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Exploring the Promise and Potential Pitfalls of AI in Structural Engineering

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Abstract:

Artificial intelligence (AI) is a rapidly evolving technology seeing widespread use across education and engineering practice. For example, students are using AI to assist with learning, professors are using it to help develop learning activities, and structural engineers are using it to create conceptual designs for building projects. There are, however, concerns that come with the implementation of AI, such as the bias it can perpetuate through its training data or the ethics of using AI to supplement one's own writing and creation processes. As the ubiquity of AI has increased, professors are talking about it more in their courses, with new courses being developed to teach engineering students how to create and use AI models to solve technical problems. Professors must now provide students with documentation clearly outlining the acceptable use of generative AI tools in their courses. It is imperative that students be equipped to judge for themselves what is an appropriate use of AI as they go into engineering practice. This paper will provide an overview of how AI is being used in structural engineering practice and the concerns that students and engineers should be aware of when using AI in practice. The paper will describe a learning activity employed in an introductory structural engineering course to support students' development of ethical judgement around the use of AI in structural engineering practice. Finally, a qualitative analysis of student artifacts and feedback will be done to identify themes in students' perceptions around the ethical use of AI in structural engineering practice and to assess how the learning activities contributed to these perceptions. Overall, students found the activity to be valuable, noting that it improved their awareness of AI applications and potential issues. The results highlighted the importance of educators emphasizing that students must change their mindset and interactions with AI throughout their higher education and engineering apprenticeships, transitioning from AI being the "expert" that can assist them in their learning, to them being the expert that can check the technical accuracy of AI output.

Introduction

Artificial intelligence (AI) has been a topic of growing interest in education and engineering practice in recent years [1-2]. The use of generative AI in higher education has been polarizing, with some educators promoting it as a beneficial study tool that can level the playing field for students from different educational backgrounds [3-4], while others view it as detrimental to student's critical thinking and creativity [5]. In engineering practice, AI-powered tools are being used to facilitate design and administrative tasks [6], thus freeing up time for engineers to focus on the complex tasks that are not yet easily or reliably automated with AI. While some civil engineering programs are incorporating AI into their curricula [7], much of the focus has been on teaching students how to develop and use AI models to supplement aspects of the engineering design process [8] or how they can use it to enhance their learning [9-10]. Recent studies have begun to establish ethical frameworks for the use of AI in structural engineering practice [11]. This paper focuses on the training civil engineering students need to develop the ethical judgment to evaluate how and where to employ the ever-evolving landscape of AI tools in their future engineering practice. Specifically, this paper focuses on applications in structural engineering; however, the concepts and framework could be applied in other civil engineering disciplines.

Artificial intelligence is an umbrella term that can cover a wide range of computer-powered algorithms—from Machine Learning (ML) tools used to develop predictive statistical models and computer vision classifiers, to generative AI tools that can create coherent text and graphics from user prompts, to agentic AI tools that can complete multi-step tasks by employing different tools. While ML and AI have been used in civil engineering research for decades [12-13], they are more recently being integrated into software used in engineering practice as the accessibility of generative AI tools in the broader society has expanded. For purposes of this paper, AI can cover any of these applications used in the structural engineering space, with a focus on the generative AI tools that are seeing more widespread growth in recent years.

In general, structural engineering design has many aspects that are well-suited to computer automation. The design rules and equations included in many structural design specifications and standards (e.g., American Society of Civil Engineers (ASCE) 7 for building loads, American Institute of Steel Construction (AISC) 360 for steel design, American Concrete Institute (ACI) 318 for reinforced concrete design, National Design Specification (NDS) for wood design, etc.) provide a framework that can automate the process of determining member sizing and spacing for the majority of members with common loading and support conditions. Such algorithms have been widely implemented in structural design software for decades [14], allowing engineers to focus their efforts on more complex aspects of the design that cannot be automated. More recent AI-powered tools used in practice have further extended software to support development of initial framing plans [8] and development of full conceptual designs to evaluate different structural forms, construction materials, and load-resisting systems [15]. In general, such AI tools were trained on historical data, whether data generated from copious design calculations representing a wide range of geometric, loading, and support conditions or from data from past structural designs. Specific applications of AI-powered tools in structural engineering practice will be discussed in more detail later in the paper.

