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Generative Artificial Intelligence for Enhanced Engineering Education; Strengths, Challenges and Validation

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Abstract

In today's rapidly evolving technological landscape, there is a pressing need to explore innovative approaches that leverage Generative Artificial Intelligence (AI) and Augmented/Mixed Reality (AR/MR) to enhance engineering education. This study investigates students' perceptions, familiarity, and opinions on generative AI and AR/MR technologies in engineering and beyond. We surveyed graduate and undergraduate students from the Civil and Mechanical Engineering departments to examine the strengths and challenges of AI in the engineering field. Additionally, exams and homework assignments were utilized to assess the accuracy of AI in solving engineering problems. The selected courses for this study included Advanced Fluid Mechanics (graduate course) and Thermodynamics from the Mechanical Engineering department as well as Transportation Engineering, Highway Engineering, and Concrete and Asphalt Lab from the Civil Engineering department. A total of 72 students participated in the study. Based on the results, we provide suggestions and recommendations to enhance the integration of AI and VR into engineering education, addressing potential challenges and opportunities for future development.

Introduction

Artificial intelligence (AI) is widely regarded as one of the most transformative inventions of the 21st century, with applications spanning diverse domains, including education. The rapid evolution of AI has introduced new opportunities and challenges in educational systems [1]. Properly integrated AI technologies have the potential to enhance student learning, assist instructors with innovative teaching tools, and improve overall educational outcomes. However, like any technology, AI's misuse or improper application can lead to unintended consequences, such as undermining learning objectives or fostering academic dishonesty [2].

Generative AI refers to algorithms that can produce new content, including text, images, and designs, by learning from existing data available in online sources. In the context of engineering education, Generative AI has been explored for its potential to revolutionize content delivery and curriculum design. For instance, a study by Anderson, president of the National Academy of

Engineering [3], discusses how Generative AI can enhance human creativity and effectiveness in engineering education, emphasizing the need for appropriate guardrails to mitigate potential negative byproducts such as misinformation and bias. Furthermore, the integration of Generative AI in teaching and learning processes within Information and Communication Technologies (ICT) engineering education has been reviewed, highlighting its potential to enhance educational practices in engineering contexts [4].

Generative AI tools, such as OpenAI's ChatGPT and DALL·E, have been utilized to support diverse educational needs, including content creation, question generation, and adaptive learning environments. For instance, generative AI can create dynamic learning modules tailored to individual student needs, enabling differentiated instruction and addressing varying levels of prior knowledge [5,6]. This personalization is particularly valuable in engineering education, where students often face challenges in grasping complex concepts. In addition to personalized instruction, generative AI aids instructors by automating administrative tasks, such as grading and feedback provision. Automated grading tools powered by AI can evaluate assignments and exams efficiently while providing detailed feedback, allowing instructors to focus more on teaching and mentoring [7].

This study aims to explore students' perceptions of AI, their familiarity with various AI tools, and their frequency of use in academic and daily life contexts. Additionally, we evaluate the accuracy and precision of popular AI platforms in solving engineering problems. Addressing this aspect is critical, as AI in academic settings could potentially serve as a shortcut for solving assignments and homework rather than a tool to enhance learning. Furthermore, we investigate whether noticeable patterns exist in solutions provided by AI compared to those completed by humans. Understanding these patterns is vital to ensure that AI supports, rather than undermines, the integrity and efficacy of education systems.

Survey

We conducted a survey involving 72 undergraduate and graduate students from the Civil, Environmental, and Construction and Mechanical Engineering Departments at a teaching focused institution to gain insights into their perceptions of AI. The survey aimed to explore several key areas, including the students' familiarity with AI, their use of specific AI tools, perceived strengths and challenges of AI, and their awareness of emerging virtual reality technologies such as Apple Vision Pro. Of the 72 participants, 26 were undergraduate students majoring in Mechanical Engineering, 43 were undergraduate students majoring in Civil Engineering and 3 were graduate students pursuing a master's degree in mechanical engineering. The survey questions are shown in Table 1.

