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Integrating Diversity, Equity, and Inclusion into Civil Testing Materials Course: A Curriculum Intervention on Infrastructure and Social Justice

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Abstract

Incorporating Diversity, Equity, and Inclusion (DEI) concepts into technical curricula is essential for preparing future engineers to address historical and ongoing inequities in infrastructure development. This study explores a curriculum intervention in a Civil Testing Materials course, where students analyzed the societal impacts of 1960s highway construction on marginalized communities through a PowerPoint presentation assignment. The assignment, which examined real-world cases such as displacement caused by highway projects in Atlanta (I-85), Detroit (I-75), Syracuse (I-81), and New Orleans (I-10), aimed to enhance students' understanding of the intersection between engineering practices and social justice. Post-intervention findings revealed that 92% of students gained a substantial understanding of the historical injustices tied to infrastructure projects, with 38% reporting an extremely strong understanding. Additionally, 77% expressed confidence in applying DEI principles in future engineering projects, and 46% found the displacement of marginalized communities to be the most impactful aspect of the assignment. Students also highlighted increased ethical awareness, practical applications of community feedback, and a broader perspective on engineering's societal implications. This paper reflects on the course design and early outcomes of the intervention, demonstrating how historically grounded assignments can foster greater awareness of DEI considerations among engineering students. By equipping students with the skills to critically assess the societal implications of engineering decisions, the intervention lays the groundwork for creating inclusive urban environments. Future efforts should focus on institutional support and scaling such initiatives to promote a more inclusive engineering education.

Introduction

The construction of the U.S. interstate highway system—spanning nearly 41,000 miles—was a major engineering achievement of the 1960s. However, this period of infrastructure expansion exacerbated racial inequities across many American communities. Numerous highways were routed directly through vulnerable urban areas, predominantly Black neighborhoods, further entrenching segregation and displacing residents [1]. Civil engineers of the time often overlooked the social ramifications of these large-scale projects - sometimes unintentionally, but at other times deliberately. Historically, engineering education has primarily emphasized technical skills, fostering a disconnect between engineering practices and the social environments they influence [1]. Consequently, racial histories intertwined with civil engineering projects have rarely been included in traditional curricula. This omission risks perpetuating systemic inequities, as today's civil engineering graduates may unknowingly reinforce structural racism, missing critical opportunities to drive transformative change toward justice and equity.

Research conducted decades after these highways were built has revealed their detrimental effects on public health and community development. It is now crucial to evaluate whether remedial efforts initiated in the mid-2000s have achieved their intended goals. If significant issues persist, the question arises: to what extent do these challenges stem from a failure to acknowledge local histories and cultural contexts—both during the original projects of the 1960s and in subsequent efforts to mitigate their impact? Beyond highways, other initiatives from the 1960s to the 2010s, such as urban renewal programs, public housing policies, redlining practices, environmental injustices, and school segregation, have also contributed to racial disparities. Incorporating these historical inequities into civil engineering education is essential for cultivating a more comprehensive understanding of the profession's societal implications [2].

By examining cases like urban renewal, public housing, and environmental racism, students can gain insight into how past infrastructure decisions marginalized minority communities. This approach bridges technical engineering skills with ethical considerations, emphasizing the responsibility engineers hold to promote equity and justice. Embedding these discussions in civil engineering courses can help prepare future professionals to design infrastructure that addresses social inequities rather than perpetuating them.

Today presents an unprecedented opportunity to reshape civil engineering as a profession that prioritizes equity and social justice, thanks to two significant developments:

1. **U.S. Infrastructure Investment and Jobs Act (2021)**
   The passage of this historic $1.2 trillion legislation represents the largest infrastructure investment in U.S. history [3]. It prioritizes addressing the needs of marginalized communities and has created high demand for civil engineers, positioning the field for rapid growth.

2. **ABET DEI Pilot Criteria**
   For the first time, the Accreditation Board for Engineering and Technology (ABET) has introduced pilot criteria for integrating diversity, equity, and inclusion into engineering learning outcomes during the 2023–2024 accreditation cycle [4]. This initiative signals a potential shift in how engineering programs approach curriculum design to incorporate DEI principles.

