

## **Reshaping Engineering Technology Education: Fostering Critical Thinking through Open-Ended Problems in the Era of Generative AI**

**Dr. Meenakshi Narayan, Miami University**

Dr. Meenakshi Narayan is currently an assistant professor and the department coordinator for robotics engineering technology at Miami University, a position she has held since the fall of 2021. She earned her Ph.D. in Mechanical Engineering from the University of Texas at Dallas in December 2020. Dr. Narayan's doctoral research was centered on the development of robust predictive control models designed to enhance patient safety during robotic interventional procedures. Her research interests encompass a wide range of areas, including dynamics systems and control, teleoperation, haptics, data-driven models, signal processing, and artificial intelligence. She applies her expertise in these domains to address challenges in healthcare and industrial automation. At Miami University, Dr. Narayan instructs courses related to electrical engineering technology and is actively involved in the creation of innovative robotics courses for the Bachelor of Technology in Robotics program. These efforts involve collaboration with industry partners and are backed by support from university endowments and funding from the Ohio Department of Higher Education. Her overarching goal is to modernize and invigorate the engineering technology curriculum to prepare students for the demands of the future workforce, aligning with the evolving needs of the industry.

**Dr. Lokesh Kumar Saharan, Gannon University**

Dr. Lokesh Saharan is currently serving as an Assistant Professor of Mechanical Engineering within the Department of Mechanical Engineering at the College of Engineering and Business at Gannon University. He obtained his Ph.D. from the University of Texas at Dallas in December 2017. Dr. Saharan's research interests encompass various fields, including engineering education, rehabilitation robotics, smart materials, soft robotics, and additive manufacturing. His academic contributions include multiple research articles published in peer-reviewed journals and conferences, as well as a book chapter. In addition to his research work, he has actively participated as a reviewer for various peer-reviewed conferences and journals. Before joining Gannon University, Dr. Saharan held the position of Assistant Professor and Department Coordinator for Mechanical Engineering at the University of Texas Permian Basin. During this time, he established and managed the Advanced Manufacturing Center, which received substantial funding of \$1.1 million from the Odessa Development Corporation. He also served as a co-principal Investigator for a Department of Education EM-Step grant valued at \$750,000. Further enriching his academic journey, Dr. Saharan contributed as an Assistant Teaching Professor at Penn State Behrend during the academic year 2019-20. Here, he played a pivotal role in developing new courses for the biomedical minor within the Mechanical Engineering department. Prior to his tenure in the United States, Dr. Saharan held the position of Assistant Professor (Instruction) in the Mechanical Engineering department at the National Institute of Technology Kurukshetra in India. Throughout his academic and research career, Dr. Saharan has made significant contributions in both teaching and research roles, spanning multiple countries and institutions.

# **Reshaping Engineering Technology Education: Fostering Critical Thinking through Open-Ended Problems in the Era of Generative AI**

## **Abstract**

Academic integrity breaches and plagiarism existed long before the rise of Generative Artificial intelligence (G-AI), where students used paid online tutoring platforms like Chegg to obtain help with homework assignments, take-home exams, and course projects. Additionally, G-AI platforms such as ChatGPT provide students with immediate support in understanding concepts and improving problem-solving abilities. However, it also opens up possibilities for students to improperly use the technology for homework and exams. This necessitates a revision in how educators design curricula and create assignments and projects. This paper discusses four teaching strategies integrated with G-AI; a) AI-assisted learning, b) Students evaluating AI generated solutions, c) Research-based learning with AI, and d) Open-ended project-based learning. Implementation of these strategies in electrical and robotics engineering technology courses such as circuits analysis, signal processing, and robotics systems is explored. These courses often require assignments that involve theoretical analysis and coding, solutions for which can easily be generated with AI. Therefore, employing these strategies in these courses is more important to effectively address plagiarism and enhance learning. An analysis comparing grade point average scores showed that student performance improved by 11.1% in the year 2023 when the proposed strategies were applied, compared to 2022 when the strategies were not implemented. This improvement was attributed to the in-class final exams conducted without access to textbooks or the internet, indicating that students had developed a solid understanding of the material and tackle final exam questions successfully. Integrating AI into teaching strategies and revamping the engineering curriculum marks a crucial advancement in preserving academic integrity and aligning with the dynamic demands of the engineering and technology fields.