Table 1. Survey questions

1. In your own words, how would you describe Artificial Intelligence (AI)?
2. Which AI tools or websites do you use most often?
3. What purposes do you primarily use AI tools for?
4. When using AI, do you double-check the accuracy of the answers/information given? If yes, how?
5. Have you used AI tools in teamwork or research projects? If yes, which part of your project benefited the most from AI tools?
6. What are the biggest challenges or shortcomings you've experienced with AI tools?
7. What are your top 5 search tools?

Survey Analysis

In the following sections, we analyze the responses to each question to gain a detailed understanding of the participants' perspectives.

Question 1: In your own words, how would you describe Artificial Intelligence (AI)?
When asked to describe Artificial Intelligence (AI) in their own words, the responses from participants revealed a wide range of perceptions, reflecting both positive and negative views of the technology. The majority of participants (36%) described AI as a tool designed to enhance efficiency and assist with tasks. Many respondents highlighted its ability to save time, streamline research, and improve productivity in academic and professional settings. Phrases such as "a helpful tool," "a way to quickly search content," and "a tool that enhances daily life" were frequently mentioned. 31% of responses likened AI to an advanced search engine or a program that processes and synthesizes large amounts of data. Participants noted its ability to provide rapid responses and summarized information from various sources on the internet. However, concerns about the accuracy and reliability of this information were also raised. 19% of the participants pointed out the limitations of AI, describing it as "unreliable," "inaccurate," or "not entirely a trusted source." Concerns were also expressed regarding AI's inability to generate truly creative or original content, with some respondents noting that it "summarizes" rather than "creates." Others cautioned about potential misuse in academic settings, where reliance on AI might discourage critical thinking and effort. Finally, some responses, about 10%, also reflected curiosity and apprehension about AI's future impact and while some saw it as a "fast-growing and multifaceted tool" with "limitless potential," others expressed concerns about its rapid development, potential misuse, and ethical implications. Notably, a few students mentioned fears about AI replacing human jobs or concentrating power and wealth.

Question 2: Which AI tools or websites do you use most often?

ChatGPT and Grammarly are the most commonly used AI tools among participants, with 75% and 65% of respondents, respectively, reporting regular usage. These tools were often mentioned together, with 57% of participants highlighting their combined use for academic and professional tasks, such as idea generation, grammar checking, and simplifying complex assignments. Beyond these two popular tools, a small percentage of respondents (3%) indicated using specialized AI platforms like GitHub Copilot for coding assistance and Mendeley for research management. Other tools, including DALL-E and Symbolab, were each mentioned by 1% of respondents, reflecting limited adoption. Notably, 10% of participants reported not using any AI tools, citing unfamiliarity or a lack of perceived value. A few respondents also mentioned leveraging AI-integrated search functions, such as Google AI, to summarize results or assist with research.

Question 3: What purposes do you primarily use AI tools for?

The primary purposes for which participants use AI tools varied significantly. A majority (65%) of students reported using AI for generating ideas, making it the most common application. Similarly, learning new concepts was identified by 50% of participants as a key purpose, emphasizing AI's role in simplifying complex material. Analyzing data and brainstorming project ideas were each cited by 35% of respondents, while 25% used AI for solving homework problems, and 20% mentioned AI's role in writing reports or essays, with specific emphasis on improving grammar and flow. Entertainment and shopping were less frequently mentioned, with 15% and 10% of respondents citing these purposes, respectively. A small portion (5%) indicated they avoid using AI tools altogether, underscoring varying levels of adoption and familiarity among students.

Question 4: When using AI, do you double-check the accuracy of the answers/information given? If yes, how?

A majority of respondents (72%) reported that they double-check the accuracy of information provided by AI. Common methods include comparing AI responses to trusted online sources (45%) or verifying with class notes and textbooks (30%). Others mentioned using AI-generated information as a starting point and corroborating it with Google searches or consulting additional references. However, 18% of participants stated they do not double-check AI outputs, either due to infrequent usage or reliance on AI for tasks like grammar correction, which they perceive as less error-prone. Notably, several respondents expressed mistrust in AI's accuracy, citing instances where AI provided incorrect or misleading information, particularly for technical tasks such as solving equations or debugging code.