With the increased use of AI tools in structural engineering practice, students need to learn how and when it is appropriate to use such tools. While most structural engineers will not be the ones developing the AI-enabled software, they will almost certainly be using it. There is a place for courses dedicated to teaching students how to develop their own AI-enabled design tools; however, we must also reinforce to students how and when they can appropriately use such AI tools, especially when they are likely not to be the ones developing the tools themselves. As an analogy, while a student may understand the computational underpinnings of commercial structural analysis software after taking a course on the finite element method, they, themselves, are unlikely to be developing their own structural analysis software; however, we still want them to think critically about how they are using the software and its outputs in engineering practice, and we reinforce this critical thinking in structural design courses where students may be using such software.

This paper presents a series of educational activities meant to teach students about the promise of AI in structural engineering and to develop their own judgement of how and when to appropriately and ethically use AI-enabled tools in structural engineering practice. Development of such critical judgement skills is especially important when appropriate use of AI as a practicing engineer may be very different from what students are being taught is an appropriate (or inappropriate) use of AI as a student (e.g., where some instructors may take a firm stance against using AI in a course). The research questions guiding this work are: (1) How do students perceive the ethics of using AI as a student vs. as a practicing engineer; and (2) How do the proposed interventions contribute to student learning on the topic of AI in structural engineering? The interventions in this paper were employed in an introductory course to structural engineering that was taught within a general B.S. in Engineering program at a private liberal arts college. The class met for 75 minutes, two times per week. There were approximately 24 students in the class engaging in the activities. Student artifacts and feedback from students were collected and analyzed to determine themes from students' perceptions about the ethics of using AI and the value of the learning activities. While the intervention was employed in an introduction to structural engineering course, the activities could easily be implemented in more advanced structural analysis and design courses.

Description of intervention

The intervention included a series of activities, described in detail below, including learning about applications of AI in structural engineering practice, a guided in-class discussion on the ethics of using AI in practice, and a final deliverable synthesizing learning. These activities were integrated into three to four class meetings spread out over three weeks; however, the activities could be modified, as described, to reduce dedicated in-class time and incorporate more out-of-class activities, if needed.

Overview of application of AI in structural engineering practice

For students to have an informed discussion about how to ethically use AI in practice, they must first be aware of its current and potential applications. In a world where most students' primary interaction with AI is through generative AI chatbots (e.g., ChatGPT, Gemini, Claude, etc.), they may not be aware of the ways AI can be used specifically to aid structural design. This overview of applications of AI in structural engineering practice was achieved through a guest speaker presentation and an in-class presentation by the instructor. The guest speaker was a practicing structural engineer from a prominent mid-sized West Coast design firm who spoke to the class synchronously via video conferencing software. They spoke about how they personally use AI in their daily practice as a structural engineer, how their company is developing and using AI tools, and their vision for how AI will transform structural engineering practice.

While a guest speaker is ideal to allow for an interactive student question and answer session, there are a variety of recorded presentations from practicing engineers available online and/or articles written by practicing engineers in trade magazines about similar topics. Students could consume one of these other media in lieu of a guest speaker to learn about how AI is impacting the structural engineering profession from the perspective of a practicing engineer. For example, many recorded presentations related to this topic are accessible, free-of-charge, including past presentations from the North American Steel Construction Conference available via the AISC Learning Portal [16-18] and a 2025 webinar series on AI in structural engineering hosted by the Coalition of American Structural Engineers (CASE), National Council of Structural Engineers Associations (NCSEA), and Structural Engineering Institute (SEI) available on YouTube [19-21]. To provide accountability and the opportunity to (formally or informally) assess student learning from the guest speaker, students were assigned a reflection where they had to summarize their key takeaways from the presentation, as well as lingering questions or curiosities they have about the topic.

