

Exploring Equity and Resilience Perceptions of Marginalized Architecture, Engineering, and Construction (AEC) Students in Infrastructure Projects

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Abstract

Natural catastrophes brought on by extreme weather events and other natural hazards are causing communities throughout the United States to face increasing levels of financial losses and human suffering. To ensure community safety and well-being in the face of these challenges, infrastructure must be equipped with climate-resilient features. However, marginalized groups disproportionately endure the social, economic, health, and environmental effects of these disasters due to decades of discriminatory policies and biases embedded in infrastructure planning. This study focuses on investigating the perceptions of marginalized architecture/engineering/construction (AEC) students about incorporating equity considerations while developing sustainable and resilient infrastructures. For this study, the relevant underrepresented populations are African American, Hispanic American, and Native American. It is imperative to investigate how engineering graduate students including students from marginalized communities understand the connections between social justice and the infrastructure systems, given the growing importance of these concerns in our society. The study aims to address the following research objectives: (1) Understand the level of awareness of AEC marginalized students about societal inequalities within resilient infrastructure systems; (2) Highlight the perceptions regarding infrastructure resilience inequality among AEC students from various socio-demographic backgrounds; and (3) Understand the interest of marginalized students about promote systemic change as future engineering professionals. Surveys measuring students' awareness of inequity in infrastructure systems, their motivation to promote equity, and relevant demographics were used to gather data for the study in a minority-serving institution. The study included 19 marginalized AEC students who were enrolled in a sustainable approach to construction course in the Fall 2023 semester. The results showed that the majority of the students were aware of infrastructure disparities. Moreover, the student demonstrated a moderate to high level of agreement on various infrastructure inequity issues as well as indicated a higher motivation to work toward systemic change. The findings of this study would motivate educators to develop tailored educational strategies for increasing awareness of infrastructure inequality and preparing the forthcoming construction workforce including marginalized construction professionals with the skills required to ensure an equitable, sustainable, and resilient infrastructure system.

Introduction and Background

Communities across the United States are increasingly experiencing the devastating impacts of extreme weather events and changing climate conditions. The National Oceanic and Atmospheric Administration reports that in 2021 alone, there were 20 weather disaster events causing losses exceeding \$1 billion each [1]. Such disasters lead to damaged structures and infrastructure systems disrupting social services and resulting in massive financial losses. Therefore,

communities ought to consider resilience actions ahead of disasters, including preparing resources, response, and recovery activities [2]. Moreover, extreme weather events and other natural disasters can have a disproportionately negative impact on low-income communities, Indigenous populations, and communities of color due to decades of discriminatory policies and practices. For example, low-income and communities of color in Houston were disproportionately affected by Hurricane Harvey's floods [3]. Therefore, engineers and construction professionals must consider marginalized communities and underrepresented groups in the resilient infrastructure development processes associated with hazard risks. Enhanced equality has the potential to boost community adaptability and lessen the unequal allocation of losses and damages resulting from extreme events.

The concept of resilience has gained significant attention focusing on effectively managing disruptions, challenges, and shocks within systems, particularly in disaster risk management [4]. It involves the ability to plan for, absorb, recover from, and adapt to adverse events [5]. However, communities of color and other marginalized and socially vulnerable groups frequently lack the resources and expertise necessary to participate in risk mitigation, planning, and reduction, or are overlooked in planning by governments and other policy and decision-makers. Additionally, well-established institutions, like state and federal agencies, local government officials, public planners, and infrastructure development companies, can be inherently biased toward inequality. These institutions often fail to acknowledge these biases which eventually leads to failure in creating equitable infrastructure resilience [6]. Recognizing the injustices that have developed over years of practice, it is necessary to address the basic social inequalities through resilience education, particularly for architecture/engineering/construction (AEC) students from marginalized communities, which can, in turn, help to improve community resilience and adaptability equitably in the future.

