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Incorporating Artifical Intelligence Concepts and Algorithms into Foundational Engineering Courses

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Abstract

This abstract for a full paper addresses the integration of artificial intelligence (AI) topics into introductory engineering courses. With the proliferation of AI in everyday life, it is important to introduce the topic early in the engineering curriculum. This paper focuses on generative AI and machine learning topics using two different educational strategies. The objective of this research was to explore students' comprehension of AI and their motivation to engage in AI learning after being introduced to AI tools.

In a first-semester project engineering course, generative AI was introduced as a tool. Students were guided on the ethical and effective use of generative AI and were encouraged to discuss its limitations. Students had the option to use generative AI for their writing assignments. A survey instrument was used to assess their previous knowledge and use of generative AI, as well as their understanding of its limitations. A survey was also administered to the students after the writing assignments to evaluate changes in perception, use, and knowledge of generative AI technology.

In a separate introductory multidisciplinary engineering Grand Challenges class, students were presented with complex machine learning algorithms before starting a team project. The learning module introduced AI algorithms in relation to the engineering Grand Challenges specifically in the healthcare field. The module introduced students to fuzzy logic and neural networks using MATLAB™, emphasizing the ethical considerations and appropriate use of AI as a supportive tool rather than a standalone solution. The exercises used simplified examples with limited inputs, allowing students to grasp the complexities involved in using machine learning models to solve real-world problems. For the project, the students worked in teams on innovative future solutions to engineering Grand Challenges problems. The students were given the opportunity to utilize machine learning techniques in their projects. Data was collected through a survey instrument administered before the machine learning module and after the completion of the project. The surveys gauged students' knowledge and understanding of AI concepts and its limitations, and perceptions of how AI tools could address Grand Challenges. The surveys showed growth in the students' interest and knowledge of AI concepts; however, their desire to learn more about AI remained the same or decreased slightly. This paper discusses the results of the surveys from both courses and focuses on the students' perceived learning, their understanding of AI, and their interest in pursuing AI topics in the future.

Introduction

As AI continues to drive advancements in fields like automation, robotics, and data analysis, it is increasingly clear that future engineers must be familiar with AI skills and literacy. By introducing AI into foundational engineering courses, universities can better prepare students for the modern workforce while enhancing their problem-solving abilities. Previously, the study of AI algorithms was mainly a graduate-level topic. With the increase in computing power, the use of software toolboxes to implement algorithms, and access to generative AI, these tools are much more user-friendly. The goal of this research was to encourage students to seek more information

about AI and to realize that AI is useful as a tool, but generally not all-encompassing. For this study, two distinct forms of AI were selected for examination. The first was generative AI, which is increasingly versatile and, anecdotally, improving in capability. The second was machine learning (ML) algorithms, which have grown more powerful with advancements in computing but are also easier to demonstrate and utilize with pre-programmed software. The goal of the study was to introduce these modes of AI as tools for problem-solving, highlight their complexities, and explore ethical considerations and biases stemming from data configuration.

Background

AI has become a fundamental part of the educational curriculum [1]. Its growing importance in recent years drove its integration into diverse fields such as healthcare, finance, and engineering [2]. Educational institutions are increasingly emphasizing AI to assist students with the knowledge and skills necessary for an advancing job market and to prepare them for a future of technological innovations.

A key component of this preparation is advancing AI literacy, which refers to an understanding of the use and applications of AI without necessarily requiring deep technical knowledge [3]. AI literacy helps students effectively communicate, recognize, and solve problems in various contexts [4, 5]. Furthermore, it is vital for facilitating collaboration between humans and machines across learning, life, and work environments [6]. As AI becomes integrated into daily activities and professional fields, developing AI literacy ensures that individuals can adapt and thrive in a world of advancing technologies.

To address the need for AI education, Kong et al. developed a course that introduces concepts such as AI, machine learning, supervised learning, and unsupervised learning in a conceptual manner, avoiding overly technical details [7]. Engaging students with hands-on experiences has proven effective in building AI literacy. For instance, Stone et al. demonstrated that students in a freshman-level engineering class preferred working on a machine learning project, which highlights the value of interactive and project-based learning approaches in promoting deeper engagement and understanding [8]. Faculty must stay up to date with these rapidly changing technologies to familiarize students with the practical applications of AI [9]. By integrating AI into the curriculum and emphasizing both theoretical and practical learning, educational systems can supply students with the skills and knowledge to succeed in a future driven by AI. This approach ensures that individuals are not only consumers of technology but also contributors and collaborators in shaping the future.

Generative AI and Machine Learning

Generative AI was introduced as a tool that uses existing data and information to respond to user inputs to create content like text, images, and videos. While it has many applications it is widely recognized as a natural language processor. Generative AI can be misused to create fake news or images, which can spread misinformation and harm public trust. It may also inadvertently reflect biases present in the data, leading to unfair outcomes. Generative AI also has many benefits. It can save time by automating tasks and promoting innovation by revealing new possibilities. To harness the full potential of generative AI while addressing its challenges, responsible development and ethical use must be emphasized.

