Student Perceptions of Artificial Intelligence and Relevance for Professional Preparation in Civil Engineering

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Abstract

Artificial intelligence (AI) is no longer an emerging technology, and many industries are integrating AI tools into their workflows. In civil engineering, machine learning and optimization methods are being developed and applied to assist with decision-making in design, development, evaluation, maintenance, and operation of infrastructure systems. While it is difficult to gauge the progression of AI technology within the industry, it seems likely that generative AI is in use. Given the ongoing integration of AI methods and tools in civil engineering, it is important to consider how civil engineering students view AI, how they interact with AI tools as part of their education, and how prepared they are to work with AI in the profession. Using survey data, we assessed civil engineering students' understanding of AI and how they are experiencing AI in their education. The results indicate that approximately one-third of students surveyed use AI tools. On the survey, students indicated uncertainty regarding fairness and safety issues of using AI in education and in the profession. Overall, the survey results indicate that students would benefit from the introduction of AI applications in civil engineering and guidance on the ethical issues of AI use. In addition to reviewing the survey results, we recommend strategies for integrating AI into existing courses using the following examples: infrastructure monitoring, writing assignments, and engineering ethics curriculum. This study provides valuable information on how students view AI and provides a framework for instruction of AI in existing civil engineering courses. AI holds great promise for civil engineering, but caution is necessary when applying this technology so that it is incorporated in a way that preserves the reliability and reputation of the profession.

Introduction

The use of generative artificial intelligence (referred to herein as AI) has become widespread. Although the concept of AI is not new—it has been around since at least the 1950s—AI usage has increased recently due to advances in computing, algorithm development, and data availability. The increased interest in AI is apparent in scientific literature. A search of the SCOPUS database using the query ["artificial intelligence" OR AI] indicates that annual publications on AI have increased by almost an order of magnitude from 2004 to 2023. The release of ChatGPT by OpenAI in November 2022 and then Google's release of Bard in March 2023, along with other similar chatbots, has resulted in more direct access to AI tools. Despite the accessibility of tools such as ChatGPT, the use of generative AI is variable among different populations and industries [1, 2].

The influence of AI has extended to civil engineering although adoption into professional practice appears cautiously slow [3, 4]. Available AI models are well-suited for civil engineering applications [3]. In scientific literature, there are many examples of AI and machine learning: models are being used in research projects and their applications span a wide range of topics from environmental, construction, geotechnical, structural, transportation, to water resources engineering [5]. Demonstrated uses of AI in professional civil engineering practice are not as prevalent. The slow rate of adoption may be influenced by the conservative nature of civil engineering stemming from its direct charge of protecting human health and safety. Also,

adoption of AI into civil engineering education is currently limited, so future civil engineers lack training and expertise in its application [3]. Additionally, AI models typically lack transparency, which is counter to civil engineering design methods that rely on codes and formulations [3]. Transparency in civil engineering design enables internal review—including review by licensed engineers overseeing the work—and it allows for external review by owners, regulators, and other stakeholders. A transparent design makes it possible to verify compliance with codes and standards, and to evaluate designs in the context of project needs.

The emergence of AI has profoundly impacted students and educators, and the extent to which AI damages or enhances learning outcomes is under consideration [6, 7] College students are using AI tools at high rates: A study completed in the fall of 2023 estimates that more than 50% of college students are using AI [8]. The emergence of AI in education has resulted in variable responses and strategies among educators. Some faculty have completely banned AI use in their courses, while others embrace AI as a new learning tool [6].

The emergence of AI is prompting civil engineering faculty to reflect on whether we should adjust our educational approaches. For civil engineering faculty at accredited institutions, we must look to ABET for guidance [9]. While the current guidelines do not address specific tools and methodologies, it seems reasonable to expect that AI may become part of standard practice used to solve engineering problems (addressing ABET Student Outcome 1). The application of AI may also be useful in developing engineering designs that are holistic and meet a variety of public needs (addressing ABET Student Outcome 2). Communication skills are essential for engineers (ABET Student Outcome 3), so educational approaches may need to shift to ensure students are still developing communication skills given the accessibility of AI tools. Importantly, students need the "ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments" (ABET Student Outcome 4), and this requirement extends to new technology such as AI. The development of judgement seems especially relevant because of the unreliable track-record of AI and the need for oversight.