Question 5: Have you used AI tools in teamwork or research projects?

When asked about using AI tools in teamwork or research projects, students were almost evenly split. 48% of participants reported using AI in collaborative settings, while 52% indicated they had not. Among those who used AI in projects, the most common applications included brainstorming and organizing ideas (25%), writing and grammar corrections (20%), and researching and analyzing data (15%). A smaller group mentioned using AI for formatting reports or generating outlines to enhance the clarity and structure of their work. These findings suggest that while AI is used in collaborative academic tasks, there remains potential for broader adoption in teamwork and research contexts.

Question 6: What are the biggest challenges or shortcomings you've experienced with AI tools?

The most frequently cited challenge with AI tools was inaccuracy, mentioned by 40% of respondents. Participants noted that AI often produces incorrect or misleading information, particularly when solving complex problems or interpreting ambiguous prompts. Lack of contextual understanding was another common issue, reported by 25% of participants, with several describing difficulties in getting AI to generate precise or relevant answers. Additionally, 20% expressed concerns about AI's tendency to "make up" information, highlighting the need for careful verification. Smaller groups mentioned limitations such as daily usage caps (5%), challenges in understanding math order of operations (5%), and ethical concerns about overreliance on AI tools (5%). Again, 10% of participants indicated they had not encountered significant challenges due to their minimal or specific usage of AI.

Question 7: What are your top 5 search tools?

Google was the dominant search tool, used by 95% of respondents. Other frequently mentioned tools included Safari (25%), ChatGPT (20%), and YouTube (15%), with these platforms often used in conjunction with Google for specific purposes like video tutorials or generating responses to complex queries. Tools such as Bing, Firefox, and research databases (e.g., library websites, Google Scholar) were cited by 10% of participants. Interestingly, 5% of respondents mentioned social media platforms like Reddit and Instagram as supplementary tools for informal searches.

Overall, it seems that the majority of students have adopted mainstream AI tools like ChatGPT and Grammarly reflecting their value in enhancing productivity and academic performance. However, concerns about accuracy and ethical usage persist, with many students realizing the need to verify AI outputs. While AI is increasingly used for individual tasks, its integration into teamwork and research projects remains limited. Additionally, a lack of familiarity with specialized AI tools suggests an opportunity to improve AI literacy and expand its applications in educational settings.

Validation

As one of the main concerns raised by students was the accuracy and precision of AI tools, particularly in solving engineering problems and that ChatGPT was one of most popular and widely used AI tools, this section evaluates its performance in addressing that concern. This issue is also of particular importance to educators, considering that 31% of student survey participants reported using AI to assist with homework problems, which are typically designed to engage students with course materials and reinforce learning outside the classroom.

To investigate the accuracy of AI in solving homework problems, we selected problems from Advanced Fluid Mechanics and Thermodynamics given their intensity in mathematical calculations. For each course, one exam and one homework assignment were selected. ChatGPT was then used to solve those problems. The solutions were graded using the same criteria that instructors use to evaluate student submissions. The problem statements and evaluation results are provided in Tables 2 through 5.

Table 2. Thermodynamics homework 6, undergraduate course in Mechanical Engineering

Problem 1. An inventor claims to have developed a power cycle operating between hot and cold reservoirs at 1175 K and 295 K, respectively, that provides a steady state power output of (a) 28 kW, (b) 31.2 kW, while receiving energy by heat transfer from the hot reservoir at the rate 150,000 kJ/h. Evaluate each claim.

Problem 2. At steady state, a refrigeration cycle operating between hot and cold reservoirs at 300 K and 275 K, respectively, removes energy by heat transfer from the cold reservoir at a rate of 600 kW.

a) If the cycle's coefficient of performance is 4, determine the power input required, in kW.
b) Determine the minimum theoretical power required, in kW, for any such cycle.

Problem 3. By supplying energy at an average rate of 24,000 kJ/h, a heat pump maintains the temperature of a dwelling at 20˚C. If electricity costs 8.5 cents per kW-h, determine the minimum theoretical operating cost for each day of operation if the heat pump receives energy by heat transfer from

a) the outdoor air at -7˚C.
b) the ground at 5˚C.