Machine learning algorithms include methods such as classification, regression, association rule learning, feature design, and reinforcement learning. These methods enable the creation of data-driven systems, but selecting the appropriate algorithm for a specific application remains a complex and challenging task [10]. Feedforward neural networks are one of the simplest types of artificial neural networks, characterized by a unidirectional flow of information from the input layer to the output layer. They are well-suited for image recognition, speech recognition, signal processing, pattern recognition, and imprecise fields with large datasets. Fuzzy logic is useful in applications where classical binary logic is insufficient. Fuzzy logic enables degrees of truth, enabling more flexible human-like reasoning for rules or processes based on language. AI tools such as neural networks, machine learning algorithms, and natural language processing can help students explore new ways of solving problems to traditional engineering challenges.

Survey Instruments

The research question addressed was: "Does introducing generative AI and AI algorithms to freshman engineering students increase their motivation to use these tools, learn more about them, and understand their limitations?" The hypothesis was that due to the early introduction of AI concepts, students would continue to use and seek out information on AI, while better understanding its limitations. The research method involved administering a pre-survey before students began learning AI concepts, and then a post-survey later in the semester. Relational data in the form of closed-ended questions were gathered from the students through these two surveys.

The data collection method was chosen to assess the students' perceived knowledge, growth, and motivation regarding AI concepts. The research design then centered on existing knowledge and identifying the appropriate questions to ask. A pre-survey was given to establish a baseline assessment of the students' knowledge and interest in AI. Finally, a post-survey was conducted to measure growth compared to the pre-survey.

The questionnaires were created with a standardized survey instrument. All the questions were on a 10-point Likert scale to eliminate a neutral response and ranged from "Strongly Disagree" for 1 to "Strongly Agree" for 10. The questions were all closed-ended, with no open-ended questions or space for comments provided on the survey. The freshman-level project course surveys included a 'N/A' option for students who had never used generative AI. Students were only allowed one answer per question on the numbered scale. The pre-survey was given before the students started the learning module about AI concepts. The post-survey was administered at the end of the project and learning module.

Manzano-Leon et al. created a questionnaire that explored enhanced knowledge content, motivation for the subject matter, and overall enjoyment of the activity [11]. Building on this prior study, three measurement variables were chosen for this research. The three variables measured were the perceived knowledge gained and interest in AI concepts, the experience of using AI, and the interest in using and learning more about AI in the future.

Freshman-Level Project Class

The Foundations of Engineering Design I project course is the first project course engineering students complete in the general engineering curriculum at Arizona State University. The course focuses on the engineering design process through team projects. The students learn about computer modeling, basic electronics, technical writing, teamwork skills, and empathizing with a user. The students in the freshman-level project course were introduced to generative AI as a tool and permitted to use it for their writing assignments. The students were provided with an example essay generated by ChatGPT on the topic of the engineering design process. As a class, we reviewed the essay, analyzing its strengths and identifying areas for correction or improvement. We also explored ways to refine the prompt and discussed potential biases in ChatGPT responses. The pre-survey and post-survey questions are detailed in Figure 1.

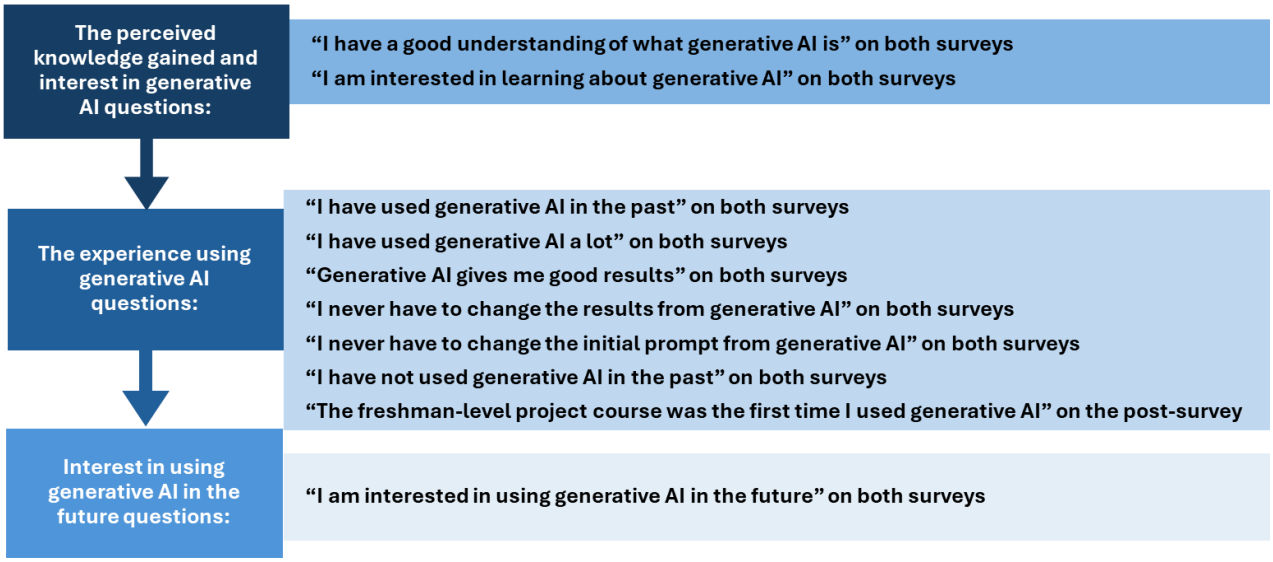

Figure 1: The questions administered on the pre-survey and post-survey aligned with project learning goals for the freshman-level project class.