In a class meeting after the guest speaker, the instructor gave a brief in-class presentation highlighting specific examples of AI-use in structural engineering practice to supplement the examples discussed by the guest speaker. Example applications presented in this case study are described below for reference, although the landscape of AI use in practice is ever changing, and examples should be revisited in future implementations.

- **Image classification:** A step-by-step guide to building an AI image classification tool to identify wind surface roughness category developed by the NCSEA [22]
- **Proprietary design tools:** An "optioneering" conceptual design tool called Asterisk produced by Thornton Tomasetti [23]

- **AI-embedded commercial software:** Pathw.ai software that streamlines structural connection design [24]
- **Chatbots:** The AISC Clark chatbot trained on AISC Specifications and Design Guides [25], the SE GPT from NCSEA that is trained on vetted structural engineering resources [26]

In lieu of an instructor-led presentation, one could instead assign students to do independent or group-based research on one or more specific AI applications and deliver brief in-class presentations or out-of-class recordings summarizing how AI was employed in each application, such that all students can get an overview of a range of potential applications.

Guided discussion on the ethical use of AI in structural engineering practice

A guided in-class discussion was used to explore students' perceptions of the ethical uses of AI. The guided discussion starts with the context most familiar to the students, the use of generative AI in school. First, they are asked to generate a list of the ways students at their institution are using AI for their schoolwork. They are encouraged to think of all uses they have seen or heard of, regardless of if they think they are ethical or appropriate uses. These uses are reported to the larger class. Then, the instructor presents the institution's Honor Code, and students are asked to independently reflect on and justify if using AI for schoolwork in these ways is a violation of the institution's Honor Code. At the institution where this activity was implemented, the Honor Code is essentially a paragraph that focuses on the importance of academic integrity and covers cheating, deception, stealing, plagiarism, and dishonesty in the academic context. Students are provided with a worksheet to write their reflective thoughts. For purposes of this paper, the anonymous worksheets were collected; however, they need not be. After their personal reflection, students are invited to discuss their opinions with the class or in small groups, and they may discuss certain scenarios or uses that do and do not violate the Honor Code. During discussion, students are encouraged to use excerpts from the Honor Code to support their stance.

The discussion then shifts to the context of using AI as a practicing structural engineer. Start by reminding students of the different uses of AI in structural engineering practice, which can range anywhere from administrative assistance in preparing reports and writing correspondences to AI-enabled structural design tools outlined in the previous section. In this context, we use the "Code of Ethics for Engineers" from the National Society of Professional Engineers (NSPE) [27] as the set of rules and obligations engineers are expected to follow, as this is the code students used in pre-requisite courses in this particular engineering program; however, another engineering code of ethics, such as the one from ASCE [28], could be used. Students review a handout with the "Code of Ethics for Engineers," which include the fundamental canons, rules of practice, and professional obligations. Students are asked to independently reflect on and later discuss whether using AI as a structural engineer is a violation of the engineering code of ethics, and to justify their answer with specific statements from the code of ethics.

The instructor may provide additional prompts or scenarios to support the discussions. For example, students may identify the specific statement in the NSPE Code of Ethics "II.2.b Engineers shall not affix their signatures to […] any plan or document not prepared under their direction or control," as one that may discourage the use of AI-generated documents or designs; however, there can be some discretion in terms of what constitutes being "prepared under their direction or control" when it comes to AI use. A deeper discussion specifically on what it means for a Professional Engineer (PE) to affix their signature or seal to a document may help students make sense of this ethical provision, following the guidance provided by NSPE [29]. Additionally, an instructor may share specific examples of ethical violations from their state's Board of Professional Engineers that may be relevant to the discussion. There are regularly examples of engineers being cited for ethical violations due, in part, to having inadequate technical knowledge of the software being used in design, which can apply to use of AI and non-AI enabled design software alike. Such examples show students that it is not uncommon for engineers to be tempted to use computational tools that extend beyond their area of expertise, as well as the severe consequences of such decisions.

