Re-Design Introductory Engineering Course for Tinkering with Generative AI and the Shifts in Students' Perceptions of Using AI for Learning

Ms. Yume Menghe Xu, Tufts University

Menghe (Yume) is a PhD student in STEM Education at Tufts University. She holds a bachelor's and a master's degree in Chemical System Engineering from the University of Tokyo, Japan. Prior to pursuing a PhD at Tufts, she designed and developed educational apps for children, and worked with students, teachers, and makerspace in Japan to host making workshops using various materials and tools. Her research interest lies in youth's identity construction in STEM learning spaces.

Dr. Ethan E. Danahy, Tufts University

Dr. Ethan Danahy is a Research Associate Professor at the Center for Engineering Education and Outreach (CEEO) with secondary appointment in the Department of Computer Science within the School of Engineering at Tufts University. Having received his graduate degrees in Computer Science and Electrical Engineering from Tufts University, he continues research in the design, implementation, and evaluation of different educational technologies. With particular attention to engaging students in the STEAM content areas, he focuses his investigations on enhancing creativity and innovation, supporting better documentation, and encouraging collaborative learning.

William Church

Re-design Introductory Engineering Course for Tinkering with Generative AI and the Shifts in Students' Perceptions of Using AI for Learning

Abstract

This study is a "Complete Paper - Research" submitted to FPD.

Undergraduate engineering school is where young people enter the professional engineering communities and form their identities in engineering. During this process, they are also developing their relationships with engineering tools and forming their views on how they want to use these tools as engineers-to-be. Generative AI is one of these engineering tools as it is being increasingly used by the engineering industry. As engineering schools are re-designing their curricula to support students learning how to use generative AI, it is important to attend to the existing relationships the students have with generative AI coming out of K-12 education, and support them to develop the relationships as they become engineers.

This study is based on an introductory engineering course for first-year engineering that is hands-on and project-based. Students create and document engineering designs using a LEGO-based robotics platform. In the fall semester of 2023, students were encouraged to use generative AI to support the production of their projects, and provided with tools built with generative AI to assist them in programming. The course adopted a tinkering mentality where both the instructors and the students explored the potential use of generative AI and constructed knowledge on how generative AI can be used for learning and engineering.

By analyzing 21 students' responses to surveys before and after the course, we studied the perceptions the students hold for generative AI upon entering engineering school, and the shifts in their perceptions after attending this course. We found that students had diverse but generally negative perceptions of using generative for learning at the beginning of the course, and constructed more nuanced, positive, but critical views of how they want to use generative AI for learning and engineering after the course. This study contributes to the body of research on generative AI in engineering education and calls for educators and educational researchers to design venues that empower students to have ownership in constructing their views of generative AI as engineers-to-be.

Introduction

> "I didn't realize how helpful AI could be and how it could be used in an education setting without it seeming like a way to cheat. At the beginning of the semester, the fact that we were told to use AI was crazy to me, but now I can't see how the class would've run without it."

This excerpt from an exit survey was written by a first-year undergraduate student who participated in an introductory engineering course re-designed to support students' tinkering with generative Artificial Intelligence (AI).

As the use of AI tools such as OpenAI's ChatGPT and DALL-E grows more widespread throughout society, many industries including engineering are embracing and adopting generative AI to create more innovation [1]. At the same time, K-12 schools are grappling with how to use generative AI in their classrooms, not only because they understand the potential of generative AI to support self-paced learning, but also because they worry about students cheating and developing independence for generative AI [2], [3]. These dueling perspectives have led to conflicted approaches within schools. For example, the New York City school district first banned ChatGPT on their school network to ensure students' academic integrity [4], but soon after repealed the ban to embrace the technology [5]. Because of the lack of established policies to guide usage, there persist mixed and underdeveloped perceptions of how to use generative AI for learning in K-12 classrooms [6].

Undergraduate-level engineering schools are where young people transition from K-12 schooling communities to professional engineering communities [7]. Entering engineering schools, young people learn to participate in the culture of engineering and develop their relationships with engineering, and they develop from novice to professional engineers [8], [9], [10], [11]. This transition also affects young people's relationships with certain tools, including generative AI, because members of differing communities can have different uses and perceptions of these tools. For example, the student quoted above seems to have a negative perception of using generative AI for learning upon arriving at an engineering school. Therefore, when designing learning experiences with generative AI for undergraduate engineering students, especially in their first year, we need to be mindful of the gap that can exist between the perceptions held from their K-12 education and those that engineering communities hold.