Data Analysis for Freshman-Level Project Class

The data analysis involved examining the pre-survey and post-survey data and conducting a final analysis to compare both surveys to determine growth in each category. Since the surveys used a Likert scale from 1 to 10, the mean and first and third-quartile values were tabulated for each question. The pre-survey results are shown in Figure 2. The pre-survey was given to 44 students and completed by 41 respondents during the Fall 2024 semester. For 38 of the respondents, this was their first full-time semester in college. The question numbers in Figure 2 refer to the following survey questions labeled by the highlighted keywords:

1. **Understand**: "I have a good understanding of what generative AI is"
2. **Learning**: "I am interested in learning about generative AI"
3. **Use**: "I have used generative AI in the past"
4. **Lot of use**: "I have used generative AI a lot"
5. **Good results**: "Generative AI gives me good results"

6. **Change results**: “I never have to change the results from generative AI”
7. **Change prompt**: “I never have to change the initial prompt from generative AI”
8. **No use**: “I have not used generative AI in the past”
9. **Future**: “I am interested in using generative AI in the future”

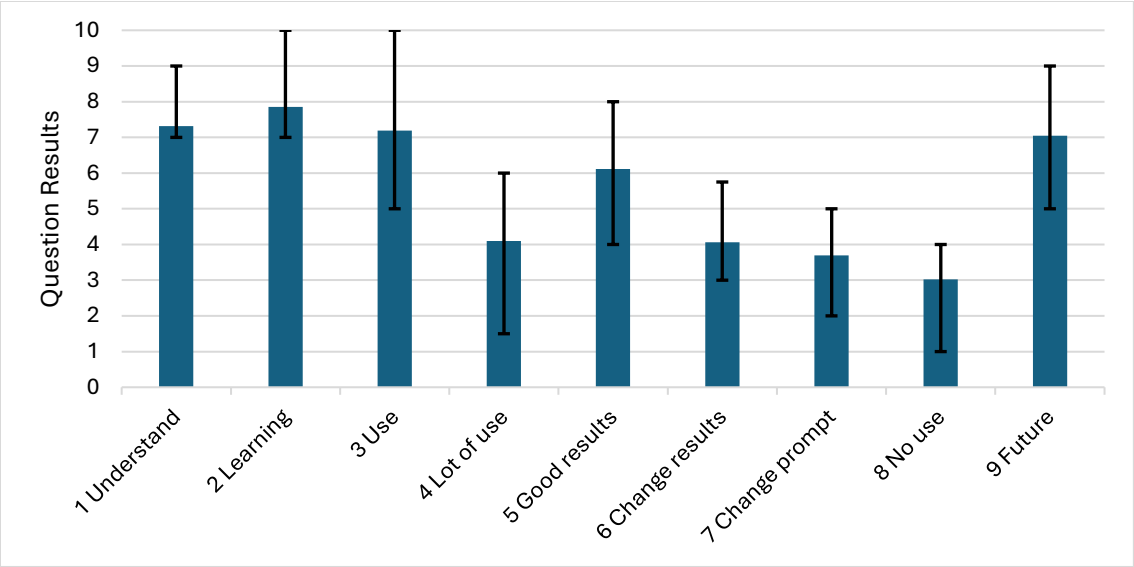

Figure 2: Response to generative AI pre-survey questions with the blue bars indicating the average response and the bar lines indicating the first and third quartile of the responses.

Overall, the students had a good understanding and interest in generative AI (Questions 1 and 2) with average responses of 7.32 and 7.85, respectively. Thirty-three students reported using generative AI in the past, while fewer students indicated frequent use (Question 4). The average response for generative AI providing good results (question 5) was 6.12, while the averages for not changing the results and the initial prompt (questions 6 and 7) were 4.06 and 3.70, respectively. The interest in using generative AI in the future showed a higher response of 7.05.

The post-survey was given to 42 students with 42 respondents after completing the learning module and writing assignments during the Fall 2024 semester. The question numbers in Figure 3 refer to the following questions labeled by the highlighted keywords:

1. **Understand**: “I have a good understanding of what generative AI is”
2. **Learning**: “I am interested in learning about generative AI”
3. **Use**: “I have used generative AI in the past”
4. **Lot of use**: “I have used generative AI a lot”
5. **Good results**: “Generative AI gives me good results”
6. **Change results**: “I never have to change the results from generative AI”
7. **Change prompt**: “I never have to change the initial prompt from generative AI”
8. **No use**: “I have not used generative AI in the past”
9. **Future**: “I am interested in using generative AI in the future”