Through this discussion, students may have varying opinions on their ethical judgements of different applications of AI. To the extent possible, the instructor can ask students to reference specific sections of the NSPE Code of Ethics, to encourage students to use professional codes in support of their decision-making, and they can ask students to elaborate on specific actions that can be taken to change whether a certain application is ethical or not. To aid in the discussions, the instructor can provide specific scenarios for students to consider, which can also help to highlight specific ethical considerations that the students may not identify themselves. Some examples of specific scenarios and ethical considerations are summarized in Table 1. In some cases, it may be unclear if a scenario complies with or violates an ethical code, in which case students can discuss specific details of the scenario that may cause it to go one way or the other. This activity is in alignment with ABET Student Outcome (SO) 4: "an ability to 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," and explicit mention of scenarios involving the environmental impacts of AI and the societal impacts related to public safety and data privacy can address the variety of contexts in which the ethics of AI can be considered.

Table 1: Example scenarios of AI use that can be brought up during the guided discussion to highlight specific ethical considerations

Example scenario	**Ethical considerations [relevant NSPE/ASCE Code of Ethics section]**
A structural engineer uses AI to write portions of a technical report.	• Issuing objective and truthful statements [II.3/1c] • Giving credit for work [III.9.a/5b]
A structural engineer uses an AI-enabled software that automatically generates framing plans and drawing sets based on a structural analysis model.	• Affixing seals to plans prepared by others [II.2.b/4g] • Approving conformity with applicable standards [II.1.b/3b]
A structural engineer uses AI heavily in all aspects of their work, including daily administrative tasks, assistance in preparing documents, and development of in-house AI tools that can be used to aid design. They are concerned about the environmental impacts associated with the energy and water usage from the data centers used to support large AI models.	• Adhering to sustainability principles [III.2.d/2a]
A structural engineer wants to develop their own AI design tool using a public AI platform. To train their AI tool, they upload design calculations and floor plans from previous projects they have worked on.	• Revealing information without consent of client [II.1.c/4e]
A structural engineer uses AI to design a floor framing system, something the engineer can do themselves but can be done much more quickly with AI.	• Holding paramount public safety [I.1/1a] • Approving conformity with applicable standards [II.1.b/3b] • Performing services only in areas of competence [II.2/4f]
A structural engineer uses AI to research a relatively new structural system they have never designed before, asking it what limit states and applicable code provisions must be checked.	• Performing services only in areas of competence [II.2/4f] • Continuing professional development [III.2.e/3g]
A senior structural engineer, who is responsible for stamping all structural drawings produced by the team of engineers working under their supervision, suspects that a junior engineer used AI to produce a design, although all the resulting member sizes and load path seem reasonable based on the senior engineer's years of experience.	• Holding paramount public safety [I.1/1a] • Affixing seals to plans prepared by others [II.2.b/4g] • Approving conformity with applicable standards [II.1.b/3b] • Participating in career guidance [III.2.a/3e]

After discussing the ethics of various applications of AI in structural engineering practice, the instructor can have students discuss the conditions (i.e., guardrails) needed to ensure that an engineer is using AI ethically. To support this discussion, an instructor may ask them to reflect on ways they may ethically use non-AI structural analysis and design tools, and how any lessons learned from this may transfer to use of AI-enabled tools. The results of this discussion can be used in the follow-on activity described below.