As we move forward in educating future civil engineers, we must come to terms with the reality of AI, the impact it has on education, and the impact that it has on the profession. Since AI is still being introduced into civil engineering practice, it is important for educators to be forward-thinkers and anticipate the types of experiences and knowledge that future civil engineers need.

Study Objectives and Research Questions

The broader study objective is to consider whether the development of AI changes our approach to civil engineering education. In addressing this larger issue, we seek to better understand our students' experiences with AI and their viewpoints. We also consider how AI could be introduced into existing civil engineering coursework. In our study, we address these questions:

1. What are civil engineering students' views on AI?
2. How are civil engineering students learning about and experiencing AI in their education?
3. Do civil engineering students understand the relevance of AI in their discipline?
4. Do civil engineering students understand the ethical concerns and professional responsibilities regarding AI?

Survey Design and Data Collection

The assessment instrument used in this study was an anonymous survey distributed using Microsoft Forms. There were 11 questions on the survey: five had yes/no responses, three allowed students to type in responses, and two consisted of multiple statements with Likert scale responses. The final question was about class standing. We chose not to include demographic questions in the survey because our civil engineering program student population is relatively small (<100), and collection of such data could have allowed for identification of survey participants. Our Institutional Review Board (IRB) approved the survey prior to its distribution.

Students completed the survey on their own time (outside of class). Survey participants were recruited by emailing the authors' advisees and by advertising the study in the following classes being taught by the authors: senior project, steel design, and construction engineering.

We advertised the study to civil engineering students but could not limit responses because of the anonymous nature of the survey. For example, the construction engineering class had 27 students and four of the students were engineering management majors with a concentration in civil engineering. We felt that the educational background and career interests of these students were sufficiently aligned with civil engineering majors, which warranted their inclusion in the study. Most of the students targeted were undergraduates; however, there were a limited number of graduate students and blended undergraduate/graduate students.

Survey Results

The study yielded 37 responses. Most of the survey participants were seniors (65%) but we also had responses from freshmen (5%), sophomores (3%), juniors (16%), and graduate students (11%). Responses to open-ended questions were coded by the authors. The "likert" package in R was used to visualize the survey responses [10].

Our first objective in conducting the survey was to better understand our civil engineering students' understanding of AI. We found that most students (92%) were confident in their understanding of AI although fewer students (81%) were confident in their understanding of the ethical concerns of AI (Fig. 1).

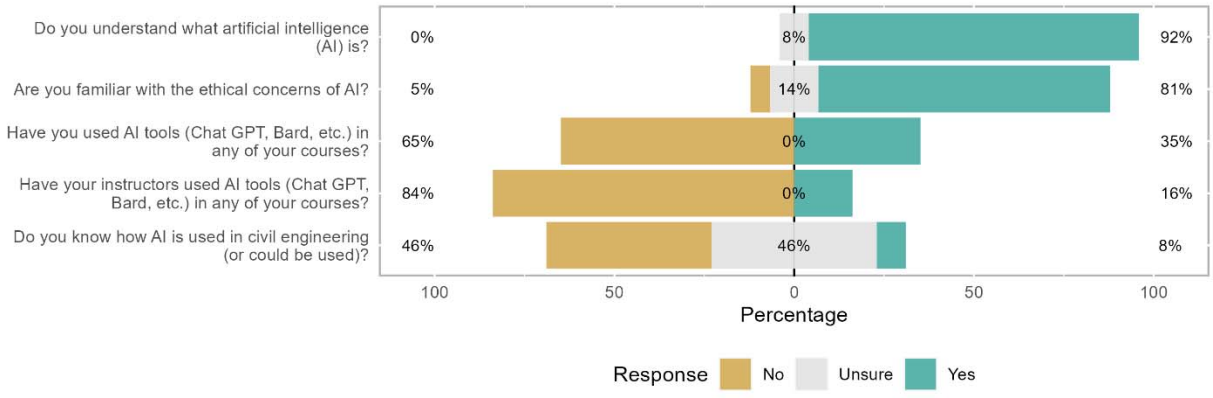

Fig. 1. Student responses to survey questions regarding AI and coursework.