Tinkering as a creative and improvisational approach to design problems has been studied as valuable for learning engineering [12], [13], [14], [15], [16], [17]. It supports active and playful exploration and constructing knowledge of materials and tools. Learning environments designed with tinkering allow young people to have control over tools [18] and explore new paths and new possibilities [15]. First-year engineering students as the engineers-to-be should be empowered to form their own ethical views on how they would like to learn and do engineering with generative AI. Therefore, tinkering-based learning environments have the potential to empower engineering students with various existing perceptions to form new perceptions on using generative AI as engineers.

This study describes an introductory engineering course re-designed for first-year engineering students to tinker with generative AI. During the course, students were encouraged to use ChatGPT to generate code to program robots and build websites for documentation. Through thematic analysis of students' responses to the surveys before and after the course, we report on the themes in students' perceptions of generative AI for their learning before the course and the shifts in their perceptions after the course. We discuss the implications of designing undergraduate engineering courses to support students who are exploring the use of generative AI as they begin to participate in professional engineering communities.

Background

Generative AI in engineering education

Although nascent, there is an emerging body of research on using generative AI in engineering education. The majority of the research is focused on teaching programming, with scholars designing educational tools and programs for students to learn programming with generative AI. For example, Kazemitabaar et al. [19] conducted a controlled study with young people aged 10-17 who were novice learners in introductory programming. Comparing the group that used OpenAI's code generator Codex and the baseline group that did not use Codex for their learning, the authors found that the Codex group performed better at generating code during the evaluation and post-test. In another study, Kazemitabaar et al. [20] developed CodeAid, a Large Language Model-based programming assistant for undergraduate students similar to a teaching assistant. CodeAid was designed to support students in programming by answering questions about code, helping to write code, and helping to fix code. Through studying the class deployment of CodeAid over a semester, the authors proposed design implications for designing AI assistants in educational contexts.

While it is important to study generative AI as a learning tool for specific engineering skills, it is also necessary to situate generative AI in engineering education programs and consider its impact on engineering students' processes of becoming engineers. Khanolkar et al. [21] studied the engineering course curricula of two Canadian universities and found that the universities did not offer adequate courses to teach both AI and engineering design, despite research showing that AI can benefit the engineering design process drastically. Similarly, Naser [22] pointed out that engineering schools should incorporate learning about AI across their curricula because of the growth of AI use in the industry. This study contributes to the literature on how to design learning of generative AI in engineering education. We specifically look into how first-year engineering students may hold perceptions about using generative AI for engineering that is different from professional engineers, and how to design venues to support them explore their relationship with generative AI as they become engineers.

Tinkering-based engineering learning environments

Tinkering as the creative and improvisational approach to design problems has been studied extensively in engineering education [12], [13], [14], [15], [16], [17]. Through tinkering, one iteratively experiments with various materials and utilizes various tools to test and modify their designs [15], [23]. In this process of open-ended inquiry [13], [16], one actively and playfully constructs knowledge of these materials and tools. Tinkering breaks down the power structure in classrooms where teachers are the "givers" of knowledge while students are the "receivers". Both teachers and students become learners when tinkering because tinkering is about learning with and from the materials and tools [24], [25], [26]. Since we want first-year engineering students to have agency in developing their own views about how they want to use generative AI for learning and engineering, enabling them to tinker with generative AI as an engineering tool is a promising design approach.

To understand how first-year engineering students as engineers-to-be develop their perceptions of using generative AI for learning and engineering, we re-designed an introductory engineering course to support students in tinkering with generative AI. We studied their development in perceptions guided by two research questions:

RQ1. What perceptions of using generative AI for learning do young people bring when they enter engineering school?
RQ2. How do first-year engineering students' perceptions of using generative AI for learning and engineering shift after attending a course re-designed to support them in tinkering with generative AI?

Re-design of the course: 'Simple Robotics'

The course of focus, "Simple Robotics", is one of 14 introductory engineering courses offered at a medium-sized private university in New England. All first-year students in the School of Engineering are required to take one of these courses in their first semester. Although these 14 courses are taught by different engineering professors from different departments around different topics, they all aim to introduce first-year engineering students to engineering design processes and engineering ethics, with an emphasis on group work and project-based learning.

With the second author as the instructor, Simple Robotics is a hands-on and project-based course that has been offered each year for over 8 years. The course provides an introduction to the basic principles of robotics, including the concepts of robot construction, programming, and elementary controls. It is offered to students with minimal or no prior programming/building background. During the course, students go through weekly challenges in small groups to create robotics projects using a LEGO-based robotics platform.

In the fall semester of 2023, the instructor redesigned the course to explore the use of generative AI for learning and engineering with the students. Because generative AI is still new to engineering education and engineering, the instructor framed the course as a collaborative experiment with the students about how generative AI can be used in engineering education and engineering. He positioned himself as a learner exploring alongside the students and encouraged them to "push the envelope" of the use of generative AI in order to see the potential along with any downsides. As a guardrail for the ethical concerns of generative AI, he created venues in the class to maintain open communication about the exploration.