## **Introduction**

The challenge of academic integrity breaches and plagiarism in engineering education has been prevalent since decades, due to the evolution of paid online tutoring platforms such as Chegg and CourseHero, to name a few. Initially established to offer more affordable textbook options to students from various disciplines, the scope of these platforms expanded to online tutoring services, where students could receive direct assistance on their academic tasks<sup>1,2</sup>. The system allows students to post specific homework and exam questions, to which tutors respond with detailed answers. However, this convenience for students has led to potential misuse, increasing

concerns around academic integrity within the community in critical fields engineering technology<sup>3</sup>.

Similarly, Generative Artificial Intelligence (G-AI) platforms such as ChatGPT, Google Bard, and Github Copilot offer real-time personalized feedback, programming help, and virtual simulations for students to gain practical experience. However, few educators have expressed concern regarding misinformation generated from AI training data and ethical issues like misuse by students (plagiarism)<sup>4</sup>. If implemented appropriately, G-AI hints at future advancements and benefits to the academic community despite the limitations<sup>5</sup>. As G-AI becomes increasingly prevalent in educational environments, it is important to recognize the benefit of integrating G-AI in a manner that enhances student learning capabilities, while also addressing plagiarism. Strategic designs of course curriculum that focuses on collaborations with AI for self-learning, assigning open-ended research-based problems could improve innovative capabilities among students<sup>6</sup>. This approach preserves the integrity of the learning process and trains students with the skills needed to handle modern technology challenges.

### **Resolving plagiarism with online tutoring platforms**

Several educators have been addressing the challenges of plagiarism from online tutoring platforms using innovative and collaborative solutions<sup>7,8,9</sup>. One approach involved forging contractual agreements between educational institutions and online tutoring platforms. These agreements aimed to establish a framework for protecting students against integrity breaches while maintaining the educational support these platforms provide. A critical aspect of such agreements is leveraging Chegg's user account data to enforce academic integrity policies effectively, particularly for the tutors involved. By monitoring the types of questions posted by students and the answers provided by tutors, these platforms identify and mitigate misuse<sup>10</sup>. Another solution to curb the posting of exam and homework questions to implement account restrictions was proposed<sup>11</sup>. If a student attempted to post direct questions from an assignment or exam, their account would be temporarily disabled from posting further questions. This measure sought to discourage students from using the platform as a means to bypass learning and understanding the material on their own.

Another critical approach that was recognized few years ago to navigate through the plagiarism issue was to incorporate project-based learning in the courses<sup>12</sup>. Their approach consisted of using GitLab platform to interact with instructors and fellow students, edit class activities, code and share programming homeworks, and assigning open-ended problems, making it more engaging for students. However without productive use, these platforms may hinder educational objectives if human tutors merely solve problems for students without providing actual tutoring, thus compromising learning goals. Another issue encountered is the limited availability of online human tutors to aid student learning. Given the real-time accessibility and extensive knowledge database of G-AI, students are increasingly relying on this platform for learning support and assistance with their assignments.

## **G-AI for enhanced learning**

Recent papers have explored the integration of G-AI into student learning, alongside conducting data analysis on its effects on student learning and creativity. Despite these efforts, considerable work remains in identifying effective strategies for implementing AI within educational frameworks to boost student learning outcomes<sup>13,14</sup>. One such work by Michel et al. discusses utilization of personalized feedback and supplementary learning resources with G-AI to promote self-directed learning, especially among students with language barriers, learning disabilities, or those engaged in distance learning<sup>15</sup>. Additionally, their work also mentions ideas for instructors to create lesson plans, resources, and assessments, thereby allowing them to focus on more complex educational tasks and personalized student interactions. The advantage for researchers is determined by G-AI's assistance with literature reviews, data analysis, and hypothesis generation, which lightens their workload and enhances the time available for creative thinking.