Traditional approaches to resilience often concentrate on immediate services, security, and infrastructure without addressing underlying systemic inequalities. In order to attain equitable resilience, AEC professionals need to challenge and transform the systemic structures that perpetuate vulnerabilities within communities [7]. This means eliminating discriminatory practices, addressing social and economic disparities, and ensuring that resilience strategies benefit all segments of society. In order to enable systemic change, governance innovations, foresight processes, knowledge transfers, and learning-by-doing are required [8]. Additionally, skills and capacity building within a workforce can create systemic change that carries over to future projects [9]. There is also a need to learn from past approaches and past failures so that resilience can deliver genuine systemic change that empowers and benefits poor and marginalized people [10]. Without embracing systemic change, the risk remains of reinforcing existing vulnerabilities and failing to address the root causes that leave certain populations disproportionately exposed to the impacts of crises and disasters. Thus, the call for systemic change should be paramount for the future AEC workforce in the pursuit of building resilient and equitable infrastructure for the benefit of all.

The Accrediting Board for Engineering and Technology (ABET) exclusively accredits engineering programs, while the accreditation of construction management programs is

conducted by the American Council for Construction Education (ACCE). Traditionally, construction education in the United States focused on managerial, technical, and procedural aspects. However, in the past decade, the industry's environmental impact has gained recognition, prompting owners to demand the integration of sustainability in the construction process [11]. Acknowledging this shift, construction programs are now incorporating sustainability-related courses into their curricula [12]. ACCE standards mandate that construction management graduates understand the basic principles of sustainable construction [13]. Likewise, recent changes in ABET Engineering Accreditation Criteria (EAC) underline the importance of sustainability, risk, resilience, diversity, equity, and inclusion in addressing civil engineering challenges [14]. To meet these evolving criteria, design solutions must now consider risk assessment, societal and environmental impacts, relevant codes, standards, regulations, sustainability, and resilience [15]. Therefore, it is crucial to understand and enhance the awareness of AEC students about equity in developing sustainable and resilient infrastructure. Such awareness of equity ensures that these professionals consider the diverse needs, vulnerabilities, and priorities of all community members, promoting fairness and inclusivity in infrastructure development.

Many engineers play vital roles in responding to natural disasters. Among these, engineers with AEC backgrounds hold particular significance because their discipline focuses on public infrastructure. The work of AEC professionals frequently involves direct interaction with society, potentially fostering an increased understanding of societal needs compared to other disciplines. This research assessed the AEC students' understanding and awareness of the connections between social justice and resilient infrastructure systems, given the growing importance of these concerns in our society. The study was implemented in a minority-serving institution in the US which supported the notion that students from historically marginalized communities such as African-American, Hispanic, and Native American could serve as agents of change to equitable developments in the AEC industry. Literature has highlighted the low participation of marginalized communities in civil and construction industries as well as in the academic sector [16]. Furthermore, very few studies focused on improving the competencies of Hispanic and other historically marginalized students in AEC including communication and presentation skills and other professional skills, while other studies assessed their preferences for sustainability and relevant career choices [17]–[19]. In order to support the skilled labor shortage in the AEC industry as well as to preserve the economic success of the US, marginalized professionals must be involved in infrastructure construction projects. Moreover, awareness of equitable infrastructure resilience can facilitate marginalized ethnic communities to actively participate in decision-making processes related to infrastructure development. This involvement can lead to the creation of solutions that better align with the community's unique needs and aspirations. Furthermore, infrastructure projects can have adverse environmental impacts, and marginalized communities often bear the brunt of these effects. Understanding equitable resilience enables marginalized ethnic students to advocate for environmental justice and sustainable practices in infrastructure development.