Our second objective in conducting the survey was to better understand how civil engineering students are learning about and experiencing AI in their education. Almost two-thirds of students surveyed (65%) reported never using AI tools on assignments (Fig. 1). Of the students that have used AI on assignments, most reported using AI to research a topic (69%). Less frequent uses included using AI for writing code, solving problems, and getting assistance with writing. Instructor use of AI in courses was even less frequent than student use—only 16% of students reported their instructors using AI (Fig. 1). Note that the third and fourth questions in Fig. 1 did not have an "Unsure" response option.

Student views of AI indicate their concerns with using AI in coursework (Fig. 2). Most students (at least 70%) felt that using AI without acknowledgement is unethical and constitutes cheating if the instructor does not permit it. Most students (53%) saw the value of learning about AI to be ready for the workplace; however, enthusiasm for AI in education was more limited with only 46% of students believing that AI could improve learning and only 30% believing AI should be introduced. The use of AI by instructors received mixed responses—notably, almost half of respondents (44%) were neutral in whether instructors should use AI for teaching, assessment, and grading. Similarly, most students (59% or more) did not have an opinion about whether AI in educational settings was fair or safe. Almost half of respondents (49%) did not think that AI could be trusted for academic purposes. Overall, students were neutral on many of the statements contained in Fig. 2—neutral response rates ranged from 19% to 63%. Students also had the option not to respond to this question if they were unsure. Response rates for all statements in Fig. 2 were above 90%.

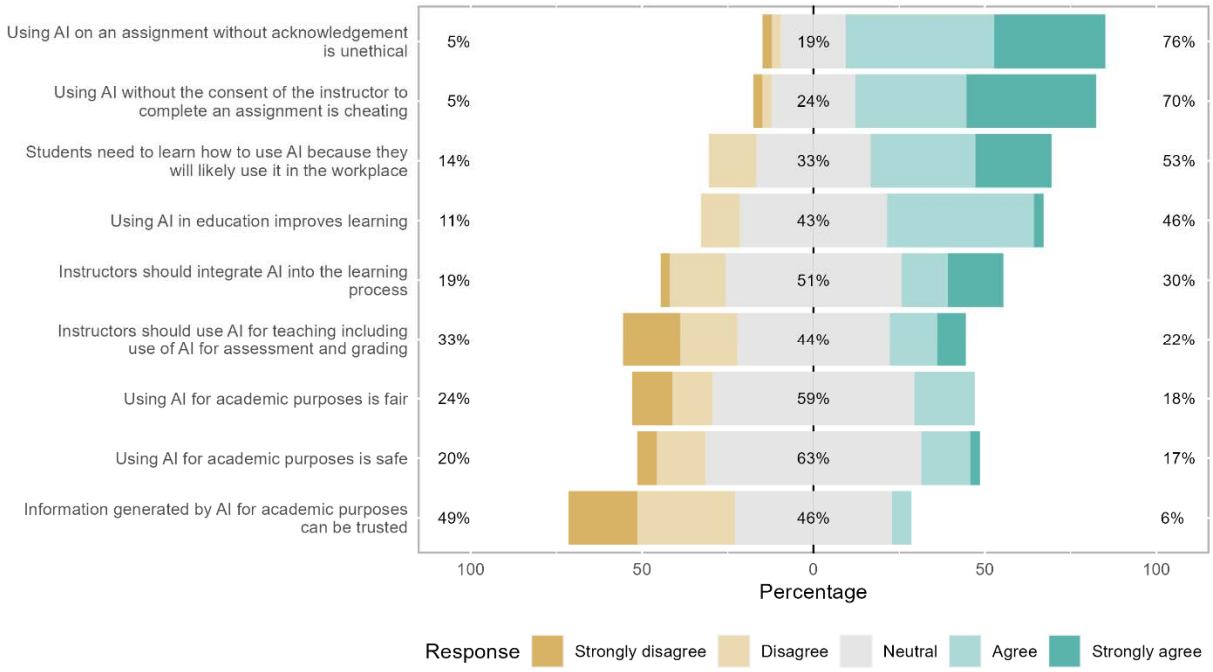

Fig. 2. Student responses to survey questions regarding perceptions of AI in education.