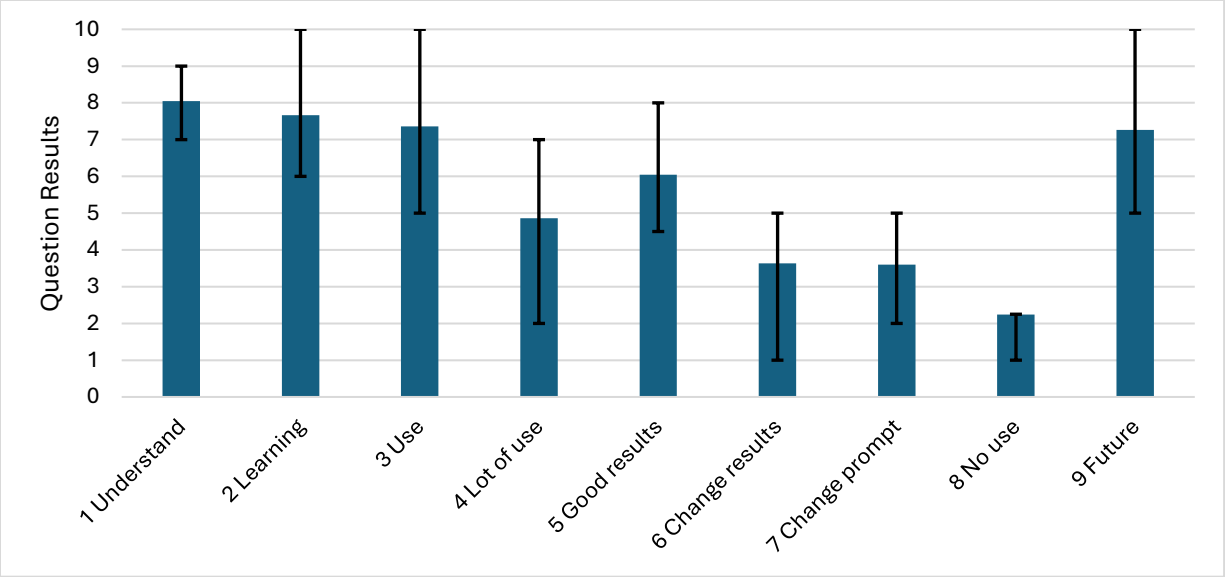

Figure 3: Response to generative AI post-survey questions with the blue bars indicating the average response and the bar lines indicating the first and third quartile of the responses.

Of the nine questions that were on the pre-survey and repeated on the post-survey, the most significant growth was observed in Questions 1 and 4, which measured perceived knowledge gained and the use of generative AI, respectively. Six students used generative AI for the first time during the freshman-level project course writing assignments. Questions 6 and 8 showed a slight drop in average response on the post-survey. The average response to question 6, which asked "I never have to change the results from generative AI" decreased from 4.06 on the pre-survey to 3.63 on the post-survey, with the first quartile dropping from 2 to 1. This indicates that students were reviewing the results and adjusting the output. Question 8 asked "I have not used generative AI in the past" and dropped from 3.02 to 2.24 from the pre-survey to the post-survey. This was also expected since six students used generative AI for the first time on this assignment. Question 2 asking "I am interested in learning about generative AI" had a slight drop from 7.85 on the pre-survey to 7.67 on the post-survey. The interest in learning about generative AI decreased slightly, while the interest in using it increased slightly.

Grand Challenges Class and Artificial Intelligence Learning Module

The Grand Challenges class is a multidisciplinary introductory course on the National Academy of Engineering (NAE) Grand Challenges. In this course, students learn about the fourteen Engineering Grand Challenges emphasizing the fields of health, sustainability, security, and joy of living. The students focused on individual research while collaborating on a team project that addressed future solutions to contemporary challenges. Through the project, the students empathized with a user, determined requirements, brainstormed, researched current and future technologies, determined societal implications, and designed a prototype.

Before the project began, the students were presented with an AI learning module. They were given an overview of AI, computational intelligence (CI), and machine learning. Next, they learned about feedforward neural networks and their application across various industries, including their transformative role in healthcare for imaging and diagnostics. During the class,

we explored bias and ethical concerns in training data and how to mitigate these biases, particularly in the healthcare field. We tackled the issue of data quality and availability and how AI models depend on high-quality, representative data. This highlighted the need to be able to perform data preprocessing skills and validation. Additionally, we discussed the lack of transparency since many AI models are treated as “black boxes”, making it difficult to interpret how decisions are made. Ultimately, we considered how the lack of transparency impacts patient trust in healthcare technology.

As a part of the learning exercise on feedforward neural networks, the students were given a spreadsheet to characterize certain objects by size, color, and shape. The students used MATLAB™ and the Statistics & Machine Learning Toolbox to input the spreadsheet values into the classification learner. The students trained 32 different classifiers to recognize a red apple from the list of random objects, identifying two classifiers with 100% accuracy and five classifiers with accuracy above 90%. The students then had another spreadsheet of data for testing that was slightly different. The students were able to determine that the 100% and the 90% trained classifiers were able to accurately determine the red apple from the testing data. Through this example, students verified that feedforward neural networks were effective at using “messy” data. Next, the students were introduced to fuzzy logic algorithms. Using the fuzzy logic designer in MATLAB™, the students input data ranges for temperature and pulse oximeter values for a patient. Based on the fuzzification rules, the students were able to set outputs as “normal”, “see a doctor”, or “call 911” (refer to Figure 4).