Another paper highlights the successful application and evaluation of AI in grading assessments across various subjects including physics and mathematics, aiming to alleviate the grading burden on instructors<sup>16</sup>. Their approach consisted of assigning a pass or fail grade as the primary evaluation technique for subjective questions. For questions with definitive answers such as numerical queries with a single correct solution, specific grades were assigned. Their overall goal was to assess the feasibility of using ChatGPT to complete different assessment tasks and gauge the level of difficulty involved. However, their study primarily emphasized the benefits of employing G-AI for instructors over students.

Yeralan et al aims at enhancing the educational experience, including self-learning tutorials for students, self-assessments, and writing assignments with a focus on grammar and editing<sup>14</sup>. Students were encouraged to independently explore and grasp complex concepts at their own pace, assess their understanding through self-administered tests, and refine their writing skills through assignments specifically targeted at improving grammar and editing proficiency. Their main goal was to provide students the necessary tools needed for a more engaging and effective learning.

## **Motivation and paper objective**

The referenced literature mainly provide statistical analyses on the effects of G-AI on student learning and creativity, or utilize ChatGPT to lessen grading loads on instructors. The literature also offer quick fixes for how students might use ChatGPT for tasks like writing, editing, self-study, and self-evaluations. To our knowledge, there is not yet a comprehensive guide on integrating AI into classroom settings to enhance learning, creativity, and possibly decrease plagiarism. This paper aims to introduce a structured collection of the following learning strategies that can be seamlessly integrated into the course curriculum.

Recent study by Habib et al explores the enhancement of divergent thinking in students through the strategic use of G-AI, highlighting its potential to foster creativity<sup>6</sup>. Their work primarily presents data and statistics on the impact of AI on divergent thinking. In contrast, our paper emphasizes the adoption of systematic learning strategies with detailed examples tailored for engineering education. While Habib et al focus on students exploring specific topics and validating their ideas against AI-generated content, our proposed approach focuses on how

students can leverage the vast knowledge database of AI to discover innovative technological concepts and pursue the development of novel technologies.

The paper proposes the following methods that can be adopted and integrated into existing pedagogical approaches for engineering education. The novelty in this paper is to provide detailed suggestions on the G-AI integrated teaching approaches that could be incorporated across many courses in general. The examples presented are limited to few electrical engineering technology and robotics technology courses.

- **AI-assisted learning** - a modern approach to improve understanding of theoretical concepts combining AI-assisted interactive learning with traditional assessments to ensure independent problem-solving skills.
- **Evaluating AI generated solutions** - assess AI-generated solutions fostering a deeper understanding of theoretical concepts in fields where AI accuracy is evolving, yet acknowledging its limitations with hands-on problem-solving.
- **Research-based learning with AI** - an approach to encourage students to explore state-of-art technological research in the field, and identify current limitations and novel technological solutions.
- **Innovative project-based learning** - encourage students to work on an open-ended project that focuses on applying theoretical knowledge to enhance existing technologies for new uses, thereby equipping students with collaborative and innovative skills for future technological challenges.

There are several G-AI platforms in market; however, this paper will use GPT 4.0 to illustrate the learning strategies being proposed with examples drawn from electrical engineering and robotics technology courses such as signal processing, circuits design, and introduction to robotic systems.

## **G-AI Integrated Teaching Strategies**

This section discusses proposed educational strategies for general courses in electrical engineering and robotics technology.