Together, the surge in infrastructure investment and the ABET pilot criteria create a pivotal moment to reimagine civil engineering education. By embedding DEI concepts into the core technical curriculum, educators can better prepare students to address societal challenges and advance equity. These efforts have the potential to fundamentally transform the profession, leaving a lasting impact on future generations of civil engineers.

Methodology

This study aimed to explore the integration of Diversity, Equity, and Inclusion (DEI) concepts into civil engineering education through a historically grounded assignment focused on the societal impacts of infrastructure development. The methodology consisted of designing, implementing, and assessing a student assignment that examines the intersection of civil engineering practices, systemic inequities, and the long-term consequences of infrastructure decisions on marginalized communities.

Assignment Design

The assignment was developed to facilitate student understanding of the historical and social dimensions of civil engineering projects, with a specific focus on highway construction in the 1960s. The assignment incorporated the following elements:

a) **Contextual Background**: Students were provided with a historical overview of the U.S. interstate highway program, including its goals and the rationale for expansion into urban areas.

b) **Case Study Approach**: The students were divided into four groups and each group researched on a specific highway project (e.g., I-10 in New Orleans, I-81 in Syracuse, I-

85 in Atlanta, or I-75 in Detroit) to investigate in-depth. The case study framework required students to examine:

    - The demographic, economic, and cultural characteristics of the community before highway construction.
    - The planning and decision-making processes, including public engagement or resistance.
    - The immediate and long-term impacts of the project on the affected community.

c) **Critical Analysis and Reflection**: Students were instructed to analyze the disproportionate effects of these projects on low-income and marginalized communities, reflected on the lessons for contemporary civil engineering practices, and proposed frameworks for integrating DEI principles into modern infrastructure planning.

d) **Presentation Requirements**: Students were tasked with creating a 15-minute equivalent PowerPoint presentation to convey their findings. The assignment instructions emphasized clarity, critical thinking, and visual communication.

Implementation

The assignment was integrated into a civil engineering course focused on infrastructure development (Civil Materials Testing). Students were given two months to complete the assignment. To support their work, resources such as historical documents, planning reports, and academic articles were instructed. The instructor conducted preliminary briefing to introduce DEI concepts and guide students in selecting case studies and developing their analysis.

The rationale of selecting the civil materials testing course (the typical topics covered are the traditional civil engineering materials i.e. cement, concrete, aggregates etc.) was based on multiple considerations. First and foremost, this course is mandatory, foundational subject in the curriculum, introducing students to the materials that form the backbone of infrastructure development. Another suitable option could be the highway planning course which is elective for transportation emphasis students. In addition, Civil Material Testing is a stepping stone for students to innovate in material science. By embedding DEI concepts into the course, students are encouraged to think about creating sustainable, cost-effective materials that address equity issues. For instance, modern materials can be designed to minimize environmental harm in disadvantaged areas or to reduce costs in resource-limited communities. Similar initiatives were undertaken by Casper et al. (2021) [5] where the authors introduced new assignments in the Civil Engineering Materials course where students completed pre-class readings about a regional highway reconstruction project, including articles about neighborhood opposition to the project, and participated in an in-class discussion. Finally, the instructor teaches a range of courses at the institution, with civil materials testing being the most closely aligned course for incorporating social justice themes in infrastructure.

Evaluation Criteria

Student presentations were evaluated using a comprehensive rubric that emphasized both technical and critical dimensions of the assignment:

- **Content (40%)**: Depth of research on historical context, community impact analysis, and relevance to DEI.

- **Clarity and Organization (20%)**: Logical structure, clear explanations, and smooth transitions between slides.
- **Visual Design (15%)**: Effective use of maps, photos, and data visualization.
- **Critical Thinking and Reflection (15%)**: Insightful reflections on historical lessons and proposals for inclusive infrastructure practices.
- **Presentation Delivery (10%)**: Engagement, clarity, and adherence to time limits.

Data Collection and Analysis

The data collected from this assignment included student presentations, reflective comments, and evaluation on the presentation topic. These artifacts were analyzed to assess the effectiveness of the assignment in achieving the following objectives:

- Increasing student understanding of systemic inequities in civil engineering.
- Encouraging critical reflection on the role of DEI in infrastructure planning.
- Promoting creative and inclusive problem-solving in engineering practice.