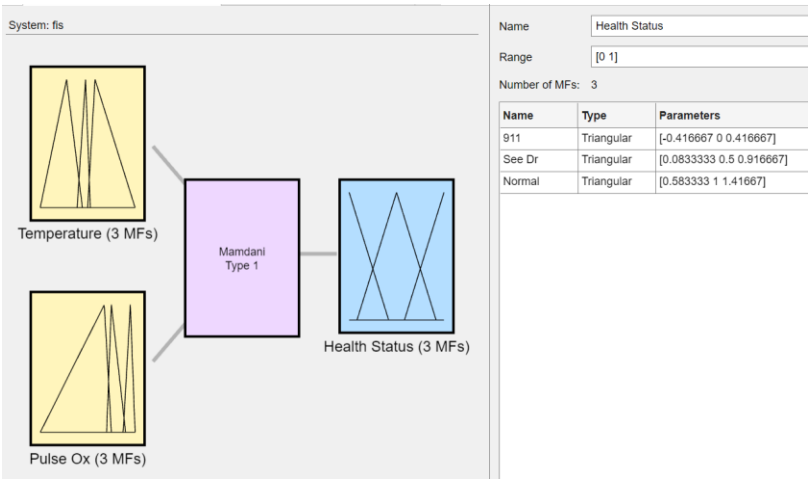

Figure 4: Fuzzy logic designer in MATLAB™ for health status using temperature and pulse oximeter readings.

The Grand Challenges course surveys focused on the perceived knowledge, understanding, and interest in specific AI topics and algorithms. The pre-survey and post-survey questions are detailed in Figure 5.

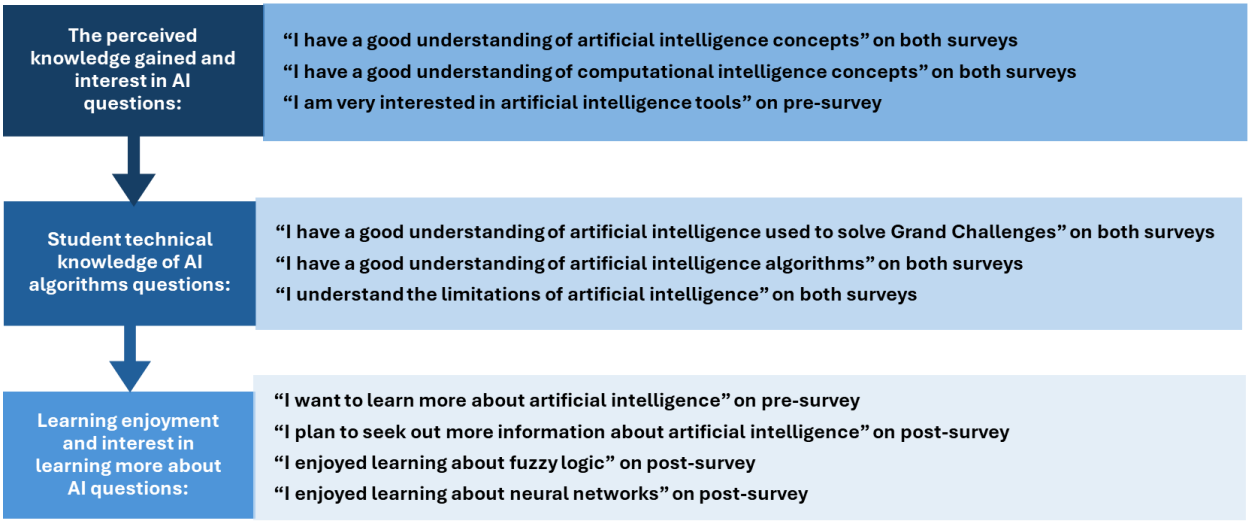

Figure 5: The questions administered on the pre-survey and post-survey aligned by project learning goals for the Grand Challenges class.

Data Analysis for Grand Challenges Class

The pre-survey results are shown in Figure 6. The pre-survey was administered to 18 students, all of whom completed the survey during the Fall 2024 semester. For 12 of the 18 students, it was their first full-time semester in college. The question numbers in Figure 6 refer to the following questions labeled by the highlighted keywords:

1. **Understand AI**: "I have a good understanding of artificial intelligence concepts"
2. **Understand CI**: "I have a good understanding of computational intelligence concepts"
3. **Tools**: "I am very interested in artificial intelligence tools"
4. **Grand Challenges**: "I have a good understanding of artificial intelligence used to solve Grand Challenges"
5. **Algorithms**: "I have a good understanding of artificial intelligence algorithms"
6. **Limitations**: "I understand the limitations of artificial intelligence"
7. **Learn**: "I want to learn more about artificial intelligence"

