses against flooding? Will they be more adversely affected by flooding?	0.78%	$n = 32$
Harm reduction action	How the community's oppression is not made worse by the project team	Marginalized groups—If people are to be affected, are they a part of a previously marginalized group? Can things be done to not affect them?	0.10%	$n = 4$

considerations ($n = 212$). First, the majority of the students reflected on the project management considerations. These included considerations regarding cost ("Costs—scale of wall, how large/small it can be"), schedule ("Schedule—construction may have to move faster, design simplified"), safety ("Safety—keep laborers and people living nearby safe"), and team dynamics ("Motivations of the people working the project"). The project management considerations were avoidant as they reflected the for-profit concerns that may not always be representative of the community needs. The for-profit concerns are normalized in civil engineering as the field is driven by industry demands. Second, the students reflected on the community considerations including aspects such as community safety (such as a respondent of the Bangladesh problem: "Safety of citizens in area") and culture (such as a respondent of the no context problem: "Any cultural significance of site or construction?"). An example of a community consideration included the importance of culturally appropriate design ("Appearance must be inoffensive to the public"). In these excerpts, students described community needs and well-being. They reflected on the positive and negative impacts that the retaining wall had on the community. Unlike other avoidant responses, community considerations excerpts actually mentioned the people and the need to protect their interests. Notably, 72.5% of students considered the community in some way. While the excerpts did not directly discuss inequities and oppression, they were still socially engaged and differed from other avoidant responses where the people were invisible. Third, the students reflected on the infrastructure considerations including the design (such as a respondent of the no context problem: "The design may need to change based on the characteristics of materials used"), maintenance (such as a respondent of the Bangladesh problem: "Build it well because region is very poor, may not be repaired for many years"), and funding (such as a respondent of the Mississippi problem: "You can't build anything if you don't have the money.") The technical considerations were avoidant as they excluded the people. The difficulty of thinking beyond technical considerations even when students are asked about "nontechnical" needs, or those needs that are not directly related to the physical design and construction of a project, which may include social, cultural, historical, and institutional factors and context, is not surprising as civil engineering education heavily focuses on technical aspects and on socio-technical dualisms. Finally, the students reflected on the environmental considerations such as the effect of the retaining wall on the wildlife, soils, and the surrounding ecosystems (e.g., "Environmental effects: a retaining wall could affect buildings around it as stresses in the soil will change").

Finally, 4.04% of the excerpts ($n = 167$) demonstrated critical action attitudes. In these excerpts, students discussed action that is intentionally taken to uproot the inequities underlying social issues while working on building the retaining wall. Respondents mentioned awareness of nontechnical factors such as sociopolitical issues, sociopolitical action, and politics. One student, responding to the Mississippi problem, asked if race was a dividing factor ("Is race a dividing factor in where these people live?") while another, also in response to the Mississippi problem, asked: "Is any group of individuals disproportionately affected?" These responses demonstrate a level of sociopolitical awareness and questioning that was not identified in the vast majority of responses. A response to the Bangladesh problem asserted that marginalized populations mattered more than the retaining wall ("As I said before, I think the retaining wall is not the most important thing. Why have only poor people died?"). This response indicated a level of critical reflection about poor communities and their increased risks to flooding. In this excerpt, the student questioned issues of power, class, and access to safety. This is a direct application of critical action attitudes as this student is "breaking the silence surrounding the inequity that facilitates collusion, complicity, and compliance with inequity" (Jemal & Bussey, 2018, p. 46). Another student, in response to the Mississippi problem, indicated a critical action attitude by suggesting that they would consider how infrastructure improves or affects disproportionately underserved communities ("Are poorer communities more likely to have insufficient defenses against flooding?"). Similarly, a student who responded to the no context problem asked: "Equitable construction: is it affecting all people equally?" These responses demonstrate the understanding of systemic inequities and the fact that communities become impoverished when oppression and inequities impact them. Lastly, several responses addressed the political nature of building a wall, and the ways that corrupt power may attempt to influence the project. These responses demonstrate active engagement in collecting information about how sociopolitical influences may try to gain control of the project.