Aligning with this research need, this study focuses on investigating the perceptions of marginalized architecture/engineering/construction (AEC) students about incorporating equity considerations while developing sustainable and resilient infrastructures. For this study, the relevant underrepresented populations are African American, Hispanic American, and Native American. It is imperative to investigate how engineering graduate students including students from marginalized communities understand the connections between social justice and the infrastructure systems, given the growing importance of these concerns in our society. The study aims to address the following research objectives: (1) Understand the level of awareness of AEC marginalized students about societal inequalities within resilient infrastructure systems; (2) Highlight the perceptions regarding infrastructure resilience inequality among AEC students from various socio-demographic backgrounds; and (3) Understand the interest of marginalized students about promote systemic change as future engineering professionals. Surveys measuring students' awareness of inequity in infrastructure systems, their motivation to promote equity, and relevant demographics were used to gather data for the study in a minority-serving institution. The study included 19 marginalized AEC students who were enrolled in a sustainable approach to construction course in the Fall 2023 semester. The findings of this study can motivate educators to develop targeted strategies and educational modules, ensuring that marginalized AEC students possess the essential knowledge and perspectives to develop equitable, sustainable, and resilient infrastructures.

Methodology

This research investigated how marginalized AEC students comprehend the relationships between social justice and infrastructure systems in the context of developing disaster resilience. To achieve this objective, the study surveyed students who were enrolled in a Sustainable Approach to Construction course under the construction management program in the Fall 2023 semester. Sustainable construction is a cross-listed 3-credit elective course offered to both undergraduate and graduate level students. An online surveying tool, Qualtrics, was used to prepare and distribute the survey among the participants. The survey was divided into three parts. In part one, the survey presents the students with a story concerning a social problem that focuses on inequity in infrastructure resilience. After the story, there were two open-ended questions to evaluate students' understanding of the problem which included: (1) What issue do you believe is illustrated in this scenario? and (2) What measures can be taken to overcome this problem? In part two, the survey asked five-point Likert scale questions related to students' awareness of equitable infrastructure resilience and their interest in systemic change. In part three, the students were asked questions related to their socio-demographic information.

Survey data was collected for the current study through convenience sampling. Participants in this method were chosen according to their convenience and accessibility. In particular, those who took part in the study were registered students for the Fall semester of 2023 in the cross-listed Sustainable Approach to Construction course. This indicates that participants were selected from among the students who decided to enroll in that course for that particular academic year. The Institutional Review Board (IRB) at the university reviewed the survey and deemed the survey exempt beyond the initial review. All students were informed that the survey was

optional, and they could choose to withdraw at any time without penalty. The study received 51 responses through the survey. Then the authors filtered the survey responses based on ethnicity and included 19 responses of ethnically marginalized students including African American, Hispanic American, and Native American.

The study conducted a qualitative analysis of the collected survey responses. Qualitative content analysis was performed on open-ended responses. The content analysis involved manual keyword search analysis which included keywords such as equity/ inequity/ racism/ disparity/ fair/ unfair/ prioritization/ equality/ segregation/ preferences/ negligence/ bias/ discrimination/ overlooked/ socio-economic advantage/ inequality to find instances of equitable resilience in the responses. Moreover, the study utilized boxplots to analyze the 5-point Likert scale responses to demonstrate the student’s awareness of equitable infrastructure resilience as well as present the students’ interest in contributing to systemic change. Boxplots were created using R-Studio to showcase the participants’ level of interest.

Results

This section presents the results of the survey responses collected through this research. Figure 1 demonstrates students’ socio-demographic backgrounds, including gender, age, origin, ethnicity, highest level of education, current class standing, current GPA, majors, and employment status. The sociodemographic questions included multiple-choice responses within the survey. Figure 1 highlights that among the 19 participants, 37% declared themselves as Hispanic, whereas 63% were non-Hispanic students. Moreover, almost 21% of the students were identified as African American, 42% as Asian, and 32% as other ethnicities.