The in-class guided discussion activity can be modified to be done outside of class, if needed. For example, discussion prompts can be posted on an interactive class discussion board, or as a prompt for a reflective essay. The instructor should be conscientious, however, that written responses could be AI-generated, diminishing the student's personal reflection and practice in exercising their ethical judgement. Providing an opportunity to discuss their thoughts during a class session can be beneficial, even if it is a shortened discussion after some out-of-class reflection. For example, students will benefit from hearing the perspectives of others, especially those that may interpret or apply the ethical codes differently than themselves. Having an instructor or other students bring up scenarios and ethical considerations they had not considered themselves can also broaden their awareness of ethical dilemmas that may not always present a clear right or wrong approach.

To informally assess the efficacy and value of the in-class discussion, the students were asked to anonymously respond to the following prompts:

- Have your impressions on the ethics of using AI in structural design changed based on today's discussion? If so, how?
- Was this discussion of AI use in Structural Engineering valuable? If so, what part and how?
- What suggestions do you have to improve this or other discussion of AI in engineering courses?

Deliverable to synthesize learning

Some state licensing boards are developing their own guidelines on the use of AI in engineering services [30]. These guidelines are written in the context of alignment with licensing board laws and rules, and not necessarily in the context of practical "Dos and Don'ts" for the engineer. In this activity, students are asked to synthesize what they have learned by producing practical guidance on how to ethically use AI in engineering practice. Students are given the scenario that they are a junior engineer at a structural design firm, and based on their proficiency with using AI, they have been asked by their boss to produce guidance for engineers at their company on how to appropriately use AI. The only stipulation in this assignment is that the product they produce should be engaging (i.e., not just a page of text) and something they would find helpful as a junior engineer. In this implementation, students were given 15 minutes of time in class to create their products in groups of two to three, after which they would share their products with the class. The products created in this class included infographics (several of which were produced with generative AI tools using student input) and short videos; however, other example products could include podcasts, websites, interactive choice-based games, etc. This activity could easily be expanded into a longer in-class activity and/or as an out-of-class assignment.

Results

Student artifacts were reviewed to gain insights on student perceptions and the efficacy of the learning activity, guided by the following research questions:

1. How do students perceive the ethics of using AI as a student vs. as a practicing engineer?
2. How do the proposed interventions contribute to student learning on the topic of AI in structural engineering?

Specifically, the individual responses on the worksheets from the guided in-class discussion and the group-based deliverable synthesizing guidance for practicing structural engineers were qualitatively reviewed to identify themes. Twenty-two students submitted a worksheet (questions left blank were ignored when compiling responses), and eight groups submitted the final deliverable. The author did an initial review of the artifacts to make observations and identify a set of codes. The artifacts were then re-reviewed and coded. After reviewing the coded data, the author grouped similar codes to establish emergent themes from the artifacts. These emergent themes are identified and discussed below.

Initial thoughts on AI use as student and structural engineer

Prior to group discussion, students were asked to reflect individually on how/if use of AI as a student or structural engineer was a violation of the university's honor code or the NSPE Code of Ethics, respectively. Both the honor code and code of ethics were provided as reference. Students were asked to note their initial thoughts on their worksheets. Nearly all students noted the nuance of their response, depending on how AI was being used. The resulting themes, examples demonstrating those themes, and frequency of responses for each theme are presented in Table 2.

Two key themes emerged from the question pertaining to use of AI as a student. Students generally agreed that using AI as a student is not a violation of the university's honor code if it is only being used in a supporting role, but that it is a violation if AI is being used to produce entire essays or submissions. Additionally, almost a quarter of students noted that it is acceptable to use AI if it is being properly and transparently acknowledged, or that it is only a violation of the honor code if the student is deceptively trying to pass the AI work off as their own.