6.2 | Statistical inference results: The role of CRPS on TA levels

The statistical analysis shows a statistically significant relationship between the TA levels and CRPS (Table 5). Specifically, students who were randomly assigned to the Bangladesh version provided more destructive and more critical action attitudes ($p < .01$). Further exploring this result by performing separate analyses for cisgender male and female students, we find that this relationship is driven by responses from the cisgender male students ($p < .01$), but not

TABLE 5 Number of observed and expected transformative action levels across contexts for all participants ($n = 375$).

		Critical	Destructive	Avoidant	*p*-value
No context	Observed	7	21	123	**.0009**
	Expected	6.93	33.15	110.91	Effect size: .14
Mississippi	Observed	3	30	119	
	Expected	6.98	33.37	111.65	
Bangladesh	Observed	13	59	126	
	Expected	9.09	43.47	145.44	
No context (males only)	Observed	6	14	86	**.0031**
	Expected	5.27	22.32	78.42	Effect size: .15
Mississippi (males only)	Observed	1	18	80	
	Expected	4.92	20.84	73.24	
Bangladesh (males only)	Observed	10	40	87	
	Expected	6.81	28.84	101.35	
No context (females only)	Observed	1	7	32	**.6107**
	Expected	1.41	9.86	28.73	Effect size: .09
Mississippi (females only)	Observed	2	12	37	
	Expected	1.8	12.57	36.63	
Bangladesh (females only)	Observed	2	16	33	
	Expected	1.8	12.57	36.64	

Note: Effect sizes for statistically significant tests are moderate as shown by Cramer's V.

cisgender female students ($p > .1$). No other tested demographic factors showed significant associations with the TA coding. The following demographic factors were tested versus destructive, critical, and avoidant: institution, sex, gender, class standing, income, first generation, race, ethnicity, English as a second language, college age versus non-traditional, and heterosexual.

7 | DISCUSSION

Civil engineering education does not yet sufficiently focus on educating holistic engineers who can think critically (Beder, 1999; Bucciarelli, 2008; Conlon, 2008; Trbušić, 2014; Zandvoort, 2008). To address the need to educate engineers who have a positive social impact, recent educational (e.g., ABET, engineering for development programs) and research efforts (Catalano, 2006a, 2006b; Catalano & Baillie, 2006; Nieusma & Blue, 2012; Riley, 2008; Riley et al., 2015) have increased their focus on critical action. Nevertheless, it is not known whether these efforts have been efficacious. This research evaluates whether civil engineering students are indeed considering critical action in their engineering work. Specifically, this paper answers: To what extent do civil engineering students demonstrate critical action attitudes when prompted by engineering problem-solving?

In general, our analysis indicates that the majority of the excerpts (90.40%) maintain an avoidant action attitude in their engineering work. They did not often address issues that disproportionately impact marginalized communities. Students tended to focus on the for-profits concerns. This is not surprising considering the field's focus on materialism and serving the industry. Despite being asked about nontechnical issues, many students continued to focus on technical knowledge. This aligns with previous work that discussed civil engineers' resistance to public welfare issues (Cech, 2014; Nguyen et al., 2020; Niles et al., 2020). The resistance to critical action may manifest out of the desire to align with students' perception of the dominant engineering identity, where a “real engineer” needs to treat other skills outside their technical expertise as less valuable (Niles et al., 2020).

However, in our study, simply providing CRPS made students more likely to engage both destructive and critical action attitudes. Nearly 5% of excerpts indicated destructive action attitudes, showing ill regard for communities and/or demonstrating a plan to act that would significantly harm already vulnerable people. Destructive action attitudes were reflected through their beliefs that communities were inferior. These beliefs were visible through students' assumption of criminality and assumptions of intelligence. It is deeply troubling, though perhaps not surprising, that CRPS caused an increase in the destructive factors that were listed. Beliefs of superiority are widespread in engineering culture (Riley, 2008) and are visible in the everyday narratives regarding engineers being knowledgeable (e.g., "Trust me, I am an engineer"). For example, Riley (2008) brings attention to the need for transforming the engineering curriculum beyond Western knowledge and examples. Such changes can increase engineers' critical consciousness and appreciation for non-Western societies and people. And indeed, as our data show, curricular change that adds social context to engineering problems must explicitly engage students with these issues so that we can not only elicit but disrupt deep seated and often taken-for-granted biases.