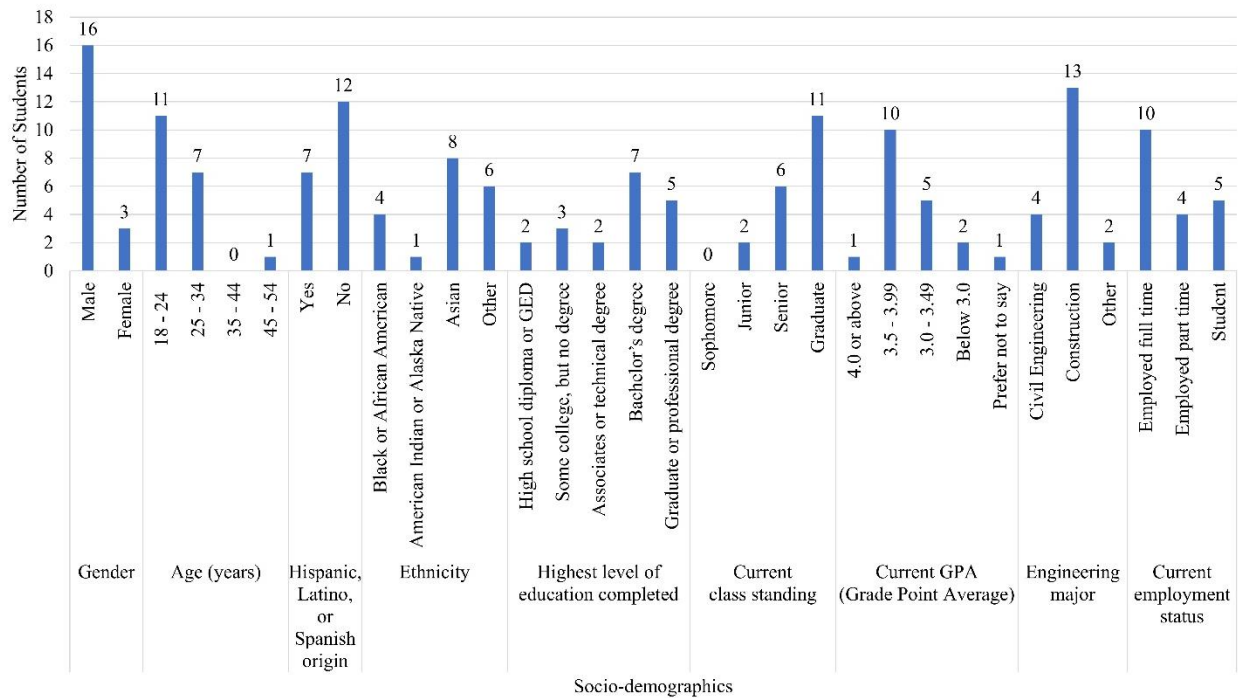


Figure 1. Students' socio-demographics (n=19)

The authors manually analyzed the two open-ended questions to determine the ability of the marginalized AEC students to recognize issues related to inequity. The responses having one or more of the keywords mentioned in the Methodology section were considered as "Presence of inequity issue". If none of these keywords were found in the responses, then the answers were considered as "Absence of inequity issue". Figure 2 shows that 15 out of 19 students could identify the inequity issue whereas the remaining 4 responses did not contain the keywords. This suggests that a significant portion of marginalized AEC students exhibit a certain degree of awareness regarding existing inequity issues in resilient infrastructure development.

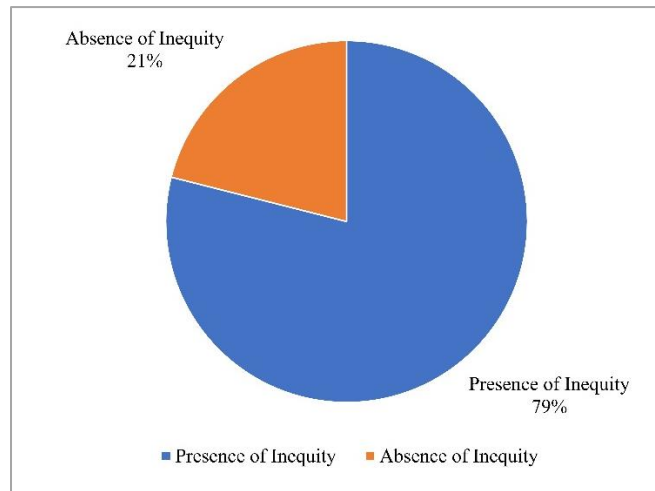


Figure 2. Piechart showing students' ability to identify infrastructure inequity issue