The students were provided with web-based tools "PrimeBot" and "WebDeveloperBot", both developed by the instructor and his team incorporating the API of ChatGPT (refer to figure 1 for screenshots). With prompts input by users, "PrimeBot" generates Python code for programming LEGO Education SPIKE Prime Robotics sets, and "WebDeveloperBot" generates HTML code to help create online portfolios. The students were encouraged to use these tools for their projects and reflect on their use. They were also provided with "GeneralBot" which has the same features as ChatGPT. The students were informed that all data including students' input and the bots' output would be collected through these tools to improve the class experience.

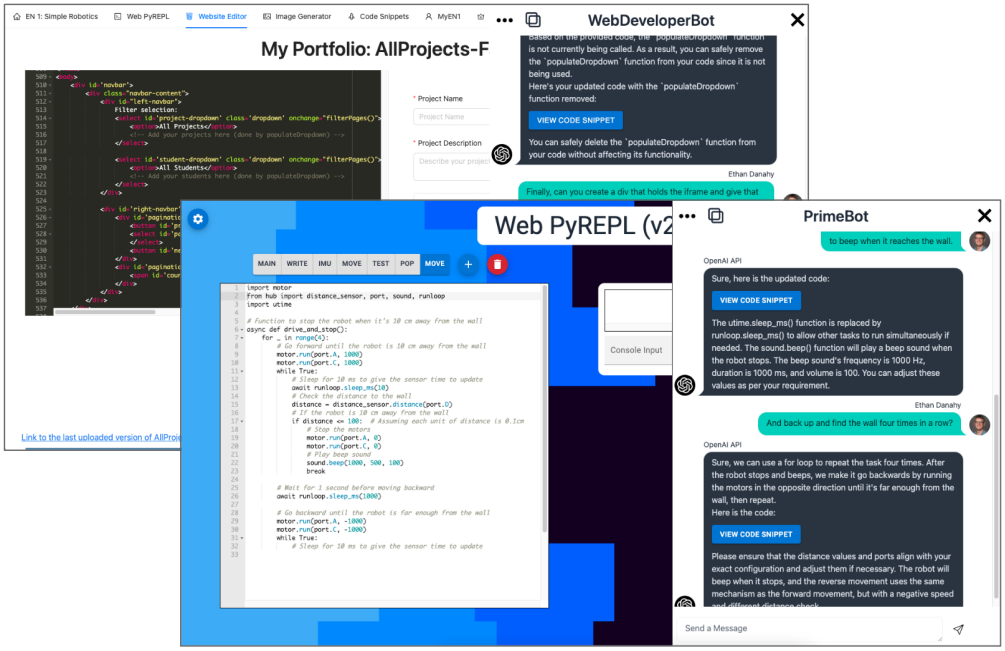

Figure 1. Screenshots for "PrimeBot" and "WebDeveloperBot"

The instructor made adaptations to his course along the way to better support students' use of generative AI and also demonstrated that he was tinkering with generative AI along with the students. For example, after the second session of the course, the instructor found that the students were asking many questions regarding the syllabus in "GeneralBot". However, because "GeneralBot" was the same as ChatGPT and the syllabus was not included in the training data, "GeneralBot" was unable to provide students with answers. Seeing this phenomenon, the instructor and the team created "SyllabusBot" and introduced it in the next session. It was created based on the syllabus contents so that the students could ask questions about the syllabus

Research method

Data source

Out of the 30 students enrolled in the course, 22 consented to participate in the study. All study participants were first-year students who intend to declare their majors in engineering school. The data used in this study are students' responses to the surveys before and after the Simple Robotics course. These two surveys aim to understand students' prior experience in skills related to this course (such as coding and building LEGO), their attitudes toward using AI for learning, and their attitudes towards using AI in engineering professions. The questions in the pre and post-surveys are not identical because the post-survey was also intended for the students to reflect on their participation in the course. The post-survey was designed based on the pre-survey questions and responses, along with students' emergent reactions observed throughout the course. For this study, we analyzed the open-response questions related to the students' experiences and perceptions of AI in the pre and post-survey. The questions we analyzed are listed in Table 1 and numbered for the convenience of analysis. The answers to the questions

were anonymized, but pre-survey answers were associated with their corresponding post-survey answers.