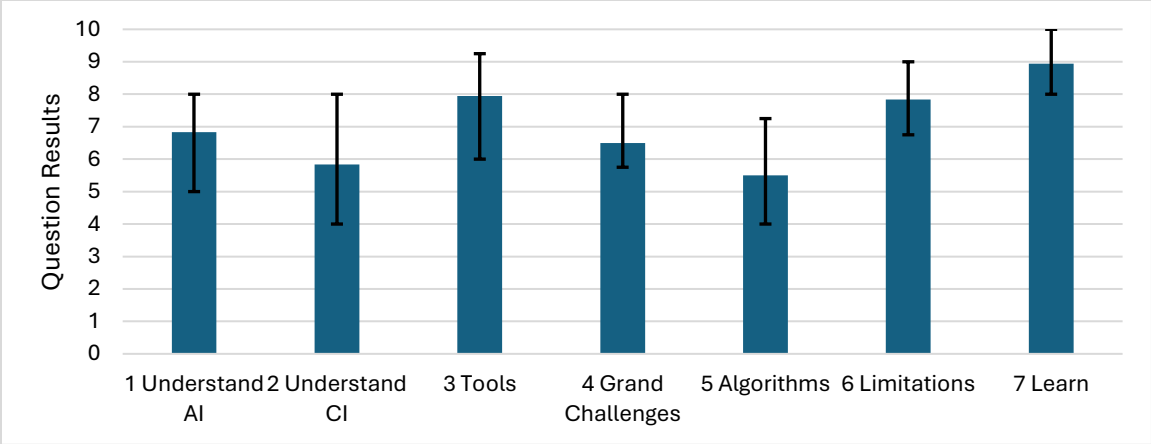

Figure 6: Response to Grand Challenges AI concepts pre-survey questions with the blue bars indicating the average response and the bar lines indicating the first and third quartile of the responses.

In the pre-survey, the students demonstrated a fairly high perceived understanding of AI and CI concepts with average responses of 6.83 and 5.83 respectively, and a very high interest in AI tools with an average response of 7.94. Their perceived knowledge of how to use the tools was lower, with average responses of 6.5 and 5.5 for questions 4 and 5. The average response for perceived knowledge of AI limitations was 7.83. The desire to learn more about AI had the highest average response, at 8.94, with an upper quartile of 10.

The post-survey was given to 18 students, all of whom responded, after completion of the project during the Fall 2024 semester. The question numbers in Figure 7 refer to the following questions labeled by the highlighted keywords:

1. **Understand AI**: “I have a good understanding of artificial intelligence concepts”
2. **Understand CI**: “I have a good understanding of computational intelligence concepts”
3. **Tools**: “I am very interested in artificial intelligence tools”
4. **Grand Challenges**: “I have a good understanding of artificial intelligence used to solve Grand Challenges”
5. **Algorithms**: “I have a good understanding of artificial intelligence algorithms”
6. **Limitations**: “I understand the limitations of artificial intelligence”
7. **Seek**: “I plan to seek out more information about artificial intelligence”
8. **Enjoy FL**: “I enjoyed learning about fuzzy logic”
9. **Enjoy NN**: “I enjoyed learning about neural networks”

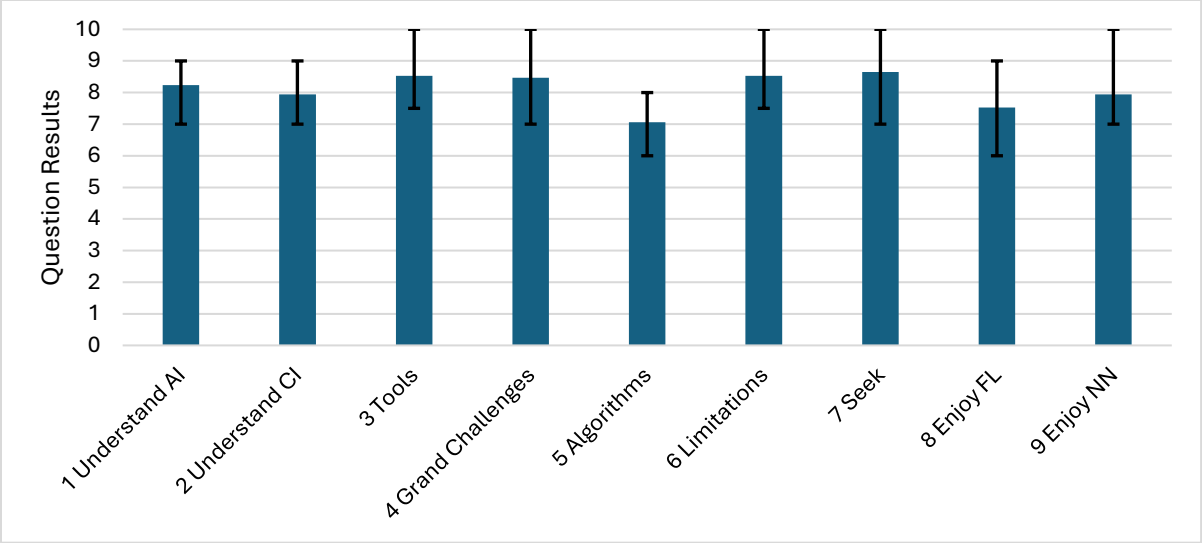

Figure 7: Response to Grand Challenges AI concepts post-survey questions with the blue bars indicating the average response and the bar lines indicating the first and third quartile of the responses.