Graded Problem	Points obtained	Area of weakness	Comments
Problem 1	10/30	Conceptual error, wrong conclusion	method was correct
Problem 2	30/30		Solved correctly
Problem 3	40/40		Solved correctly
Total	**80/100**	Letter grade of **B**	

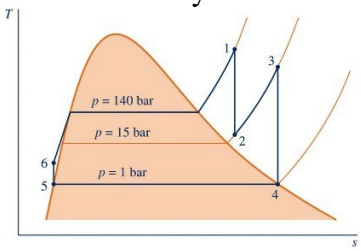
Table 3. Thermodynamics final exam, undergraduate course in Mechanical Engineering

Problem 1. Steam enters an adiabatic turbine operating at steady-state at 100 bar and 700ºC and leaves at 1 bar with a quality of 97 percent. The mass flow rate of the steam is 12 kg/s. Neglecting changes in kinetic and potential energies, determine the power output from this turbine.

Problem 2. Nitrogen is compressed adiabatically (Q=0) in a piston-cylinder device from 100 kPa and 17ºC to 600 kpa and 227ºC. Assume nitrogen is an ideal gas with constant specific heat capacities; C_p=1.04 kJ/(kg.K) & C_v=0.7425 kJ/(kg.K) calculate work done on the nitrogen in kJ/kg and the entropy change during this process, in kJ/kg.K?

Problem 3. In a vapor-compression refrigeration cycle, ammonia exits the evaporator as a saturated vapor at -22˚C. The refrigerant enters the condenser at 16 bar and 160˚C, and saturated liquid exits at 16 bar. There is no significant heat transfer between the compressor and its surroundings, and the refrigerant passes through the evaporator with a negligible change in pressure. If the refrigerating capacity is 150 kW, Determine the mass flow rate of the refrigerant, in kg/s, the power input to the compressor, in kW, the coefficient on performance, the isentropic compressor efficiency, the rate of entropy production, in kW/K, for the compressor?

Problem 4. Steam is the working fluid in the ideal reheat cycle shown below together with the operational data. If the mass flow rate is 3.6 kg/s, determine the power developed by the cycle, in kW, and the cycle thermal efficiency.



State	p (bar)	T (°C)	h (kJ/kg)
1	140	520.0	3377.8
2	15	201.2	2800.0
3	15	428.9	3318.5
4	1	99.63	2675.5
5	1	99.63	417.46
6	140		431.96

Problem 5. Moist air at dry bulb temperature of 40 ºC and wet bulb temperature of 30 ºC enters a dehumidifier operating at steady state with a volumetric flow rate of 325 m^3/min. The moist air passes over a cooling coil and water vapor condenses. Condensate exits the dehumidifier at 18 ºC. Saturated moist air exits in a separate stream at the same temperature (18 ºC). There is no significant loss of energy by heat transfer to the surroundings and pressure remains constant at 1atm (101.3 kPa). Find the mass flowrate of the dry air in kg/min, find the rate at which water is condensed in kg/min?

Graded Problem	Points obtained	Area of weakness	Comments
Problem 1	17/20	Algebraic error	Method was correct
Problem 2	10/20	Wrong equation for work	Method was correct
Problem 3	6/20	Read wrong numbers from tables	Method was correct
Problem 4	13/20	Wrong equation for heat transfer in boiler	Method was not correct
Problem 5	9/20	Read wrong numbers from tables, conceptual error about psychrometric chart	Method was correct
Total	**55/100**	Letter grade of **F**	

Table 4. Advanced Fluid Mechanics homework 9, graduate course in Mechanical Engineering

Problem 1. An inventor claims to have developed a power cycle operating between hot and cold reservoirs at 1175 K and 295 K, respectively, that provides a steady state power output of (a) 28 kW, (b) 31.2 kW, while receiving energy by heat transfer from the hot reservoir at the rate 150,000 kJ/h. Evaluate each claim.