Additionally, the study used boxplots to assess the participants' awareness of various statements related to equitable infrastructure resilience. The study included 3 statements regarding students' awareness, 3 statements related to students' personal experience with social inequalities, 2 statements related to learning about equitable resilience, and lastly 2 statements regarding the implementation of equitable resilience in real projects. The participants were instructed to rate the statements on a five-point Likert scale (1 = None at all, 2 = Slightly, 3 = Moderately, 4 = Greatly, 5 = Significantly). Figure 3 illustrates that statements such as awareness of vulnerable communities to natural disasters (S1), recognition of specific social or economic factors rendering communities more susceptible to infrastructure-related vulnerabilities (S2), and awareness of social injustices and infrastructure inequities (S3), all had a median value of 3, signifying a moderate level of awareness regarding equity in infrastructure resilience. Statements addressing personal experiences and abilities, such as encountering situations involving social inequalities influencing engineering decisions (S4), the ability to define resilient infrastructure in the context of natural disasters (S5), and the ability to provide examples of resilient infrastructure projects addressing societal inequalities (S6), also had a median value of 3, indicating a moderate level of agreement on the participants' perceived capabilities regarding equitable infrastructure resilience knowledge. Statements focused on learning equitable resilience through education,

such as the extent to which civil engineering/construction management programs cover topics related to equity in developing resilient infrastructure (S7) and studying any case studies or projects that focus on ensuring equity and social justice in resilient infrastructure systems (S8), had a median value of 3, suggesting a moderate effort by higher education authorities to instill such knowledge among Architecture, Engineering, and Construction (AEC) students. On the other hand, statements 9 and 10 had a median value of 4 signifying a strong agreement among students that it is critical to consider social equity in the planning and implementation of infrastructure resilience as well as that access to transportation is crucial for overall resilience during and after disasters for a community.