Results and Discussion

After the presentation on the topic, the students were asked to participate in a survey to express their understanding of the topic. There were five multiple choice questions and one open ended question to analyze the perception of the students. The questions were designed to capture the understanding of historical context, incorporation of marginalized communities' inconvenience, concept of infrastructure equity, application of DEI in future projects. Moreover, the students expressed their qualitative views on the topic in the open-ended question. The following paragraphs describe the findings from the survey.

Understanding the historical context

These results suggest that most students (92%) felt they gained a substantial understanding of historical injustices associated with infrastructure projects (Figure 1a). Among 92%, 38% of the students reported extremely well understanding while 54% reported it as somewhat well. The remaining 8% of the students remained neutral on this topic. This indicates that the intervention effectively highlighted the social dimensions of engineering practices, which are often overlooked in traditional engineering education.

Similar initiatives by Casper et al. (2021) revealed 60% of the students of the intervention course reported of understanding the society-engineering interaction [5]. The authors mentioned that students addressed the social impact of engineering in various ways, though their discussions primarily centered on the relevance of community and society to engineering. Recognizing these injustices is not merely about understanding the past; it serves as a foundation for preventing similar inequities in future projects. Moreover, understanding historical injustices helps students appreciate the interconnectedness of technical and social dimensions in engineering. As noted by Riley (2008) [6], infrastructure projects often have long-term implications for community health, economic stability, and social cohesion. By learning from past mistakes, future engineers can develop innovative solutions that prioritize community needs and minimize adverse impacts.

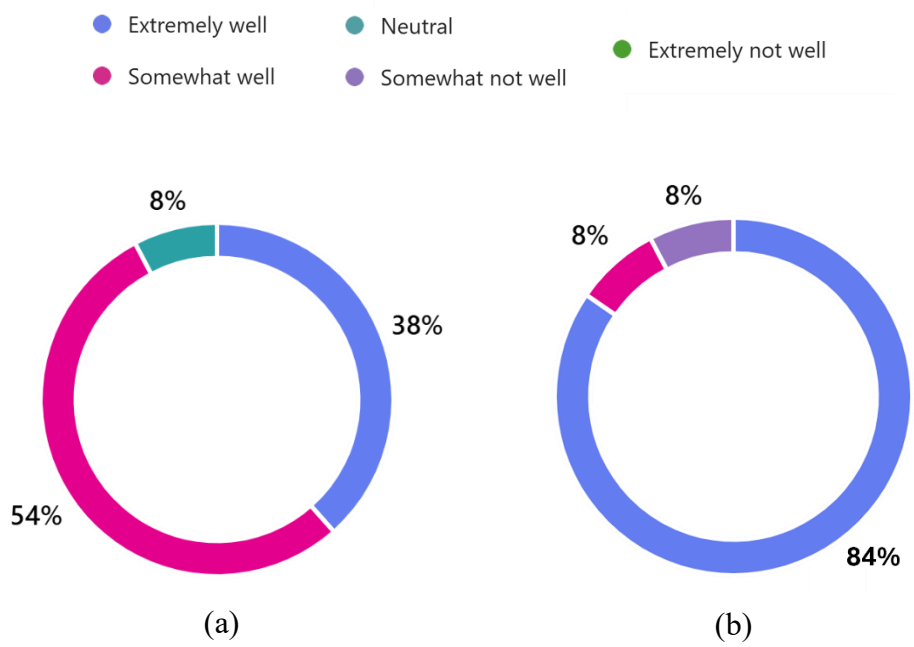

Figure 1: (a) Understanding the historical context, (b) Importance of considerations for marginalized communities

Importance of considerations for marginalized communities

Students were asked to rate the importance of considering the impacts of infrastructure projects on marginalized communities. A combined 92% of students regarded this consideration as extremely and somewhat well, demonstrating a heightened awareness of ethical responsibilities in engineering design. The remaining 8% of the students mentioned they did not understand the topic well (Figure 1b). This percentage of students can be linked to the 8% students who remained neutral when asked about the understanding of the topic in the previous section. These students may not have been fully engaged with the material due to a lack of interest, insufficient motivation, or distractions during the lesson. In addition, the topic of marginalized communities and systemic inequities in infrastructure projects is multifaceted and may have been challenging for some students to understand fully, especially if they lack experience analyzing social dimensions in technical contexts. Moreover, some students might have had preconceived notions or biases that prevented them from appreciating the significance of marginalized communities' experiences in the case study.