Table 2: Emergent themes from pre-discussion prompts asking if use of AI is in violation of relevant ethical codes as a student and structural engineer and final deliverables providing AI guidance to practicing engineers

Theme	Examples	% of pre-discussion responses		% of final deliverables [n=8]
		As a student [n=21]	As an engineer [n=22]	
AI as a support tool	• OK to use AI for brainstorming, outlining, etc.; not for entire product • It's just another resource; like an internet search • OK to use AI to support learning • OK if it's speeding up mundane tasks	86%	23%	75%
Acknowledgement	• Not OK if you're trying to pass AI work off as your own • Must acknowledge AI use	24%	18%	38%
Human responsibility	• A competent human must check the work of AI • AI cannot have compassion or nuanced opinions like humans	0%	68%	100%
Data concerns	• AI can be biased • Need to consider information security and IP for AI products	0%	23%	63%

These same themes appeared in the students' responses asking if using AI as a practicing structural engineer was a violation of the NSPE Code of Ethics, however, to a lesser extent. In this context, responses were more likely to mention that use of AI in engineering practice is only acceptable if it is being done within the realm of the engineer's competency and if the engineer is doing a check on all AI results and calculations—demonstrating the concern for public safety in the context of engineering design. Additionally, in the context of engineering practice, students noted concerns for data privacy, biases in the training data, and intellectual property with the use of AI tools, which were not noted as concerns in the context of using AI as a student. One observation, which did not appear in the themes presented in Table 2, is that 9% of the responses indicated that AI can be used to check human work (the opposite of the majority of responses indicating that a human should check the work of AI).

It is worth noting that this in-class discussion occurred after the students had heard the guest speaker talk about how their company uses AI in structural engineering practice, which included some discussion of considerations safety and trustworthiness of data. Therefore, students' initial reflections on using AI as a structural engineer may have been influenced by what they heard from the guest speaker or the instructor's previous presentations.

Student recommendations on AI use in structural engineering

As a synthesis at the end of the presentations and discussions about AI use in engineering, students worked in groups to create a shareable product that informs other structural engineers on how to appropriately use AI in practice. For this case study, the students were given 15 minutes of class time to create these products to share with the class. Most groups generated some sort of infographic, with one group producing a short video. Five of the eight groups disclosed using AI to help generate the infographic, four of which had typographical errors, which students highlighted as an example of potential errors with AI-generated content. In the deliverables, students generally provided tips and best practices for using AI or a list of "dos and don'ts." The key themes observed in these deliverables are also presented in Table 2, and the data are separated into further subthemes in the following paragraph.

In their final deliverables, all groups acknowledged the importance of competent Professional Engineers being ultimately responsible for their designs and needing to check all AI outputs, demonstrating the prioritization of public safety. Most groups also acknowledged that use of AI in a supporting role was also acceptable (75% in Table 2), explicitly providing examples (subthemes) such as using AI as a personal assistant to help write emails or draft reports (50%), or to help within brainstorming conceptual designs (38%). Similarly, most groups made some mentions of needing to consider the data used to train AI-based tools (63% in Table 2), specifically mentioning subthemes of privacy of client data (38%), potential biases in training data (25%), and knowing the limitations and quality of the training data that was used (13%). Less than half the groups mentioned the need for transparency and acknowledgement when AI is used (38% in Table 2).

Value of the intervention

At the end of the in-class discussion, students were asked to respond to prompts on their worksheet about how the discussion changed their impressions of AI use in structural engineering, the value of the discussion activities, and suggestions for improving the discussion (for this course and other engineering courses).

When asked if the in-class discussion changed their perceptions on the ethics of using AI in structural engineering practice, about half of students indicated their opinions had not changed, and half indicated a change in opinions. Half the responses indicated changes in their awareness of AI, both in terms of the benefits that AI can bring to structural engineering practice and in the potential ethical issues with AI usage. A smaller number of responses (25%) indicated a change in their perceptions of the engineer's responsibility for understanding and taking responsibility for AI outputs. Additionally, a few responses (20%) noted that their impressions have changed in that they now see how widely used AI can be in engineering practice and that they need to be prepared to responsibly use it as an engineer.