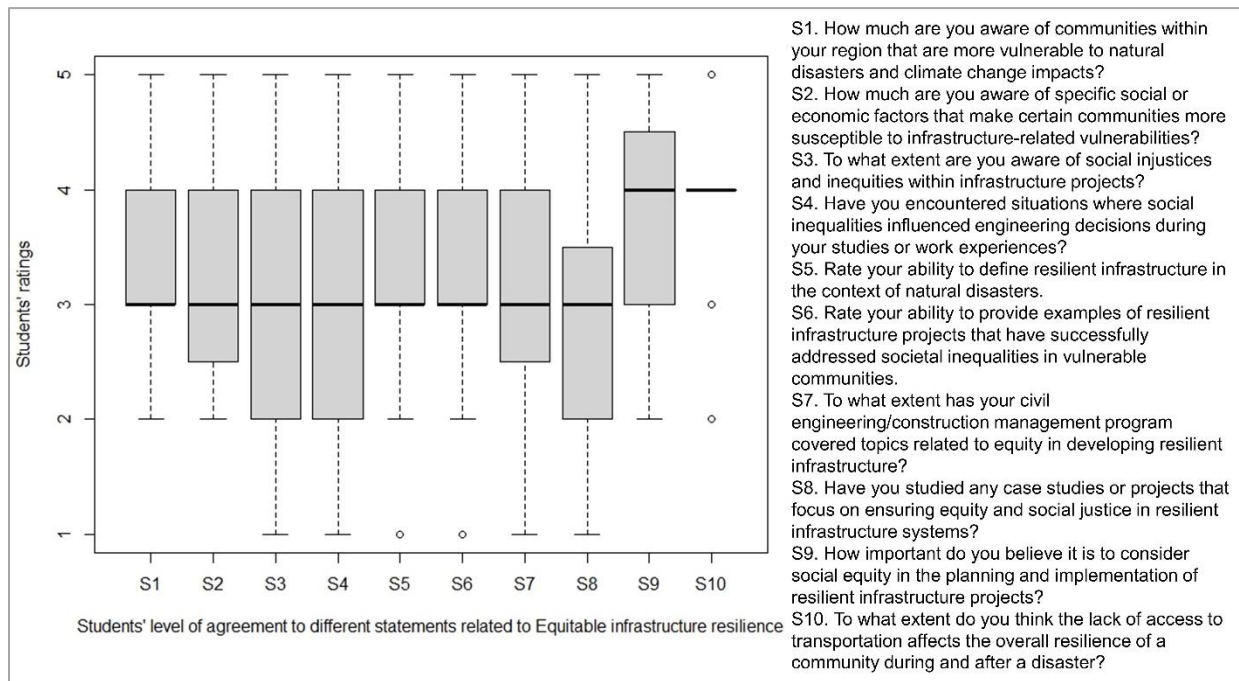


Figure 3. Boxplots presenting students' rating on statements related to equitable infrastructure resilience (1 = None at all, 2 = Slightly, 3 = Moderately, 4 = Greatly, 5 = Significantly)

Furthermore, the study utilized boxplots to reflect students' responses related to their interest in working toward systemic change as shown in Figure 4. The survey included 8 statements: S1. Motivation to contribute to systemic change within the field of civil and construction engineering; S2. Belief of civil and construction professionals having a role in promoting systemic change in areas related to social justice and equity; S3. Importance to work on projects that have a positive social impact and address societal inequalities; S4. Interest in specializing in areas of civil and construction engineering that specifically focus on social equity and justice; S5. Willingness to advocate for social justice and equity considerations in engineering projects, even if it requires challenging established practices; S6. Open to collaborating with community organizations or advocacy groups to promote equitable engineering practices; S7. Influence do you believe civil engineers have in promoting systemic change within the profession and society; S8. Feel empowered to initiate or support initiatives that challenge social injustices within engineering projects.

The students were allowed to rate their level of interest from 1 to 5 (1 = None at all, 2 = Slightly, 3 = Moderately, 4 = Greatly, 5 = Significantly) on these eight statements. The findings highlighted that all the statements had a median value of 4. This indicates that marginalized students in the fields of architecture, engineering, and construction (AEC) show an enhanced willingness to participate in efforts toward systemic transformation. This readiness among marginalized AEC students implies a notable inclination towards engaging in activities and initiatives aimed at broader, transformative changes within their respective fields. Such findings underscore the potential for these students to play a significant role in driving positive, systemic shifts within the AEC industry, fostering inclusivity, and advancing equity. Additionally, statements such as S4 and S5 had a median value of 3. This suggests that the students might be less inclined to specialize in engineering fields that explicitly address social justice concerns, as indicated in S4. Moreover, students might exhibit less willingness to advocate for social justice within engineering projects and challenge established practices, as evidenced by their responses to S5. Nonetheless, the overall findings suggest that the marginalized AEC students exhibit a greater readiness to contribute to systemic change.