Likelihood of DEI principles in future engineering projects

After receiving the perception of the students on the topic, they were asked about the likelihood of incorporating DEI principles in future engineering projects as professional engineers. In addition, they were also questioned about their familiarity of equity concept in civil engineering projects prior to this intervention. 77% of the students reported that they were somewhat familiar with the concept while the remaining 23% mentioned unfamiliarity with the concept (Figure 1c). It must be mentioned that the institution is under the XYZ state university system which mandated two general education courses on DEI concepts from Fall 2023 semester. As such, the

77% mark reflects a considerable number of students' familiarity with the topic. However, in the mandatory DEI courses, the students learn about generic principles not necessarily their connection to engineering projects. While exact national benchmarks for familiarity with equity topics in civil engineering are not well-documented, surveys in related areas often show lower levels of awareness. For example, a study by LaFave et al. (2015) [7] found that engineering students nationwide reported limited exposure to social and ethical aspects of their field. However, it also highlights an opportunity to further engage the remaining 23% of students, ensuring that all graduates leave with a foundational understanding of equity in engineering practices.

While responding to the likelihood of incorporating DEI in future engineering projects, 77% of the students reported very likely to do that. 15% of the students are somewhat confident to incorporate it while the remaining 8% mentioned their unwillingness to do so (Figure 2b). This 8% can be linked to the same percentage on the previous sections where they remained neutral and reported not understanding the impact on marginalized communities. The largest pie of 77% can be linked to the same percentage who reported familiarity with the equity topic. In a similar study, Casper et al. (2021) reported that 56% of the respondents were positive about the topic which brought real world problems to the classroom [5]. However, as this kind of intervention is new and challenging in nature, 61% of the students warranted for more guidance and organization for the topic. Judge (2021) also implemented similar ideas in the classroom where the author focused on receiving more qualitative feedback rather quantitative. In addition, the study attempted to link the student outcomes with the ABET student outcomes of improving ability to 'recognize ethical and professional responsibilities in engineering situations and make informed judgments' and encouraged to 'consider the impact of engineering solutions in global, economic, environmental, and societal contexts'. The instructor received ratings from 3 to 5 on a scale of 1 to 5 where 1 was 'strongly disagree' and 5 was 'strongly agree' [8].

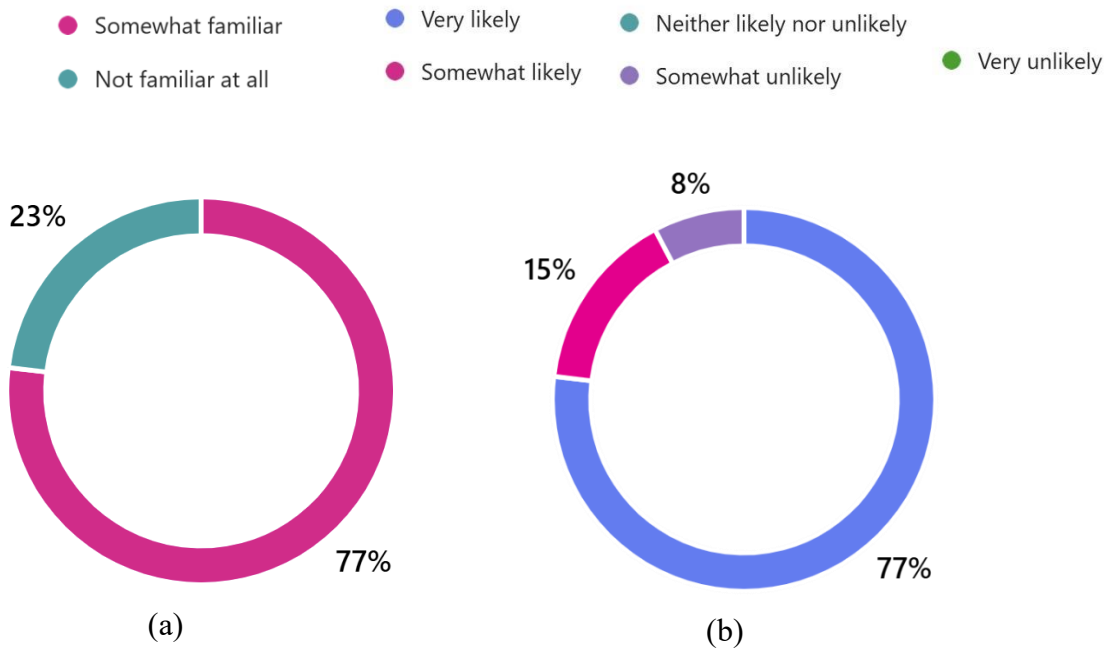

Figure 2: (a) Familiarity with the equity concept, (b) Likelihood of DEI principles inclusion