When asked about the value of the discussion, all students said it was valuable. Two key themes emerged in responses to this question, with students indicating value through increased awareness of AI's promise and potential pitfalls and how others view it (59% of responses), as well as value in developing their own ethical judgement (55% of responses). A few students specifically noted that the topic of AI usage feels like a "taboo" topic in many classes and that it is refreshing to be able to talk about it in the open.

When asked to provide suggestions for future discussions around AI in engineering, 35% of students wanted to see more real-world examples, either of how AI is being used in practice or how AI has led to ethical and engineering failures. Another 30% of students indicated they want to have more nuanced discussions like this in their engineering classes, including more discussion of the environmental impacts of AI and how uses in engineering practice may differ from those as a student. Another 15% of students gave specific suggestions on logistics of the discussion, including when in the term it should be done, arrangements of tables in the classroom, and additional assignments that can be done.

Conclusions

With the increasing use of generative AI in both higher education and structural engineering practice, it is of utmost importance that students learn how to ethically use AI in their future careers. This paper discusses learning activities that were employed in an "Introduction to Structural Engineering" course at a liberal arts college to introduce students to the potential promise and pitfalls of AI in structural engineering practice. Potential modifications of the activities are presented to make them accessible in a variety of course contexts. These activities include presentations about the uses of AI in structural engineering practice, guided in-class discussions on how use of AI as a student and structural engineer align with relevant ethical codes, and creation of a deliverable to synthesize their learning on best practices for use of AI in engineering practice.

Analysis of students' responses to a worksheet provided during the guided discussion and the final deliverables showed that students are aware of the responsibility of the (human) engineer to check work produced by AI as a matter of public safety, to an even greater extent after the in-class discussion. Students also believe it is acceptable to use AI as a support tool in their work (e.g., for outlining, drafting reports, and brainstorming designs) but not to create final products, and that it is important to consider the privacy and quality of data being used to train AI models. To a lesser extent, students noted that the use of AI should be transparently acknowledged.

Upon reflection on the students' discussion and responses to the worksheet prompts, the instructor sees the importance of discussing with students how their use of AI will and should change as they transition from student to engineer. Many students see AI as the expert, where they turn towards AI to help them learn a new concept or to check over their work; however, as an engineer responsible for public welfare, they need to be the expert that can check AI. During their education and on-the-job training, early career engineers must develop the technical judgement to evaluate AI-produced outputs and the ethical judgement to know when and how to use it. As the least frequent theme observed in student worksheet responses and final deliverables, it is also evident that we, as engineering educators and as a civil engineering profession, need to have more conversations and establish norms around how and when the use of AI-enabled tools should be acknowledged.

The learning activities employed in this paper could be applied in any structural (or civil) engineering courses in any institutional context; however, the results are limited to the students from this study at a liberal arts college and may not be generalizable to students in programs within larger colleges of engineering. For example, at the institution where this intervention was implemented, there is no formal guidance from the department or college about the use of AI, and students may regularly hear messaging from liberal arts and humanities faculty discouraging or prohibiting the use of AI; whereas that messaging may be different for students who spend the majority of their academic time within colleges of engineering that may embrace such technological advancements. Further work can explore how students' perceptions of the ethics of AI differ based on the institutional context, including how AI is being discussed across the institution. Additionally, this study only considered students from one class, resulting in a small sample size of approximately 24 students, further limiting the potential generalization of the results. Future studies implementing the proposed interventions will generate a larger sample size and provide more confidence in the results.

Future iterations of this work can include more detailed analysis of students' perceptions of the ethics of AI use in specific scenarios, and more formal assessment can be done to assess students' ethical reasoning [31] around the use of AI in engineering practice. In this paper, the student responses during the discussion were not recorded or analyzed. Having recorded focus groups, interviews, or class discussions would also provide a richer dataset for analyzing student perceptions that were not available in the brief worksheet responses, including students' perceptions of AI use in specific scenarios. Further work could also include assessing perceptions of ethical AI use by practicing engineers at various stages of their careers to see if/how their perceptions of AI change over time (e.g., as they transition from learner to expert).

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