### **AI-assisted learning**

Utilizing AI-guided learning platforms such as GPT 4.0, instructors could provide students with an interactive and dynamic means to grasp and engage with theoretical materials. Through this method, students learn how to effectively employ GPT 4.0 to delve into complex theoretical concepts, facilitating a deeper understanding through personalized explanations and the opportunity to practice a broad array of questions tailored to their learning needs. Following this period of AI-assisted learning, traditional in-class assessments are conducted, wherein students are required to apply the concepts they have learned without the aid of the internet, AI tools, or any form of assisted technology. This approach not only encourages active engagement with the material during the learning phase but also ensures that students possess a genuine, unaided understanding of the subject matter. An example problem in signal processing course for filter

design is shown in Fig.1. The students can ask any design based problem questions and learn from the generated solutions on how to design a filter, as part of a homework assignment. Then, the students would be assessed in class on filter design, in the form of a quiz or a test. This method mirrors textbook-based learning, where the focus is on individual study and practice with educational tools, followed by assessments that gauge the students' ability to independently solve problems.

**You**  
Design a digital low pass Butterworth filter with the following specifications:

1. Attenuation of 3dB at passband frequency of 1.5Hz
2. Stopband attenuation of 10 dB at the frequency of 3kHz
3. Sampling frequency of 8000Hz.

Also plot magnitude and phase responses in Matlab. Find the transfer function in Z-domain

**ChatGPT**  
To design a digital Butterworth filter with the specified requirements, you can use MATLAB's `'butter'` function to find the filter coefficients, which can be used to plot the magnitude and phase responses and also to derive the transfer function in the Z-domain.

Here are the steps:

1. **Normalize the frequencies** by the Nyquist frequency, which is half the sampling frequency. The Nyquist frequency in this case is  $f_{Nyquist} = \frac{f_{samp}}{2} = 4000$  Hz.
2. **Calculate the normalized passband and stopband frequencies** for use with the `'butter'` function:  

$$\omega_p = \frac{f_p}{f_{Nyquist}} = \frac{1.5}{4000}$$

$$\omega_s = \frac{f_s}{f_{Nyquist}} = \frac{3000}{4000}$$
3. **Use `'butterord'` to determine the order and cutoff frequency** for the filter based on the attenuation requirements.
4. **Design the filter using `'butter'`** to get the filter coefficients.
5. **Plot the magnitude and phase responses** using `'freqz'`.
6. **Find the transfer function** in the Z-domain using the filter coefficients. MATLAB's `'tf'` function can convert these coefficients into a transfer function.

Here's how you can perform all these steps in MATLAB:

**Generated Matlab code to design filter and plot response**

```
% Define specifications
fp = 1.5; % Passband frequency in Hz
fs = 3000; % Stopband frequency in Hz
Ap = 3; % Passband attenuation in dB
As = 10; % Stopband attenuation in dB
fsamp = 8000; % Sampling frequency in Hz

% Normalize the frequencies by the Nyquist frequency
fNyquist = fsamp / 2;
wp = fp / fNyquist;
ws = fs / fNyquist;

% Calculate the minimum order n and cutoff frequency
[n, Wn] = butterord(wp, ws, Ap, As);

% Design the filter using the butter function
[b, a] = butter(n, Wn);

% Plot the magnitude and phase responses
[h, f] = freqz(b, a, 1024, fsamp);
```

**You**  
Explain each line of the following code:

% Specifications  
fp = 1.5; % passband frequency in Hz  
fs = 3000; % stopband frequency in Hz  
Ap = 3; % passband attenuation in dB  
As = 10; % stopband attenuation in dB  
fsamp = 8000; % sampling frequency in Hz

% Normalized frequencies  
fNyquist = fsamp / 2;  
wp = fp / fNyquist;  
ws = fs / fNyquist;

% Calculate the minimum order of the filter  
[n, Wn] = butterord(wp, ws, Ap, As);

**Used generated Matlab code and asked GPT for explanation**

**Explanations of each line of code**

1. `'[n, Wn] = butterord(wp, ws, Ap, As);'` uses the `'butterord'` function to determine the minimum order `'n'` and the normalized cutoff frequency `'Wn'` for a Butterworth filter that meets the given specifications.