The first six questions all showed growth, with the understanding of CI concepts and the use of AI showing the most growth on questions 2 and 4. The interest in artificial intelligence tools (question 3) and the understanding of its limitations (question 6) both had increased responses of 7.94 to 8.53 and 7.83 to 8.53, respectively. There was a slight decrease in question 7 on the post-survey. The pre-survey asked, "I want to learn more about AI," while the post-survey followed up with, "I plan to seek out more information about AI". The average response dropped from 8.94 to 8.65, while the third quartile remained at 10 for both questions. The average responses to questions 8 and 9 regarding the enjoyment of learning about fuzzy logic and neural networks were high with responses of 7.53 and 7.94, respectively.

Anecdotally, one team used AI algorithms, specifically neural networks for their project to look at metrics for determining an early diagnosis of Huntington's disease. As a part of the project, the students researched and presented the ethical concerns of using AI in healthcare, along with the societal impact and patient perceptions of the technology. One student specifically joined this team after the in-class presentation using MATLAB™ to solve health-related issues. Another student was enlightened by the fact that AI could be used for more than just "answering questions and writing assignments," but also for adapting to learning styles in education and for medical diagnoses.

Overall Results

The results from this study revealed several key implications for the integration of AI education into engineering curricula, underscoring the importance of both generative AI tools and computational AI concepts as resources in engineering education. Overall, students were able to gain a broader understanding of AI as a tool. The observed growth in understanding AI concepts and algorithms across both classes indicated that early exposure to AI technologies enhanced students' AI literacy. By presenting practical applications in real-world scenarios, students gained a clearer understanding of how AI can be leveraged to address complex engineering challenges.

For example, in the Grand Challenges course, shown in Figure 8, the significant improvement in understanding AI concepts (from 6.83 to 8.24 in question 1), computational intelligence concepts (from 5.83 to 7.94 in question 2), and AI algorithms (from 5.50 to 7.06 in question 5) suggests that introducing theoretical and hands-on learning opportunities bridges the gap between theoretical AI concepts and practical problem-solving techniques.

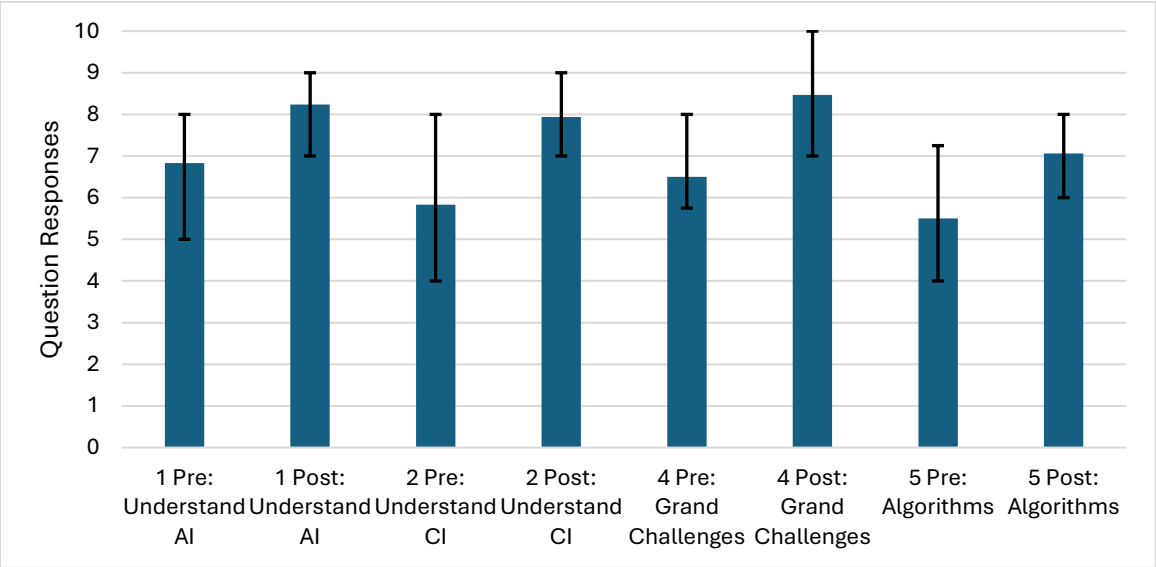

Figure 8: Grand Challenges AI concepts pre-survey and post-survey responses for **Understand AI**: good understanding of AI concepts, **Understand CI**: a good understanding of computational intelligence concepts, **Grand Challenges**: a good understanding of AI used to solve Grand Challenges, and **Algorithms**: a good understanding of AI algorithms.