The third objective in conducting our survey was to gain information on whether civil engineering students understand the relevance of AI in civil engineering. Again, most students (65-70%) recognized ethical issues about having permission to use AI on projects and to use AI

only with acknowledgment (Fig. 3). Only half (51%) of students thought that civil engineers need to know how to use AI. Even fewer students (39%) thought that civil engineers should be using AI professionally. Accordingly, only 26% of students thought that AI would improve quality on civil engineering projects. Similar to the results in Fig.2, there were many neutral responses in Fig. 3 (ranging from 19% to 47%). Students also had the option not to respond to this question if they were unsure. Response rates for all statements in Fig. 3 were above 90% except for the questions about whether using AI for civil engineering was safe (11% of students were unsure) and whether using AI for civil engineering was fair (14% of students were unsure).

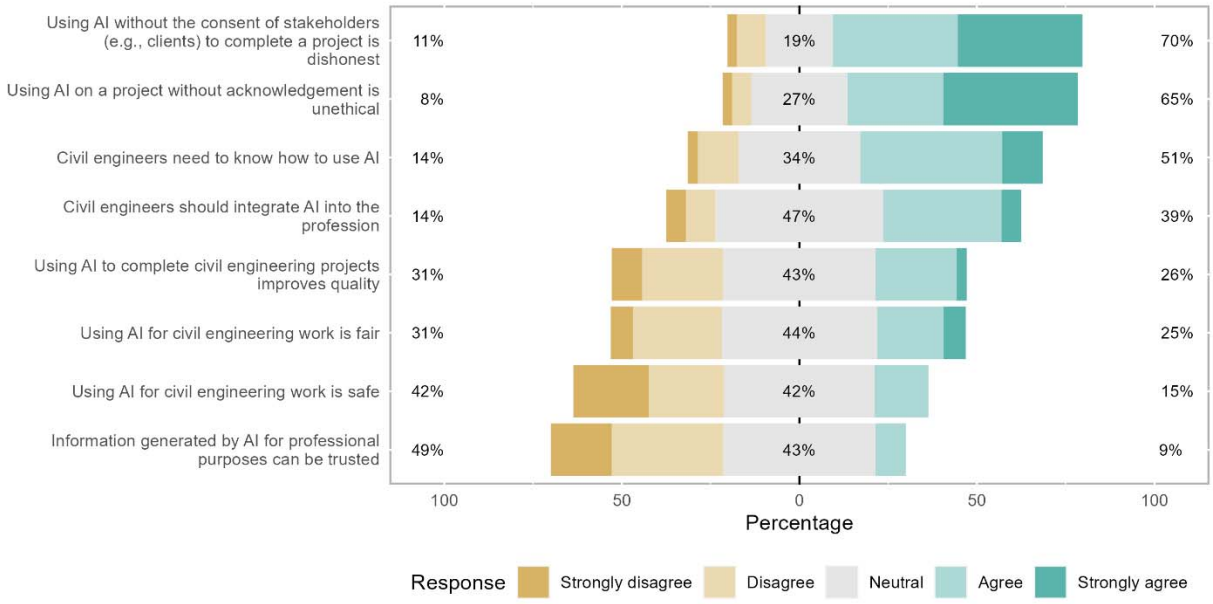

Fig. 3. Student responses to survey questions regarding perceptions of AI in civil engineering.

Responses to an open-ended question provided more insight on how students view AI being used in civil engineering. Despite 46% of students reporting limited knowledge on AI use in civil engineering (Fig. 1), they were able to list several ideas on how AI could be implemented. The most common suggestions were regarding the use of AI for calculations and design (including modeling), 43% and 41% of students included these ideas in their responses, respectively. Less frequent ideas for incorporating AI into civil engineering consisted of using AI for learning, drafting, building information modeling (BIM), editing videos, creating presentation slides, planning cities, writing code, collecting data, analyzing data in real-time, doing research, communicating, auto-populating bid forms, assessing risks, tracking construction progress, and finding design standards.