2. **Calculate the filter coefficients:**  
`'[b, a] = butter(n, Wn);'` generates the filter coefficients for the Butterworth filter of order `'n'` and normalized cutoff frequency `'Wn'`.

3. **Frequency response of the filter:**  
`'[h, f] = freqz(b, a, 1024, fsamp);'` calculates the frequency response `'h'` of the filter at 1024 points (by default, evenly spaced across the frequency band). The output `'f'` is the corresponding frequency vector, scaled according to the sampling frequency `'fsamp'`.

Figure 1: AI-assisted learning: A query on filter design was posed to GPT 4.0 which produced a step-by-step guide and MATLAB code. The next request for code clarification led to detailed explanations by GPT for each code line. Full response not shown due to space constraints.

## Evaluating G-AI solutions

By presenting students with AI-generated solutions to complex problem questions, students are encouraged to critically evaluate and identify inaccuracies or faults within these solutions. This pedagogical approach not only requires students to provide constructive feedback to the AI but also to delve into a deeper analysis of why certain AI-proposed solutions may deviate from expected results. Such exercises are particularly beneficial in courses like circuit design and fabrication, power systems design, semiconductor technology, and integrated chip design. In these fields of study, the capabilities of G-AI are still maturing and acquiring theoretical knowledge is mandatory. The utilization of AI as a learning tool in these domains enables students to engage with the material on a practical level, understanding the intricacies of theoretical procedures through active analysis. However, it is acknowledged that for tasks requiring precise circuit analysis, simulation, and design, G-AI may not always deliver accurate results. In a basic electric circuits course for example, students were asked to analyze the circuit and obtain current across each resistor from the circuit diagram shown in Fig. 2. When the problem question was posed to GPT 4.0, the procedures and the resulting answers generated were incorrect and different from the answers from an online circuit simulator, CircuitLab. This learning method enhances their problem-solving skills and equips them with the ability to independently arrive at solutions that

align closely with those generated by high precision simulation tools. This innovative educational strategy highlights the complementary role of AI in technical education, leveraging its capabilities to enrich the learning process while acknowledging and addressing its limitations through practical, hands-on problem-solving and critical analysis.