Integrating AI into coursework, particularly in the Grand Challenges course, enabled students to apply AI techniques to address Grand Challenges in health. The growth in understanding how AI can be used to solve Grand Challenges (from 6.50 to 8.47 in question 4), as shown in Figure 8, reflects the potential of such modules to prepare students for careers requiring both technical expertise and the ability to address societal ramifications.

Students' improved understanding of AI limitations (from 7.83 to 8.53, question 6 from Figures 6 and 7) highlights the importance of teaching the constraints and ethical considerations associated with AI use. Addressing these topics in class equips students with a balanced perspective, helping them navigate issues such as bias, accountability, and societal impact. These insights are especially critical as AI becomes increasingly integrated into sensitive domains like healthcare, where the consequences of misuse or overreliance can be significant.

In the freshman-level project course, there was growth in the understanding of generative AI after the completion of the learning module, however, slight since 80% of the students had previously used the technology. Even with that "I have a good idea of what generative AI is" increased from 7.32 to 8.05, and "I am interested in using generative AI in the future" increased from 7.05 to 7.26, with an upper quartile increase from 9 to 10, as shown in Figure 9. Increased confidence in using generative AI tools was evident, with students not only using these technologies but also refining prompts and results before assignment submission. This

interaction with the responses demonstrated participation with AI as a collaborative tool rather than a static solution. Such practices prepare students to assess AI outputs critically and adapt them to specific contexts. While there was slight growth in future interest in using generative AI and AI tools, the slight decline in planning to seek additional information about AI concepts in both courses could be from normal survey response variability or could suggest confidence brought about by a better understanding of the AI topics.

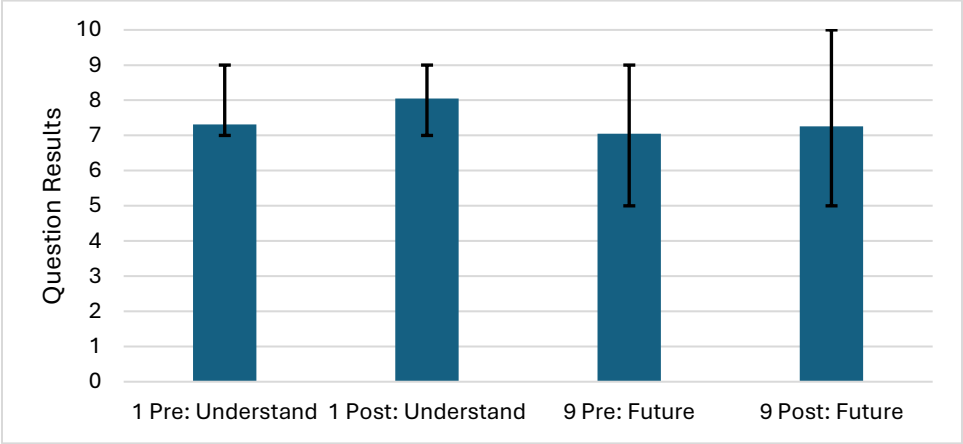

Figure 9: Generative AI pre-survey and post-survey responses for **Understand**: good understanding of generative AI and **Future**: interested in using generative AI in the future.

This research demonstrated that integrating AI into foundational engineering courses not only assisted with developing technical knowledge but also supported adaptability and critical thinking. Exposing students to both generative AI and computational AI concepts early in their academic journey provided a strong foundation for future learning and application, aligning with the goal of enabling engineering graduates with innovative skill sets for the future.

Conclusion

The integration of AI and generative AI tools into engineering education has demonstrated significant potential to enhance students' understanding, confidence, and interest in these technologies. The data from the freshman-level project course and the Grand Challenges course reveal that while many students had some prior exposure to AI, structured modules and assignments substantially deepened their understanding and practical application of AI tools.

The surveys revealed a notable increase in students' perceived knowledge of AI concepts, computational intelligence, and algorithms, particularly in the Grand Challenges course, where a focus on using AI to address Grand Challenges enriched their learning experience. Similarly, in the freshman-level project course, the introduction of generative AI not only supported technical writing, but also encouraged critical thinking and adaptive use of the AI outputs. These findings show the importance of incorporating AI-focused activities early in the curriculum to build foundational AI literacy.

Future work is planned to include assessments in future classes to review results with a larger sample size and to also expand AI integration into core engineering courses. By embedding AI technologies into assignments and making them integral to project requirements, students can

develop a more sophisticated understanding of how AI tools complement traditional engineering methods. Future work will also include incorporating these basic AI techniques into a computer modeling class, where they will be integrated with other strategies to help students assess the strengths and weaknesses of the tools in different examples. Through the progression of the class, the students will be able to analyze the limitations of AI and propose refinements. Changes to the assessment will include how well students critically evaluate AI outputs, rather than just their ability to use AI tools, and asking students to justify why a particular AI model's accuracy might not be sufficient and how they would mitigate risks.

Early introduction to AI concepts improves AI literacy and problem-solving skills, preparing students for a future where AI plays a critical role in engineering practice. By providing early exposure to AI technologies and developing a mindset of adaptability and innovation, universities can prepare their engineering students with the tools necessary for success.

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