Table 1. Open-response questions analyzed from pre and post-survey

	Question
Pre-survey	Pre-Q1. Have you used AI before? If so, provide some examples.
	Pre-Q2. Thinking about Education (and YOUR education specifically), write a few sentences about when you think ***it IS OK*** to use AI (generative AI systems like ChatGPT) in education. When/how SHOULD students be using a tool like ChatGPT?
	Pre-Q3. Thinking about Education/your education: write a few sentences about when you think ***it is NOT OK*** to use AI in education. When/how should students NOT BE using a tool like ChatGPT?
Post-survey	Post-Q1. Reflecting back on your assignments, can you describe a moment in which AI assisted/helped in your classwork? Provide an example and the details of the experience.
	Post-Q2. Reflecting back on your assignments, can you describe a moment that you spent time trying to use AI but didn't find it beneficial or helpful? Provide an example and the details of the experience.
	Post-Q3. Thinking about Education (and YOUR education specifically), write a few sentences about when you think ***it IS OK*** to use AI (generative AI systems like ChatGPT) in education. When/how SHOULD students be using a tool like ChatGPT?
	Post-Q4. Thinking about Education/your education: write a few sentences about when you think ***it is NOT OK*** to use AI in education. When/how should students NOT BE using a tool like ChatGPT?
	Post-Q5. How do you think professionals will use AI to benefit their work in the field you are interested in? E.g., if you are thinking about majoring in engineering, how would you as an engineer use AI to benefit your work?
	Post-Q6. How did this course impact your view of using AI, in both your learning and the field you are interested in pursuing later?

Data analysis

We open-coded the answers in both the pre and post-survey for a thematic analysis. We conducted three rounds of iterative inductive coding on the responses. In the first round, we open-coded the responses by assigning a short phrase to each response. We assigned multiple short phrases to some responses when the student made several different points in their

responses. In the second round of coding, we grouped similar codes into categories. For example, the codes "not OK to use AI to cheat on assignment" and "not OK to use AI to plagiarize" were put into a category of "harming academic integrity". Through this categorization, we had iterative discussions among the three authors and identified the themes presented in the following section.

Results

To situate the results, we first present the students' experiences with generative AI before attending university. In their answers to Pre-Q1, 4 out of 22 students indicated that they do not have experience using generative AI. Among the 18 students who wrote about their experiences with generative AI (many wrote about multiple types of experiences), 5 students mentioned their experience using generative AI for schoolwork. Examples included using DALL-E to generate images when making a zine for a senior English project and generating practice problems for classes. 4 talked about learning with or about generative AI in out-of-school settings. For example, one student had attended a summer program hosted by a university where they coded an AI using Q-learning and Monte Carlo tree search. 3 students used generative AI for their hobby by setting generative AI up as their opponent for video games or creating stories about characters for role-playing games. 10 students stated their experiences testing out generative AI on their own or with their peers.

We identified themes in students' responses to answer RQ1 and RQ2. For the sake of brevity, instead of providing an exhaustive list of all responses to each theme, we selected representative quotes for each theme.

RQ1. Student perceptions of using generative AI for learning before the semester

To answer RQ1, we analyzed students' answers to Pre-Q2 and Pre-Q3 and identified three themes in students' perceptions of using general AI for learning before the semester.

Generative AI can be used to supplement one's work

In their answers to Pre-Q2 - "When is it OK to use AI in education", many students expressed their belief that generative AI can be used to supplement one's work, but not to completely replace it. Most of the students' responses related to using generative AI to supplement one's writing process:

> "I've used it as a tool for very specific tasks, for example I was writing a satire article and needed to create an acronym for a set word (as in I knew the acronym but needed to come up with what it stood for). AI is good for a task like this. - ChatGPT's work should never be passed as human work—it can be used to supplement it if needed but only as a tool."

> "I personally think it could be useful as a starting point for research to direct students to helpful resources. I also think it could be helpful for refining work (ie. Grammarly)."

The students thought that generative AI could supplement their writing by brainstorming ideas and refining their work when writing. Other students drew a parallel between generative AI and search engines. One example quote is:

> "I think it is ok to use AI when it is to help guide us in a new direction we didn't think of. As a resource to help when we are stuck and want some guidance for how to go about a problem or to get an explanation of how to go about it. It's like a quick Google search except you don't have to search the internet for the answer."

To these students, generative AI can supplement one's work when one needs to obtain information about a topic. It is like searching on the internet but it saves time because generative AI gives out one curated answer without the need to verify different sources. However, the students were aware that it was necessary to confirm the credibility and cite the answers properly. Within the work writing and obtaining information on a topic, students emphasized their belief that it is ok to use generative AI to *supplement* the work but not to completely do the work *for* one.