Most impactful component of the assignment

Finally, the students were asked to identify the most impactful component of the assignment by selecting one of four provided options. As illustrated in Figure 3, 46% of the students reported that the displacement of marginalized communities was the most impactful aspect they encountered during the assignment. This response highlights the emotional and intellectual engagement of students with the social injustices tied to historical infrastructure projects, suggesting that these real-world implications resonate strongly with their understanding of engineering's societal impacts.

An equal 46% of students identified discussions of inclusive solutions as the most pressing component. This indicates a significant level of interest in exploring how engineering practices can evolve to prioritize equity and inclusivity. These discussions may have empowered students to think beyond traditional technical problem-solving and engage critically with the ethical dimensions of their future profession. It also reflects a growing recognition among students of the importance of designing infrastructure that benefits all communities equitably.

Interestingly, only 8% of students mentioned analyzing historical case studies as the most impactful element. While this percentage is relatively small, it demonstrates that some students value a deep dive into historical contexts to inform their understanding of present and future engineering practices. Case studies can offer a powerful lens for examining the consequences of past decisions, and their impact might have been perceived as less direct compared to the displacement or inclusive solution discussions.

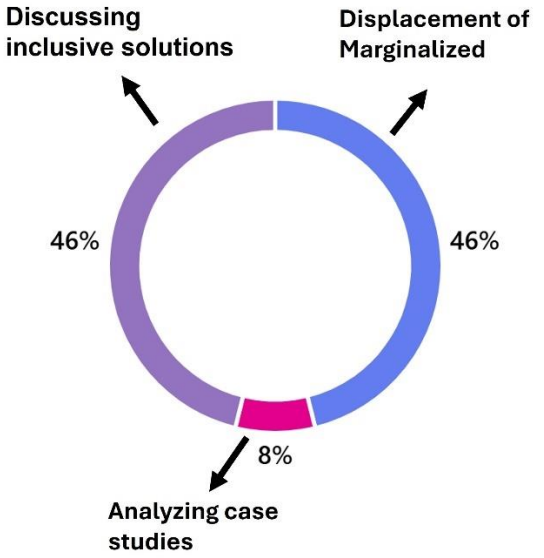

Figure 3: Most impactful component of the assignment

Surprisingly, none of the students selected reflection on modern engineering practices as the most impactful component. This result could suggest that students found historical and theoretical discussions more compelling or that the assignment's framing emphasized past events and future possibilities over current practices. It might also reflect a perception among students that modern engineering practices still struggle to address equity effectively, leaving them less inspired to engage deeply with this aspect.

Qualitative feedback

In addition to the multiple-choice questions, students also responded to one open end question to share their thoughts on the new type of assignment. The responses of the students can be divided into four categories as described below.

- **Heightened awareness:** Many students noted an increased understanding of how infrastructure projects can negatively impact communities if social considerations are overlooked. For example, one student remarked, *"This assignment has highlighted the necessity for civil engineers to understand the communities in which they work, and how their work impacts these communities."*
- **Ethical reflection:** Students frequently expressed a newfound appreciation for the ethical dimensions of engineering decisions. One response emphasized, *"It is important for engineers to take into account the environments that we alter, and the people affected by them. Good design helps; bad design hurts."*
- **Practical application:** Several participants highlighted the importance of integrating community feedback into project planning, with one stating, *"We need to ask not only the clients but also the people around the area that is being involved in the development of the project."*
- **Broader perspective:** Many students acknowledged the broader implications of engineering beyond technical execution. One response noted, *"This assignment changed my understanding a lot. Instead of looking at all the good aspects of the proposed project, it showed me that there are a lot of bad aspects of new construction."*