The final objective in conducting our survey was to gather information on civil engineering students' understanding of the ethical concerns and professional responsibilities of using AI. When asked about the ethical concerns of AI in an open-ended question, the most common responses (49%) were related to potential inaccuracies in AI output including output containing non-credible statements, mistakes, and outdated information. Other common responses included taking credit for the work of others (22%) and development of an over-reliance on AI and the subsequent lack of critical thinking that may result (19%). Other less frequent responses were

about honesty issues, doing work outside of a person's area of expertise, job loss, privacy issues, bias and discrimination, decrease in human creativity, and lack of transparency.

Discussion of Survey Results

Based on the survey responses, it appears that students are not consistently using AI in their education, or they are not accurately reporting AI use in our survey. The reported AI use by our student participants (35%) was lower than in a larger and broader study of college students where AI use was estimated to be over 50% [8]. It could be that civil engineering students are using AI at lower rates than the general college population. The use of AI in engineering education is likely limited by the prevalence of exams as assessment instruments and the use of assignments that are more difficult to generate using AI (e.g., design projects, experimental data analysis). Also, the population of students that we surveyed is relatively small (n = 37) and representative of an undergraduate teaching focused institution; there is likely a need to engage civil engineering students from a larger spectrum of institutions.

The limited use of AI by the students surveyed is likely influenced by the limited use of AI by their instructors and the policies that those instructors set in their courses. Many faculty are banning or strictly limiting the use of AI for assignments. Some faculty have embraced AI use and encourage it in their courses, but our survey respondents report limited AI use by instructors (only 16% reported having instructors use AI). Such limited use has benefits in developing student skills in critical thinking and creativity using traditional learning methods (e.g., essays). However, not using AI in coursework suggests that our graduates could potentially lack experience with AI. Distrust of AI in educational settings may also cause students to use AI in an unethical manner (e.g., without acknowledgment). Our study results may be limited by the profiles of the participants. Most of the participants were seniors and it is possible that freshmen and sophomores have had more experience with AI in their coursework. Many AI tools were not available when the seniors entered college.

While students were confident in their understanding of AI (Fig. 1), including ethical issues, we should probably challenge those assumptions in our classrooms to ensure that this confidence is well-placed. The use of AI in engineering is nuanced and requires training [11, 12]. Additionally, the responses to the open-ended question about ethics were not as strong and consistent as we might like. For example, privacy issues were only mentioned in 11% of the open-ended responses. Students recognized that consent to use AI and acknowledgment of AI use were important ethical issues. However, many students expressed uncertainty or a neutral stance about the fairness and safety of AI in both educational and professional settings.

Overall, the students surveyed were cautious about AI in educational and professional settings. The lack of certainty in many of the responses (Fig. 2 and 3) suggests that students require increased familiarity with AI applications and a better understanding of the corresponding ethical issues. If students were aware of opportunities for AI in civil engineering, they may have more buy-in for the technical skills (e.g., data analysis and computational skills) to be performed with AI in the future.

AI in the Civil Engineering Curriculum

Based on the survey results, we were motivated to investigate strategies for integrating AI into civil engineering education. While this integration could be done using new elective courses on AI and civil engineering (see [11]), we were interested in relevant topics that could incorporated into existing coursework. Our assumption is that the technical details of using AI would be covered in other courses (e.g., data science). Here, we were interested in demonstrating applications, providing opportunities to interact with and use AI efficiently, and providing clarity around the ethical issues of AI.

AI in the curriculum: Infrastructure monitoring

As civil infrastructure systems age there is an increasing need for methods and tools that allow owners to efficiently monitor and maintain these systems over time [13]. In addition to aging, considerations for changes in demand, climate change, sustainability, and available resources also influence the need for rehabilitation or new construction of infrastructure systems. Monitoring of a civil infrastructure system typically involves: 1) Sensor placement and data acquisition; 2) Condition assessment – identify, locate, and quantify severity of system condition; and 3) Decision making – monitor, repair, replace, or supplement the system. The application of AI in civil engineering emphasizes the development of methods and tools that automate data analysis and decision-making processes to plan appropriate interventions and/or construct new facilities [14-16]. Below we provide a brief overview of some topics where AI is being integrated as part of infrastructure systems monitoring. These topics are applicable across multiple technical areas within civil engineering education.