<u>Generative AI can impact academic integrity</u>

In the answers to Pre-Q3 - *"When is it NOT OK to use AI in education"*, many students mentioned the impact that generative AI can have on academic integrity. Below is an example quote that follows this theme:

> "I think that the academic use of ChatGPT is a slippery slope because the fact that the work of countless other individuals (within ChatGPT's dataset) is then used to 'bake' a new piece of information/media. Because this is technically the product of somebody else's work, then are you plagiarizing somebody by calling the work original?"

This student argued that because generative AI is based on the work created by others, completely deploying AI's output and using it as one's own work is equivalent to plagiarizing. This response used the expression "slippery slope" to emphasize that the academic use of AI is dangerous. If one starts using generative AI for academic purposes, then it may turn into a much worse situation of plagiarism.

<u>Generative AI hinders the development of skills</u>

Several students were completely against using generative AI in educational settings. They had strong opinions about generative AI potentially hindering the development of skills.

> "In terms of my education, I want to learn to write well and I won't improve if I just use ChatGPT. I do think there is some value of using it in a brainstorming stage. - I don't think students should be using ChatGPT. I am here to learn how to do things myself. I am not writing to write. I am writing to learn."

> "I think it should not be used as a way to get out of practice time. Anything that requires skill and practice to form that skill (like writing an essay) shouldn't be done with AI. I

> think that there is great importance in having your own knowledge and learning to express your own creativity."

Both of the students quoted above stated that one needs practice time in order to acquire a skill like writing. If one uses generative AI to do things related to learning, generative AI will take away the practice time, hence hindering the development of the skills. Another student said that if one did not have enough practice time to develop a skill like writing, then "they may struggle in real-world jobs to write memos or short summaries for their future employer". To these students, using generative AI will hinder the learning and the development of the skill. As with the first theme, writing was the skill raised as an example most often by the students.

RQ2. Students' shifting perceptions of using generative AI for learning through the course

From students' answers to Post-Q1 to Q6, we found that the first and second themes in the previous section ("generative AI can be used to supplement one's work" and "generative AI can impact academic integrity") are still salient in their perceptions. However, we did not see responses related to the third theme ("generative AI hinders the development of skills"). Instead, many students commented on how they saw generative AI supporting them to learn new skills. Additionally, we identified 2 main themes in students' shifting perceptions: being more open and comfortable with using generative AI to learn and being more cautious about the general use of generative AI.

<u>Generative AI can support learning</u>

Many students said that generative AI helped them learn during the course. Among these answers, some talked about how the use of "PrimeBot" supported them in learning how to program with Python, such as this quote:

> "I used AI for every solo coding portion of the class. For example, I used it to program the car that drove in a square. At first, I was unsure of what to say to the AI and I prompted it based on what I had seen in class. I realized that the AI was quite flexible and could understand me well and I had a lot of fun making it write my code. I studied the code that the AI wrote and saw how it worked. I could never have written it but I was able to copy past certain portions and change numerical values to serve my purposes. By the end of the assignment, I felt like I understood how the code was executing and I loved that."

At the beginning of this course, this student self-declared that their coding experience was 2 on a scale of 1 (none) to 5 (a lot). They had used Scratch before, coded movement onto robots, and designed a game in a coding camp. By studying the code that "PrimeBot" generated, they learned how the code executes and enjoyed the process. Similarly, other students said that by looking at the code generated by "PrimeBot", they learned about new functions that they did not know existed before.

For other students, “WebDeveloperBot” supported them in becoming familiar with HTML and creating documentation:

> “AI definitely lowered the barrier to entry for HTML for me. I don’t think that I have learned everything that I could have if I didn’t have access to AI, but on the other hand, I wouldn’t have been able to achieve what I have been able to do quickly otherwise. Now that I have a bit of a basis, I feel like I can delve into HTML with a better background than I would have before taking this class due to the way AI lessened the learning curve.”

This student above self-declared that their coding experience was 3 on a scale of 1 to 5. They were familiar with Python and C and had tried to use HTML before. It seems that their basis in other programming languages and prior contact with HTML was in great synergy with their use of “WebDeveloperBot”, which supported them in learning HTML easier and faster.

Besides coding, several students reported that generative AI helped them brainstorm ideas on what to build for their project. For example, a student talked about using generative AI’s help to come up with what animal to build in a project where students built biomimicry projects. The idea that generative AI can support brainstorming is consistent with students’ responses in the pre-survey. However, while the students mostly talked about brainstorming for the purpose of writing in the pre-survey, the students expanded the brainstorming to broader fields including coming up with project ideas in the post-survey

However, students reported one caveat regarding using generative AI for learning: they felt generative AI was less helpful as they got to know more about coding. For example, one student came into the course not knowing Python and had “PrimeBot” generating code for them. As they got to learn more about how codes work and how to code, the code generated by “PrimeBot” required more modification to work how they wanted.