Further, although only 4.04% of the excerpts indicated critical action attitudes, our results show that students were more likely to consider critical action attitudes in engineering when presented with the Bangladesh version of the engineering problem as opposed to more traditional problem framing, without an explicit focus on social justice. This aligns with existing literature that shows context influences students' engineering problem-solving (Kilgore et al., 2007); we add that the nature of the provided context also seems to matter. This study shows that engineers can and are applying engineering to promote social change. When they do, they may work across systems to dismantle oppressive conditions and systemic inequities that impact communities. It is encouraging that even a very small change—the wording of an engineering problem—was able to trigger change in the design factors students considered in our dataset. Still, it must be emphasized that this same change also triggered an increase in factors coded to destructive action attitudes, and that the vast majority of responses simply avoided engaging with critical action attitudes regardless of the version of the engineering problem they saw. As our field has long identified making a difference as the "most appealing" message for communicating the "role, importance, and career potential" of engineering (NAE, 2008, pp. 2, 8), this is a concerning finding. Clearly, more than wording changes on problem sets are needed.

Our results (Table 6) also show that cisgender male students were statistically significantly more strongly influenced by the CRPS than were cisgender female students. This result was unexpected, and our data do not provide a good explanation for this result. More qualitative research is needed to explore this finding. It is possible this result links to research that shows upper division cisgender female students show stronger engineering identities than do upper division cisgender male students (Hamlet et al., 2021). In other words, the cisgender female students may have already and strongly made up their minds regarding the fundamental nature of engineering, while cisgender male students, who on average face fewer social obstacles to persisting in engineering, may not yet have done so. Yet another possible explanation is that, due to the demographics of engineering, we were able to survey far fewer females than males, and the smaller sample size may influence the lack of statistical significance in this population.

Broadly, this set of results suggests that all civil engineers, like all people, need education that can unpack unconscious and conscious bias and better scaffold the ability to link engineering work with social justice (Lucena, 2013; Riley, 2008). As this is largely neglected in our classrooms, it is not surprising that our students' responses reflect this conspicuous absence. Following in the footsteps of scholars who are also deeply dedicated reforming engineering pedagogy (e.g., refer to Catalano, 2006a, 2006b; Kabo, 2010; Lucena, 2013; Pantazidou & Nair, 1999; Riley, 2003), we suggest this is not a failing of our students, but of our institutions and our curricula.

We suggest civil engineering curricula be tailored to include CRPS. Civil engineering students need contextualized, historical accounts of the engineering field complete with its complicity with oppression. They need to understand how systemic inequities have come to be, and how they result from systems of oppression. They need to be presented with cases where they spend time considering how to develop relationships with community members and learn from them. Then they need to understand how they might go about acting alongside those particular communities to disrupt the systemic inequities that impact humanity. We recommend a shift from isolated courses about ethics or social issues toward holistic programming in which every course requires civil engineering students to practice using a critical lens.

TABLE 6 Transformative levels by sex.

		Destructive code present		Critical code present		Avoidant code present	
	Total respondents	**Yes (%)**	**No (%)**	**Yes (%)**	**No (%)**	**Yes (%)**	**No (%)**
Male	258	6.60%	93.40%	27.90%	72.10%	98.40%	1.60%
Female	109	4.60%	95.40%	33.00%	67.00%	97.20%	2.80%

Note: A respondent may be coded to more than one category (e.g., a response may be both coded to critical and avoidant).

In other words, we recommend that ethics and social justice topics are integrated with the current technical curriculum. In this curriculum, we encourage new paradigms that align with the belief that engineering "is not a neutral enterprise" (Nasser & Romanowski, 2016, p. 411). Civil engineers have a responsibility and an opportunity to disrupt oppression in their everyday design and construction. Engineering is a political act (Apple, 1993), and civil engineering students deserve to understand the political nature of context. Our work provides evidence that this type of knowledge would change the way students do their technical work.

The paper calls for action on increasing institutional support for promoting critical action attitudes, and for changes to the current ABET professional learning outcomes related to critical action. While critical action is implied in ABET professional learning outcomes, notably within the current ABET draft changes, these outcomes continue to be vague in terms of critical action. For example, one of the ABET professional learning outcomes states that students must "recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" (ABET Engineering Accreditation Commission, 2021, p. 5) but does not clearly describe what might constitute an informed judgment or consideration of such an impact, particularly as impacts relate to systemic inequities. It is important that future ABET professional learning outcomes add an outcome that specifically focuses on addressing inequities and oppression.