Construction management

AI is being applied to automate data collection and analysis, including the collection of images and video to document construction progress [17]. The use of drones and distributed sensors is integrated into these plans for enhanced data collection. AI tools are especially beneficial for addressing complex projects that have uncertainty; these tools can be applied to study schedule impacts [18]. Zhang et al. [4] presents an example of using AI with sensors to monitor construction worker health and safety. Plans to integrate AI in construction management are often motivated by the desire to increase productivity and manage risks [17].

Water resources management

AI tools are being developed to manage different aspects of water and wastewater infrastructure that includes supply, storage, distribution, collection, and treatment systems [15]. For example, Secci et al. [19] used AI tools to simulate groundwater under a range of climate scenarios while Zhang [20] used AI tools to operate reservoirs for efficient water storage and delivery. Another area where AI is being applied is in monitoring and optimization of water treatment facilities to manage simultaneous goals such as providing adequate disinfection while minimizing disinfection by-products [21].

Transportation management

AI tools are being used in a range of applications including structural health monitoring and traffic monitoring. In structural health monitoring a characteristic of the structure is monitored (e.g. deflection, stiffness, cracks, etc.) to assess the condition of the structure, and AI is used to identify patterns in the data and determine structure usability [22]. Applications in traffic

monitoring include the use of machine learning models for optimizing traffic flow, forecasting accidents, and advancing intelligent infrastructure [15].

AI in the curriculum: Writing assignments

As noted above, the use of generative AI is rapidly evolving and has several effective functions within various technical industries, further affirming its roots into the societal framework. While several views on AI's legitimacy and disruptive nature have caused widespread phobia within the academic and professional sectors, it is necessary to understand and question the tool rather than dismiss its potential altogether. Today's students are at an advantage in learning to positively work with AI to support their readiness for diverse workforce needs. However, without AI literacy or exposure to the most positive and efficacious ways for them to use AI, the tool could hinder their subject comprehension, and enable output dependency without regard for the research process. Generative AI tools such as ChatGPT are designed to output predictive information from 'real' sources but are not always accurate. So, it is essential to encourage and show users, in this case, students, how to develop better judgment that can support their problem-solving and research process.

Although Generative AI is still growing in terms of capability and information reception, software such as 'Inciteful.XYZ', a citation synthesizer that populates similar scholarship, 'Litmaps', a resource that finds scholarship, generates literature review templates and a host of other research features, and 'HeyPi', a brainstorming and mind mapping tool for pre-writing, all can offer students easier ways of navigating research topics. Yet, beyond these intricately disruptive design systems, lies the necessity for effective teaching and learning, within higher education, between faculty and students. According to Denice Lewis, a research librarian who critically addresses generative AI and large language models as tools for research support in her 'LIB290: Information Literacy for Engineering' course [13], the classroom is a breeding ground for AI comprehension and application literacy mirrored against classical do-it-yourself research and writing formats. Anna Mills [14] also makes note of the scrutiny required to question generative AI or LLM software and use them as supplemental tools to create a foundation of knowledge. One way to mitigate students' AI-abuse is through AI-proofing or regulating curriculum through detailed rubrics that clarify objectives and learning outcomes. If instructors find ways to demystify and decriminalize the use of AI through productive pre-writing and research strategies, students could feel more inclined to use those tools resourcefully as creative measures to inform their writing voice.

AI in the curriculum: Engineering ethics

Since ethics is required in ABET accredited engineering curricula, it is reasonable to expect that AI issues could be added to existing ethics instruction. Revision of the existing curriculum could occur by incorporating AI into the case studies reviewed or by having assignments that focus on AI issues. As an example, Orchard and Radke [23] used facial recognition technology to demonstrate AI ethics in an engineering course.