Self-reflection of the instructor

Integrating DEI concepts into the current engineering curriculum presents significant challenges, stemming from factors such as institutional strategies and departmental cultures [9]. A key barrier is the traditional emphasis on developing specific learning outcomes rather than fostering holistic, inclusive identities. Research has shown that, while some instructors recognize the importance of incorporating diverse content into their courses, departmental culture often prevents them from putting these ideas into practice [10, 11]. Furthermore, the lack of established best practices and the challenge of introducing social topics into engineering courses—where the focus is often on numerical precision - make it difficult for educators to design activities that avoid triggering negative reactions [12]. As a result, linking diversity and inclusion content directly to technical material may provide a practical and effective way to make DEI concepts more accessible and relevant for both instructors and students.

The survey results and qualitative feedback from this course intervention demonstrate the efficacy of incorporating DEI principles into civil engineering education. By exploring historical and modern examples, students developed a more comprehensive understanding of the social responsibilities inherent in their profession. The high percentage of students expressing a likelihood to apply these principles in their future work suggests that this intervention successfully instilled long-term values. However, the findings also highlight the need for continued emphasis on equity and inclusion throughout the engineering curriculum. While the intervention was effective in raising awareness, this was a standalone initiative – to make the

effort successful, DEI and social justice discussions should be present consistently in other technical courses also.

To successfully implement similar initiatives at other institutions, departmental culture and collegiality are identified as critical factors for progress. Based on experience in this study, it is recommended that instructors initially approach this topic as a pilot study to build confidence and assess student interest. Furthermore, integrating the topic throughout the course, rather than limiting it to a single assignment or guest lecture, is advised to avoid presenting it as a standalone activity, which may dilute its impact. To enhance the effectiveness of such efforts, instructors could consider collaborating in small groups to co-implement the initiative across their respective courses. This approach aligns with previous research by Williams and Conyer (2016) [13], which highlights the effectiveness of faculty collaboration and group efforts when addressing sensitive topics in the classroom.

Limitations of the Study

The intervention was applied in the civil engineering materials course. As mentioned earlier, it was the closest course the instructor was able to intervene among the set of courses taught the instructor teaches at the program. The environmental aspects of the materials, i.e. how difference in use of materials affected the DEI aspect of these projects, was not covered in the course. The focus of the intervention was on the history of interstate development. As this was a pilot initiative, the instructor will attempt to include the environmental impact of the materials in the next offering of the course. The second limitation was the indirect assessment of the project. Being a pilot project in Fall 2024, the instructor collected the feedback via survey questionnaire. The instructor plans to conduct both direct and indirect assessments from next semester where the topic will be introduced as part of the lecture materials. Since this is a newly introduced topic in engineering, directly assessing knowledge of the DEI concept is essential to gauge the understanding of this concept.

Conclusions

This study demonstrates the effectiveness of integrating Diversity, Equity, and Inclusion (DEI) and social justice concepts into a Civil Testing Materials course through a historically grounded assignment. Key findings from the intervention are summarized below:

- 92% of students reported gaining a substantial understanding of the historical injustices tied to infrastructure projects, with 38% indicating an extremely strong understanding and 54% somewhat strong.
- 92% of students recognized the importance of considering the impacts of infrastructure projects on marginalized communities, while 8% struggled with this concept, potentially due to insufficient
- 77% of students reported prior familiarity with equity in civil engineering, reflecting a relatively high baseline due to institutional DEI courses, although these courses often lacked a direct connection to engineering practice.
- 77% of students expressed confidence in applying DEI principles in future engineering projects, and 15% showed some willingness, while 8% expressed hesitancy.

- 46% of students found the displacement of marginalized communities to be the most impactful aspect of the assignment. Another 46% emphasized the importance of discussions on inclusive solutions. 8% valued the analysis of historical case studies, while none selected reflection on modern engineering practices.
- Students highlighted increased ethical awareness, practical applications of community feedback, and a broader perspective on engineering's societal implications.

This intervention underscores the importance of integrating DEI concepts into technical curricula. By addressing systemic inequities and encouraging critical reflection, the assignment equips students with the skills and perspectives needed to design equitable infrastructure. Future efforts should prioritize institutional support, departmental collaboration, and faculty training to scale such initiatives and foster a more inclusive engineering education.

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