8 | LIMITATIONS

Civil engineering students' critical consciousness must be examined using a variety of methods in order to capture a holistic understanding of how they are thinking. Open-ended questions are potentially reflective of students' thinking, but we acknowledge that this study is limited by its one data source and nonlongitudinal design.

We also acknowledge that students' responses might have been determined by other institutional factors unaccounted for in the paper. Students' responses might have been determined by the university they attended and the curriculum or culture at the university. For example, certain universities might adopt curriculum that particularly embraces critical action attitudes through mandatory ethics courses or engineering courses that incorporate critical consciousness curriculum. Some, but not all, students in this sample had previously taken classes that map to ABET outcomes 2 and 4. To address this limitation, we checked for statistically significant differences in responses across universities. We found there was not a significant difference across these groups. Still, this difference in background between students may have influenced their answers to our questionnaire. This study has not explored those institutional factors, but future research is encouraged to do so.

It is also important to note that neither the selected universities nor the responding students represent a random sample of any population. Accordingly, our results cannot be statistically generalized; they are instead intended to better describe the patterns observed in this sample (Sykes et al., 2018). We selected the mixed methods approach used here in order to explore a new idea, and to robustly compare demographic subsets of our data. Still, it is also worth emphasizing that these selected methods and the unrepresentative demographic makeup of engineering and of our sample have directed attention away from the responses of members of smaller intersectional identity groups and toward more dominant groups with larger numbers. Despite our best efforts, the demographic categories on the survey may not adequately represent race, gender and sexuality, or other identity categories that may be important to critical consciousness. We also recognize the multiplicity of intersections of identities (Crenshaw, 1990) through which power and marginalization are enacted to impact students' lived experiences; due to sample size, those intersections were not included in this analysis. As such, our results should be read with this understanding.

9 | CONCLUSION

In *Notes of a Native Son* (1955), James Baldwin wrote: "I love America more than any other country in the world and, exactly for this reason, I insist on the right to criticize her perpetually." Baldwin poignantly expressed our motivation for conducting this study. Civil engineering students have the potential to contribute to the world in powerful ways and as such, they deserve an education that will enable them to do so.

This study assesses critical action attitudes among 375 undergraduate civil engineering students across 12 universities. The study uses survey data that asked students to discuss nontechnical factors that need to be considered when designing infrastructure for flooding mitigation. Using a theory of critical action, we show that the majority of civil engineering students demonstrated avoidant action attitudes while a minority of civil engineering students modeled destructive or critical action attitudes. Importantly, adding CRPS changed the types of factors engineering students considered at a statistically significant level. Specifically, the Bangladesh example that explicitly linked a problem with social justice (described in the methods section) increased the number of factors coded to both destructive and critical action. In addition, this shift seems to be the strongest among cisgender male students; no other tested demographic factors showed significant associations with the TA coding (political leaning, race, language spoken, gender, sex, class, major, and family income).

Critical action goes beyond simplistic considerations of culture and diversity. It requires both uncovering power dynamics and taking action to address them. Based on our analysis, the majority of civil engineering students did not address oppression and/or systemic inequities in their responses. Given civil engineering education's neglect of critical consciousness development, students' overwhelming orientation to avoidant stances represents a need for systemic transformation in engineering education that is grounded in critical theory and contextualization.

We believe that civil engineering education programs and classrooms also act at transformative levels. Currently, our classrooms too often avoid mention of social justice and neglect critical consciousness development entirely. By not providing civil engineering students with the education needed to disrupt oppression, civil engineering education is not apolitical or neutral; it is complicit in the perpetuation of systemic inequities through inaction. Every program and every classroom is implicated because education shapes who students are, who they are becoming, and who they will become as actors in civil engineering.

10 | A POSTSCRIPT

A review comment asked us to consider the implications of the timing of data collection, which happened before the murder of George Floyd and the subsequent protests against state-sanctioned violence across the country. Currently, some educators are actively seeking to integrate social concerns and history into their engineering classrooms. On our own campuses, students are demanding the integration of social issues in engineering curricula and some educators are responding. We wonder if data collected today would show higher levels of critical action among students. In this sense, this paper is an important data point that is particularly relevant to our times and the changes demanded of engineering pedagogy.