A first step in introducing students to AI ethics would be to introduce potential issues (Table 1). The list in Table 1 is general, not specific to engineering, and under revision as the conversation on AI develops.

Table 1. Potential AI ethics issues [24-27].

Lack of transparency and accountability (i.e., information origins are unclear)
Inaccurate information (e.g., fake images and videos, fabricated content)
Use of AI for malicious purposes (e.g., fraud)
Threats to national security (e.g., from leaked information)
Fairness issue (original creators are not acknowledged)
Honesty in how work was developed (i.e., taking credit for work done by AI)
Eroding trust of the public in information and institutions
Impact on human autonomy (e.g., algorithms may alter human behavior)
Impact on human creativity and originality
Bias and discrimination
Data privacy issues and possible surveillance uses
Users of AI may not develop or use skills in digital literacy, critical thinking, or writing
Workforce supporting AI may not be recognized or treated fairly (e.g., "ghost workers")
Autonomous AI may make decisions that violate "reasonable person" standards
Environmental impacts of AI infrastructure

AI in civil engineering can be evaluated by students using the ASCE Code of Ethics [28]. For example, Section 1.h instructs civil engineers to "consider the capabilities, limitations, and implications of current and emerging technologies when part of their work," which would be important when using AI since there are potential inaccuracies and limitations since the origins of information cannot always be traced. The prioritization of health and safety in the Code (Section 1.a) may be compromised by reliance on inaccurate or biased information and by practices that compromise privacy. Further, parts of the Code that reference fairness and non-discrimination (Section 1.f.), sustainable development (Section 2.a), and wise use of resources (Section 2.d) could potentially be compromised if AI is not used wisely. Finally, the requirement to uphold the honor of the profession (Section 3.a) should prevail in our use of AI.

AI can be introduced in ethics case studies that are focused on civil engineering (Table 2). Some of these case studies would appeal to a broad range of engineering students such as the privacy concerns over "smart city" data collection.

Table 2. Potential case studies for introducing AI ethics in civil engineering.

Lack of transparency and accountability in design (e.g., design references are unclear)
Fairness issue (e.g., original designers are not acknowledged)
Honesty in how designs were developed (i.e., taking credit for work done by AI)
AI introduces cyber security threats for critical infrastructure (e.g., dams)
AI may generate inaccurate information about civil infrastructure (e.g., drinking water)
AI used to allocate funds for transportation projects could lead to bias and discrimination
AI used to predict environmental violations could lead to bias and discrimination
Crowd-sourced air quality monitoring over-represents pollution in wealthier neighborhoods
Data collection in "smart city" paradigms threatens data privacy
Life cycle assessment quantify environmental impacts of AI infrastructure

While the application of ethics to AI in civil engineering shares many common elements with ethics in other engineering disciplines, there are aspects of civil engineering that make the corresponding AI ethics unique. One issue is that civil engineers have direct responsibility for human health and safety due to the critical infrastructure that we design, construct, and operate. There is a low tolerance for failure and a need to maintain trust. The possibility of inaccuracies in

AI and the inability to trace the sources of information make many AI uses problematic. When ethical and/or legal problems arise, accountability and the assignment of blame-responsibility is necessary and might be difficult where AI is used.

Conclusions

A survey of civil engineering students indicates that students are using AI in their coursework, which is consistent with national studies of college students. The students reported little use of AI by faculty in their courses. Although the survey respondents felt comfortable about their understanding of AI and the corresponding ethical issues, they communicated uncertainty or a neutral stance on several ethical and professional issues. The survey results indicate that students would benefit from exposure to civil engineering applications where AI is or could be used. They would also benefit from more directed and thoughtful writing instruction that incorporates AI use. Further, incorporation of AI ethics into existing engineering ethics curriculum is recommended and should be done with reference to a code of ethics. We anticipate future work in developing specific assignments that address AI applications in civil engineering. Such assignments would cover technical approaches, the use of AI as a writing tool, and coverage of the ethical concerns of AI. AI presents opportunities for civil engineering, but it must be incorporated in a manner that preserves human health and safety and the other expectations demanded of civil engineers. Given the rapid development of AI, building responsible AI use into civil engineering education is advised.

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