<u>More open to using generative AI to learn</u>

Among the responses to Post-Q6 - “How did this course impact your view of using AI, in both your learning and the field you are interested in pursuing later?”, many students shared a positive shift in their perceptions of using generative AI for learning such as the comment below:

> “I view AI as a much more important thing. I had heard that it would change the world and that it was the future, but now I fully believe it. Whereas previously, I had felt like ChatGPT was an annoying way for people to cheat on homework, I now use it daily or almost daily. I have it give me lessons on a random topic, or I might ask it what I should make for breakfast after listing my available ingredients. I see how valuable it can be and I want to proactively incorporate it into my learning and career. I am very grateful to this course because this mindset shift towards AI might well change my life.”

Similar to what many other students wrote in the responses, this student thought that generative AI was harmful to learning because it would only provide a venue for plagiarism. However, these students now hold a different perspective after the course. For example, the student from the previous quote became proactive in using generative AI to support learning and even support

their daily life. Another student said that because this course "provided a space to experiment and test its limitations in addition to discovering how it may be used in an ethical, helpful way", they came to realize how generative AI can be a useful tool for students and professionals.

More cautious about using generative AI

However, not all students became completely positive about using generative AI. Many students talked about becoming more cautious about using generative AI for learning and engineering.

> "I'd say that it made me a little bit more comfortable using AI as a resource, but at the same time, it also made me more wary of the ways that I used it, particularly when it came to coding. While it can be helpful to get a sense of how to write a program that does what you want it to, especially if you have limited syntax knowledge, it often ends up including things which aren't entirely necessary or overcomplicate things, and if I know what I'm doing, I generally prefer to write things myself, while keeping AI and the internet as a source of knowledge to draw from."

Like this student, many students reflected on their experience using generative AI for coding to form their opinions on using generative AI. They recalled generative AI not always giving them the answers they wanted and needing to adapt the code for their use. A student stressed the importance of "learning with what AI gives you and manipulating it into what you needed to be done." To these students, generative AI can serve as a resource, but one should not rely completely on the code that generative AI provides. Instead, one should learn how to code and cultivate the literacy to evaluate and manipulate what is generated by AI.

Other students expressed their caution about generative AI beyond the context of coding:

> "I was surprised to know it was trained on the entire internet and not like peer review articles or factual information. This definitely makes me more cautious when using it."

The student above learned that ChatGPT was trained on a database that was not verified for its credibility and therefore became cautious about using generative AI as a source. Another student said that they were surprised by generative AI's large carbon footprint because of a conversation they had in class about its environmental impact. Students expressed their general interest in considering the pros and cons of using generative AI for learning and in society in general.

Discussion and conclusion

At the beginning of the semester—their very first at the university—the students' perceptions about using generative AI in education were diverse but did not seem positive in general. Their imagined use of generative AI in education was mostly limited to supplemental work, such as brainstorming acronyms and refining the grammar for writing. They believed that the use of generative AI can impact academic integrity and if one relies too much on generative AI, it can hinder one's learning and development of skills. They did not mention much about the advantages of using generative AI to learn.

We recall that at the beginning of the course when the instructor announced that the students were encouraged to use generative AI for their projects, many students expressed their astonishment. Perhaps this reaction reflected their experiences in K-12 education, where using generative AI for learning carried a negative connotation and was associated with plagiarism.

After the course where the students tinkered and experimented with generative AI for their projects, the students elaborated on more diverse ways generative AI can support learning. They learned that generative AI can support them in getting to know how a certain programming language works and in brainstorming ideas to kickstart their projects. At the same time, they developed more awareness of the drawbacks of generative AI and refined critical views on how to work together with generative AI. Compared to the beginning of the semester, they developed a more nuanced understanding of how they want to use generative AI for their learning and their process of becoming engineers.

Engineering school is where the students develop their identities in the engineering community and their relationships with engineering [7], [11]. Throughout the course "Simple Robotics", we observed the students making sense of what practices people engage in within the engineering community. For example, at the beginning of the semester when they were asked about their perception of using generative AI for education, they mostly discussed practices related to writing. In contrast, at the end of the semester, they expanded their thinking by considering engineering practices such as programming and brainstorming ideas for projects. By experimenting with generative AI in a classroom setting, the students also explored how they would use generative AI with engineering practices.

Although we do not have data to directly associate the students' participation in the course and their shift in perceptions, we know that the other courses these students participated in (e.g. Mathematics, Physics, and Writing) were not designed to provide much space for them to use generative AI. Therefore, we infer that the course "Simple Robotics" provided a venue for students to explore how they can use generative AI for learning. Through the framing of the course activities as tinkering with generative AI, and through the instructor's effort to frame himself also as a learner and to show the students how he experimented with generative AI, the students engaged with open-ended inquiry to construct broader and more nuanced perceptions of generative AI.