ORCID

Riley Drake https://orcid.org/0000-0002-8111-7010
Cristina Poleacovschi https://orcid.org/0000-0002-1187-9677
Kasey M. Faust https://orcid.org/0000-0001-7986-4757
Arie True-Funk https://orcid.org/0000-0003-4955-7961
Jessica Kaminsky https://orcid.org/0000-0002-1340-7913

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How to cite this article: Drake, R., Poleacovschi, C., Faust, K. M., True-Funk, A., & Kaminsky, J. (2023). Civil engineering students as avoidant actors: Using culturally relevant problem-solving to increase critical action attitudes. *Journal of Engineering Education*, *112*(2), 262–283. https://doi.org/10.1002/jee.20507

APPENDIX A

REQUIRED COURSEWORK AT INSTITUTIONS

TABLE A1 Required related coursework at institutions.

Institution	Diversity/humanities/social sciences
1	
2	
3	
4	X
5	X
6	X
7	
8	
9	X
10	X
11	X
12	X

APPENDIX B

PARTICIPANT DEMOGRAPHICS

TABLE B1 Participant demographics.

	Gender total	Male		Female		Other gender		White (including Middle Eastern)		Asian (including Indian subcontinent and Philippines)		Black or African American (including African and Caribbean)		Did not respond to race	
University	*N*	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
A	12	8	67%	2	17%	2	17%	7	58%	1	8%	0	0%	4	33%
B	56	40	71%	15	27%	1	2%	51	91%	3	5%	2	4%	0	0%
C	15	14	93%	1	7%	0	0%	10	67%	1	7%	0	0%	4	27%
D	12	10	83%	2	17%	0	0%	10	83%	1	8%	0	0%	1	8%
E	20	14	70%	4	20%	2	10%	17	85%	0	0%	0	0%	3	15%
F	38	26	68%	12	32%	0	0%	31	82%	2	5%	2	5%	3	8%
G	20	14	70%	3	15%	3	15%	17	85%	0	0%	0	0%	3	15%
H	18	17	94%	1	6%	0	0%	11	61%	3	17%	0	0%	4	22%
I	17	12	71%	5	29%	0	0%	14	82%	2	12%	0	0%	1	6%
J	33	18	55%	14	42%	1	3%	16	48%	12	36%	2	6%	3	9%
K	47	29	62%	16	34%	2	4%	24	51%	19	40%	0	0%	4	9%
L	87	56	64%	30	34%	1	1%	70	80%	5	6%	0	0%	2	2%

APPENDIX C

ENGINEERING MAJORS AND ABET ACCREDITATION

TABLE C1 Engineering majors and ABET accreditation.

Institution	Architecture	Environmental	Civil	Construction	ABET
1	X	X	X		Only civil
2			X		Only civil
3		X	X	X	Only civil
4			X	X	Construction and civil
5	X	X	X	X	Only civil
6		X	X	X	Only civil
7		X	X	X	Only civil
8		X	X		Only civil
9	X	X	X		Environmental and civil
10		X	X	X	Only civil
11		X	X	X	Construction and civil
12		X	X	X	Only civil

AUTHOR BIOGRAPHIES

Riley Drake is an Assistant Professor of School Counseling at University of Wisconsin-Stout, Department of Counseling, Rehabilitation, and Human Services, University of Wisconsin-Stout, 240F Heritage Hall, Menomonie, WI 54751, USA. draker@uwstout.edu.

Cristina Poleacovschi is an Assistant Professor in the Department of Civil Construction and Environmental Engineering at Iowa State University, 402 Town Engineering, Ames, IA 50011, USA. poleacov@iastate.edu.

Kasey M. Faust is an Associate Professor in the Department of Civil, Architectural and Environmental Engineering at The University of Texas at Austin, 301E E Dean Keeton St c1700, Austin, TX 78712, USA. faustk@utexas.edu.

Arie True-Funk is a PhD candidate affiliated with the Polk County Housing Trust Fund, 505 Fifth Ave, Suite 1000, Des Moines, IA 50309, USA. atruefunk@pchtf.org.

Jessica Kaminsky is an Associate Professor in the Civil and Environmental Engineering Department at the University of Washington, More Hall 121H, Seattle, WA 98195, USA. jkaminsk@uw.edu.