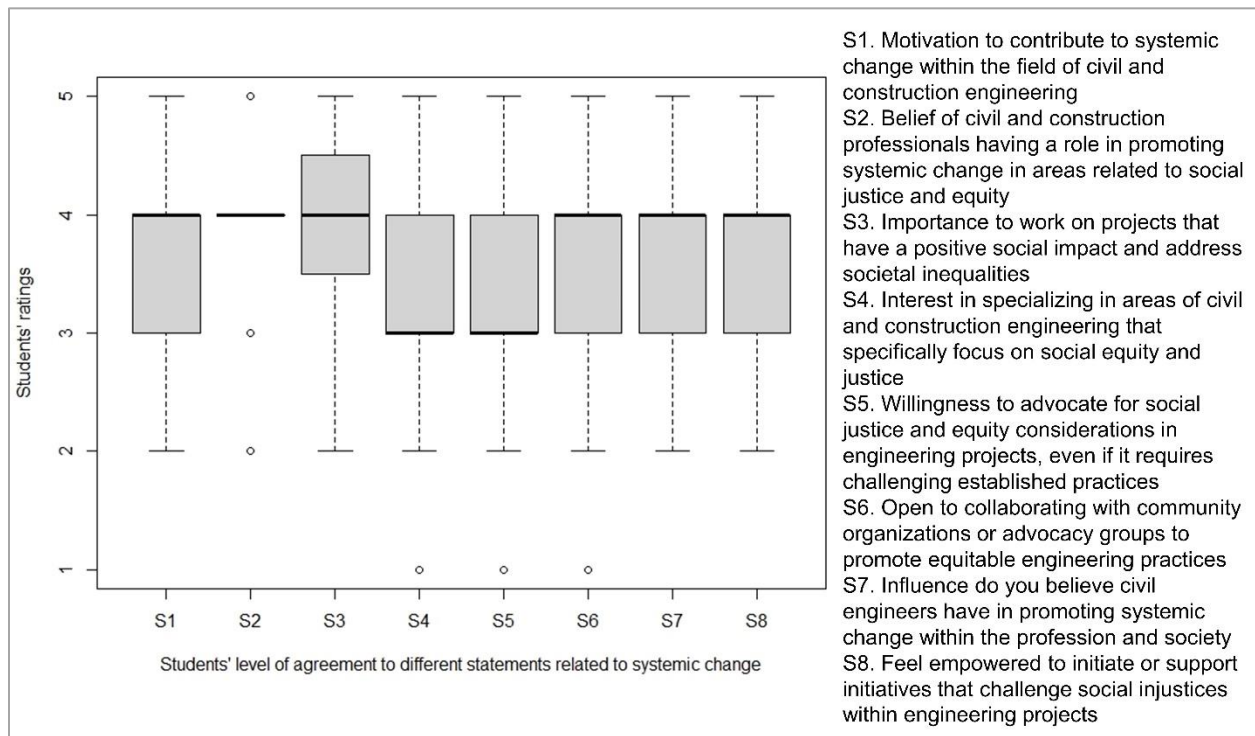


Figure 4. Boxplots demonstrating students' responses related to their interest in working toward systemic change (1 = None at all, 2 = Slightly, 3 = Moderately, 4 = Greatly, 5 = Significantly)

Limitations and Future Works

This research acknowledges some limitations. Participants may provide responses based on self-assessment, which can be influenced by personal perspectives, experiences, and perceptions.

Additionally, convenience sampling may impose some restrictions on how broadly the results can be applied because it does not guarantee that the sample is representative of the total population but rather only includes those who were most easily accessible or available to participate in the study. Nonetheless, this study provides a novel insight into marginalized AEC students' perceptions of equity in the infrastructure resilience context and can be used as a foundation for future studies. Future research could consider surveying other minority engineering students from other majors to provide a more comprehensive perspective on the state of the awareness of equitable and resilient infrastructure. Future work can also consider incorporating supplementary inquiries such as interviewing marginalized students which will help to delve deeper into the reasons behind the observed perceptions obtained in this research.

Conclusion

Infrastructure systems and buildings need to be both functional and resistant to hazards for a community to thrive. It is becoming critical for universities to be active in sustainable and resilient education as it empowers students to contribute to developing sustainable and resilient infrastructure projects. Likewise, it is critical to enhance the awareness of future marginalized AEC professionals about equity while developing such projects. Such knowledge and awareness can allow them to gain the ability to offer valuable feedback to project teams and contribute to decision-making processes while embracing equity. This study delivers value to both the industry and academic community by highlighting the need to educate marginalized students to fortify the foundation of infrastructure equity knowledge, particularly in the context of disaster resilience. The results suggest that the students possess some degree of awareness of equitable and resilient infrastructure. Additionally, students are willing to work towards systemic change. Future recommendations may include that AEC curricula should put a higher emphasis on teaching equitable sustainability and resilient topics to instigate enhanced awareness among students. In order to promote such awareness, universities can focus on creating and implementing sustainable, equitable, and resilient infrastructure-related courses and ensure that marginalized students are well-equipped to address societal inequalities within the domain of sustainable and resilient infrastructure.

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