Implications and future work

When provided with a venue to tinker with generative AI, the first-year engineering students as engineers-to-be engaged in open-ended inquiry to explore how they would like to use generative AI for their learning and engineering. The tinkering mentality supported the course to have flat power dynamics between the instructor and the students, positioning the instructor and the students to be learners who were "in this together". Throughout this course, we saw that the students constructed a broader and more nuanced understanding of their view on using generative AI. They were empowered to explore and figure out their own views and relationships.

This study contributes to the nascent body of research on generative AI in undergraduate engineering education. It provides initial findings about first-year students' diverse but rather negative perspectives about using generative AI for learning and their shifting perceptions as they develop more nuanced understandings of generative AI. To better understand how to design venues to support this shift, further qualitative research through in-depth interviews with the students and studying classroom video data can be done, guided by these questions: What is the process underlying students constructing their perceptions about generative AI? How did moments in the course support it? What is the role of the instructor in supporting this process?

Furthermore, this study can be conducted with students in engineering schools of other institutions. The student body from this research is from a medium-sized private university in New England, so results may be dependent on the demography. Other considerations may be needed when re-designing introductory engineering courses for a different demographic to tinker with generative AI.

The students' views of and relationships with generative AI will keep developing and may even drastically change as they continue their journey in engineering school. This is also true for their relationships with other tools in engineering. Instead of imposing views on them, engineering schools should support them in grappling with these views with agency and ownership as they will become the future of engineering and will carry the torch to shape the culture of engineering.

References

[1] M. Chui, L. Yee, B. Hall, A. Singla, and A. Sukharevsky, "The state of AI in 2023: Generative AI's breakout year. McKinsey & Company," 2023. Accessed: Jan. 31, 2024. [Online]. Available: https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2023-generative-ais-breakout-year

[2] B. A. Becker, P. Denny, J. Finnie-Ansley, A. Luxton-Reilly, J. Prather, and E. A. Santos, "Programming is hard - or at least it used to be: Educational opportunities and challenges of AI code generation," in *Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 1*, Toronto ON Canada: ACM, Mar. 2023, pp. 500–506.

[3] M. Kazemitabaar, X. Hou, A. Henley, B. J. Ericson, D. Weintrop, and T. Grossman, "How Novices Use LLM-Based Code Generators to Solve CS1 Coding Tasks in a Self-Paced Learning Environment." arXiv, Sep. 25, 2023. Accessed: Jan. 24, 2024. [Online]. Available: http://arxiv.org/abs/2309.14049

[4] K. Roose, "Don't ban ChatGPT in schools. Teach with it. - The New York Times." Accessed: Nov. 22, 2023. [Online]. Available: https://www.nytimes.com/2023/01/12/technology/chatgpt-schools-teachers.html

[5] N. Singer, "Despite cheating fears, schools repeal ChatGPT bans," *The New York Times*, Aug. 24, 2023. Accessed: Dec. 13, 2023. [Online]. Available: https://www.nytimes.com/2023/08/24/business/schools-chatgpt-chatbot-bans.html

[6] Alyson Klein, "Schools Desperately Need Guidance on AI. Who Will Step Up?" Accessed: Jan. 31, 2024. [Online]. Available: https://www.edweek.org/technology/schools-desperately-need-guidance-on-ai-who-will-step-up/2023/11