Problem 2. At steady state, a refrigeration cycle operating between hot and cold reservoirs at 300 K and 275 K, respectively, removes energy by heat transfer from the cold reservoir at a rate of 600 kW.

c) If the cycle's coefficient of performance is 4, determine the power input required, in kW.
d) Determine the minimum theoretical power required, in kW, for any such cycle.

Problem 3. By supplying energy at an average rate of 24,000 kJ/h, a heat pump maintains the temperature of a dwelling at 20˚C. If electricity costs 8.5 cents per kW-h, determine the minimum theoretical operating cost for each day of operation if the heat pump receives energy by heat transfer from

c) the outdoor air at -7˚C.
d) the ground at 5˚C.

Graded Problem	Points obtained	Area of weakness	Comments
Problem 1	30/30		Solved correctly
Problem 2	25/30	Correct equations, wrong conclusion, algebraic error	Method was correct
Problem 3	0/40	Wrong equations	Method was not correct
Total	**55/100**	Letter grade of **F**	

Table 5. Advanced Fluid Mechanics final exam, graduate course in Mechanical Engineering

Problem 1. Consider the case of laminar flow over a plate of unit width W and length L in a uniform flow of magnitude U. A boundary layer forms. For simplicity, assume the velocity profile has a quadratic form: $\frac{u(y)}{U_\infty} = 2\eta + \eta^2$ where $\eta = \frac{y}{\delta}$

Using control volume considerations, find the mass flow ejected out from the boundary layer between the leading edge of the plate and length L? Find the relationship between the displacement thickness and the boundary layer thickness?

Problem 2. A laminar boundary layer velocity profile is approximated by

$$\begin{cases} \frac{u}{U_\infty} = \left[2 - \left(\frac{y}{\delta}\right)\right]\left(\frac{y}{\delta}\right) & y \le \delta \\ u = U_\infty & y > \delta \end{cases}$$

(a) Show that this profile satisfies the appropriate boundary conditions.

(b) Use the momentum integral equation to determine the boundary layer thickness,

Problem 3. Two immiscible, incompressible, viscous fluids having the same densities but different viscosities are contained between two infinite, horizontal, parallel plates. The bottom plate is fixed and the upper plate moves with a constant velocity *U*. Determine the velocity at the interface. Express your answer in terms of *U*, μ_1 and μ_2. The motion of the fluid is caused entirely by the movement of the upper plate; that is, there is no pressure gradient in the *x* direction. The fluid velocity and shearing stress are continuous across the interface between the two fluids. Assume laminar flow.

Problem 4. A semi-cylindrical 2D body is situated within an incompressible, inviscid uniform flow of strength U_∞. The cylinder has a radius R. The pressure on the upstream cylinder surface is given by the solution for uniform flow+doublet flow, $F(z) = U_\infty(z + \frac{R^2}{z})$. The upstream pressure is designated as P_∞. The pressure on the downstream cylinder surface is constant and specified to equal the inviscid pressure value corresponding to P(R,90º). Find an expression for the cylinder pressure over $(\frac{\pi}{2} < \theta < \frac{3\pi}{2})$? What is drag force for the object?

Graded Problem	Points obtained	Area of weakness	Comments
Problem 1	10/25	Did not understand the problem, solved partially. Algebraic error	Wrong method
Problem 2	15/25	Wrong equation, conceptual error	Wrong method
Problem 3	5/25	Wrong equation	Wrong method
Problem 4	5/25	Wrong equation & derivation	Wrong method
Total	**35/100**	Letter grade of **F**	

Discussion

Although many AI tools are available, and this number is increasing every day, students primarily reported using or being aware of the most prominent ones: ChatGPT, Grammarly, Gemini and GitHub Copilot. This highlights the need for educators to introduce AI tools in the classroom to familiarize students with their potential benefits in their careers or daily lives. Students who leverage these tools can complete tasks more efficiently, effectively, and even innovatively. Equipping students with such tools will also make them competitive in the job market, similar to how software skills have consistently appealed to recruiters.

AI is primarily used to generate new ideas or learning about different topics. A small percentage of students mentioned using AI for other purposes like scheduling and shopping. This shows that despite AI's extensive capabilities, AI use is still limited to a few specific tasks. One major concern and skepticism among students was the accuracy of AI generated results. This skepticism was supported by our validation study of AI's performance in solving somewhat complex engineering homework and exam problems. The study revealed that AI correctly solved only 20% of problems. In 40% of the cases, the solution method was entirely incorrect and in another 40%, while the approach was initially correct, errors occurred at some stage in the solution process. Additionally, AI often struggled to fully understand problem statements, failing to interpret tested problems accurately. Based on these findings, we suggest that AI be used primarily to get some initial thoughts or ideas, as it frequently provides an accurate outline for the solution. However, students should be encouraged to critically evaluate and refine AI-generated suggestions to ensure accuracy. Moreover, our investigation found no noticeable patterns in AI solutions that could differentiate them from human-generated solutions. AI made various types of errors, including algebraic errors, wrong interpretations and conclusions, wrong approaches, miscalculated derivatives, and misreading data from tables.

Finally, as indicated by the survey, one immediate area where AI can be utilized is helping students enhance their creativity. Creativity and experience are vital to the design process, particularly in generating innovative ideas and solutions. AI can support students by providing multiple suggestions and alternatives, fostering their ability to think creatively.

Conclusions

This study highlighted that students primarily use well-known AI tools such as ChatGPT and Grammarly, with limited awareness or usage of other tools like Gemini and GitHub Copilot. The primary functions of AI for students were generating new ideas, learning new concepts, solving homework problems, analyzing data, entertainment, and proofreading. However, a significant concern among students was the accuracy and reliability of AI tools. Nearly 40% of respondents

reported that they routinely double-check AI-generated results using alternative sources, indicating a lack of complete trust in AI outputs.

In the second part of this research, we assessed the accuracy of AI (ChatGPT) in solving engineering problems in Thermodynamics (undergraduate) and Advanced Fluid Mechanics (graduate). For each course, one exam problem and one homework assignment were selected, and ChatGPT was used to generate solutions. These solutions were then graded by instructors using the same evaluation criteria as when grading student work. The results revealed significant limitations in AI's ability to solve engineering problems accurately. While 20% of the problems were solved correctly, 40% involved errors despite following the correct initial approach, and the remaining 40% exhibited entirely incorrect methods and results. This demonstrates that while AI can provide a starting framework for problem-solving, its outputs require careful validation and refinement, especially in technical and mathematically intensive fields like engineering.

These findings underscore the importance of educating students not only on the use of AI tools but also on their limitations and potential pitfalls. Encouraging critical evaluation and responsible usage of AI is essential to maximize its benefits while minimizing reliance on potentially inaccurate outputs. Furthermore, integrating a wider range of AI tools into the curriculum and fostering familiarity with emerging technologies like virtual reality could better prepare students for future challenges and opportunities in their academic and professional journeys.

Future Work and Suggestions

While many AI tools are available today, the majority of students reported using only well-known AI tools like ChatGPT and Grammarly. Humans, as innovative toolmakers, have continually pushed the boundaries of possibility, and AI is one of the most powerful tools created to date. It is essential for educators to expose students to a broader range of AI tools and demonstrate how these tools can deliver faster and higher-quality results. This will better prepare students to leverage AI effectively in their academic and professional pursuits.

In our future research, we will expand on the homework assignments used for validations, explore a variety of AI tools that have the potential to benefit educational systems and investigate their effectiveness in enhancing students' learning experiences. Also, there have been suggestions to let students do the homework first, then use AI tools for guidance and checking the accuracy of their solution and finally submit it to the instructor for final grading. This might be useful in guiding the students in the right direction if their initial approach was wrong. Additionally, recognizing the growing importance of virtual reality in education, we plan to integrate Apple Vision Pro—a current virtual reality headset—into classroom activities. This will

allow us to study its strengths, challenges, and overall impact on student engagement and understanding. Finally, as a significant portion of students use AI primarily for brainstorming and generating new ideas, we aim to explore innovative ways to harness AI's capabilities for fostering creativity.

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