[7] J. Lave and E. Wenger, *Situated learning : Legitimate peripheral participation*. New York: Cambridge University Press, 1991.
[8] C. McCall, L. D. McNair, and D. R. Simmons, "Advancing from outsider to insider: A grounded theory of professional identity negotiation in undergraduate engineering," *J. Eng. Educ.*, vol. 110, no. 2, pp. 393–413, 2021.
[9] K. L. Meyers, M. W. Ohland, A. L. Pawley, S. E. Silliman, and K. A. Smith, "Factors relating to engineering identity," *Glob. J. Eng. Educ.*, vol. 14, no. 1, 2012.
[10] D. M. Hatmaker, "Engineering identity: Gender and professional identity negotiation among women engineers: identity negotiation among women engineers," *Gend. Work Organ.*, vol. 20, no. 4, pp. 382–396, 2013, doi: 10.1111/j.1468-0432.2012.00589.x.
[11] Y. M. Xu and B. Gravel, "A case study: Making facilitates an engineering student's (re)negotiation with her disciplinary relationships," in *2023 ASEE Annual Conference & Exposition*, Baltimore, Maryland, 2023.
[12] G. M. Quan and A. Gupta, "Tensions in the productivity of design task tinkering," *J. Eng. Educ.*, vol. 109, no. 1, pp. 88–106, Jan. 2020, doi: 10.1002/jee.20303.
[13] M. Berland, T. Martin, T. Benton, C. Petrick Smith, and D. Davis, "Using learning analytics to understand the learning pathways of novice programmers," *J. Learn. Sci.*, vol. 22, no. 4, pp. 564–599, Oct. 2013, doi: 10.1080/10508406.2013.836655.
[14] S. Vossoughi and B. Bevan, "Making and tinkering: A review of the literature." Commissioned paper for Successful Out-of-School STEM Learning: A Consensus Study, Board on Science Education, National Research Council, Washington, DC., Jun. 2014. [Online]. Available: http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_089888.pdf
[15] M. Resnick and E. Rosenbaum, "Designing for tinkerability," in *Design, Make, Play*, M. Honey, Ed., New York: Routledge, 2013, p. 19.
[16] M. Tissenbaum, "I see what you did there! Divergent collaboration and learner transitions from unproductive to productive states in open-ended inquiry," *Comput. Educ.*, vol. 145, p. 103739, Feb. 2020, doi: 10.1016/j.compedu.2019.103739.
[17] B. Bevan, J. P. Gutwill, M. Petrich, and K. Wilkinson, "Learning Through STEM-Rich Tinkering: Findings From a Jointly Negotiated Research Project Taken Up in Practice: LEARNING THROUGH STEM-RICH TINKERING," *Sci. Educ.*, vol. 99, no. 1, pp. 98–120, Jan. 2015, doi: 10.1002/sce.21151.
[18] S. De Freitas and T. Neumann, "The use of 'exploratory learning' for supporting immersive learning in virtual environments," *Comput. Educ.*, vol. 52, no. 2, pp. 343–352, Feb. 2009, doi: 10.1016/j.compedu.2008.09.010.
[19] M. Kazemitabaar, J. Chow, C. K. T. Ma, B. J. Ericson, D. Weintrop, and T. Grossman, "Studying the effect of AI Code Generators on Supporting Novice Learners in Introductory Programming," in *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, Apr. 2023, pp. 1–23. doi: 10.1145/3544548.3580919.
[20] M. Kazemitabaar *et al.*, "CodeAid: Evaluating a Classroom Deployment of an LLM-based Programming Assistant that Balances Student and Educator Needs." arXiv, Jan. 20, 2024. Accessed: Feb. 08, 2024. [Online]. Available: http://arxiv.org/abs/2401.11314
[21] P. M. Khanolkar, M. Gad, J. Liao, A. Hurst, and A. Olechowski, "A pilot study on the prevalence of artificial intelligence in Canadian engineering design curricula," *Proc. Can. Eng. Educ. Assoc. CEEA*, Jun. 2021, doi: 10.24908/pceea.vi0.14919.
[22] M. Z. Naser, "A faculty's perspective on infusing artificial intelligence into civil

engineering education," *J. Civ. Eng. Educ.*, vol. 148, no. 4, p. 02522001, Oct. 2022, doi: 10.1061/(ASCE)EI.2643-9115.0000065.

[23] L. Lyons, M. Tissenbaum, M. Berland, R. Eydt, L. Wielgus, and A. Mechtley, "Designing visible engineering: Supporting tinkering performances in museums," in *Proceedings of the 14th International Conference on Interaction Design and Children*, Boston Massachusetts: ACM, Jun. 2015, pp. 49–58. doi: 10.1145/2771839.2771845.

[24] F. Campos, T. Soster, and P. Blikstein, "Sorry, I Was in Teacher Mode Today: Pivotal Tensions and Contradictory Discourses in Real-World Implementations of School Makerspaces," in *Proceedings of FabLearn 2019*, New York NY USA: ACM, Mar. 2019, pp. 96–103. doi: 10.1145/3311890.3311903.

[25] S. Vossoughi, N. R. Davis, A. Jackson, R. Echevarria, A. Muñoz, and M. Escudé, "Beyond the binary of adult versus child centered learning: Pedagogies of joint activity in the context of making," *Cogn. Instr.*, vol. 39, no. 3, pp. 211–241, Jul. 2021, doi: 10.1080/07370008.2020.1860052.

[26] S. Vossoughi, P. K. Hooper, and M. Escudé, "Making through the lens of culture and power: Toward transformative visions for educational equity," *Harv. Educ. Rev.*, vol. 86, no. 2, pp. 206–232, Jun. 2016, doi: 10.17763/0017-8055.86.2.206.