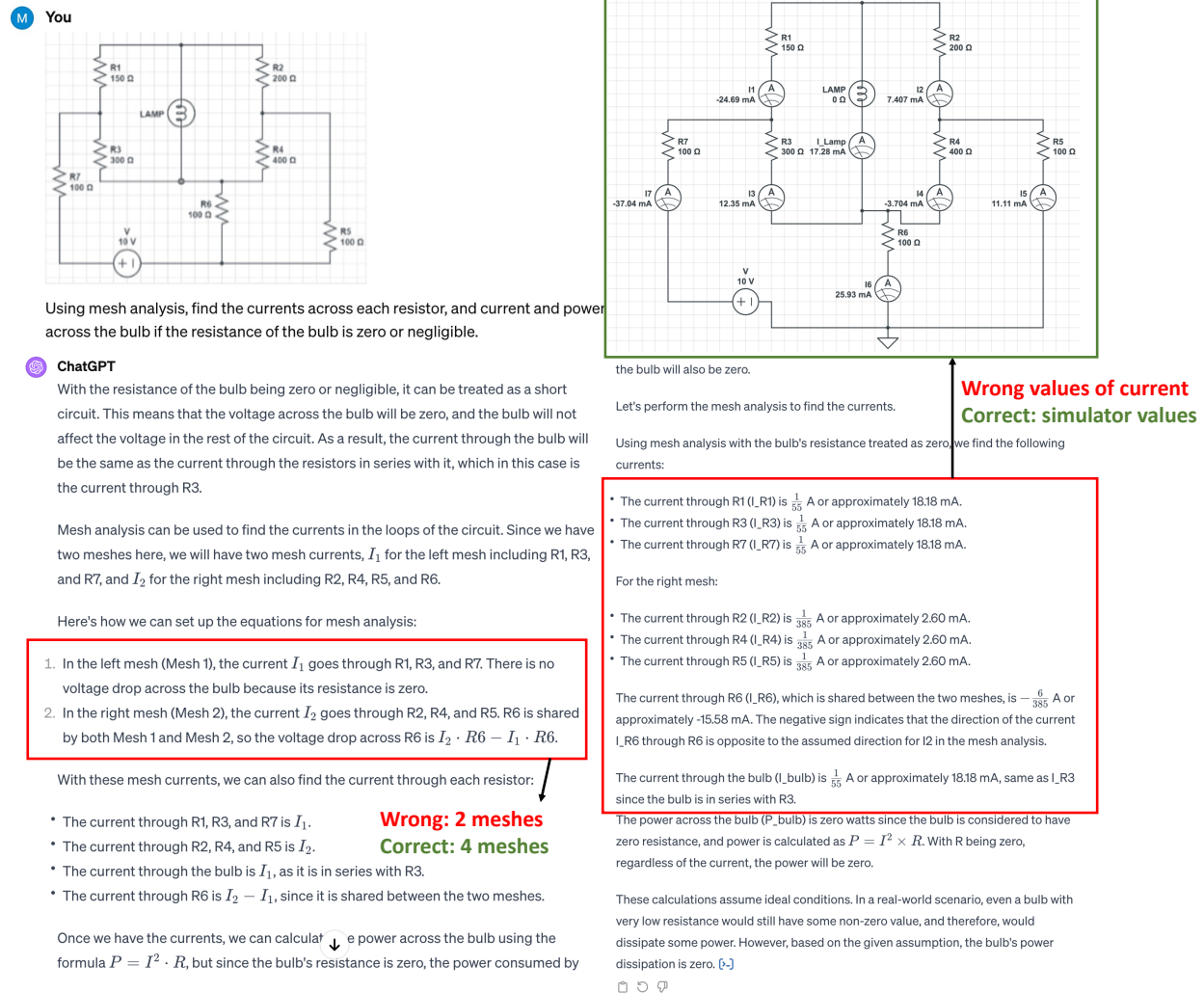


Figure 2: Evaluating AI for electric circuits analysis: A query on circuit analysis problem with an image of circuit diagram was fed as inputs to GPT 4.0. Detailed analysis and solutions generated from GPT 4.0 are different from the correct answers provided by CircuitLab simulator.

## Research-based learning with G-AI

In an effort to modernize engineering education, students are encouraged to explore the current state of technology, pinpoint its limitations, and brainstorm possible improvements emphasizing the importance of understanding and developing concepts. For example, we utilize GPT 4.0 to generate up-to-date lists of advancements in areas like filtering technologies in diverse applications. GPT 4.0 provided a comprehensive overview of recent progress in filtering techniques upon request, as demonstrated in Fig. 3. Students are encouraged to select topics



within their interest areas and to seek out the latest research papers on these subjects. For those unfamiliar with the process of locating these papers, GPT 4.0 also offers guidance on using academic databases like Google Scholar. By engaging with current literature, students gain insights into the forefront of technology and its potential for refinement. Students then share their analyses and original ideas through presentations, which could be included as part of their assessment. This approach nurtures creative thought and ensures that students are well-versed in the latest technological developments and are prepared to identify and contribute to novel innovations.

**You**  
what is the state-of-art technology in filter design. Is there ongoing research in this field?

**ChatGPT**  
As of my last update in April 2023, the state-of-the-art technology in filter design encompasses several advanced methodologies and areas of research, reflecting the field's dynamic nature and its critical role across various applications, from telecommunications to signal processing and biomedical engineering. Ongoing research in filter design is vibrant, with several key trends and innovations shaping the landscape:

- 1. Advanced Digital Filters:**
  - Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) Filters:** Research continues to refine these filters, focusing on optimizing their performance for specific applications, such as reducing computational complexity or improving stability and accuracy.
  - Adaptive Filters:** These filters adjust their parameters in real-time based on the input signal characteristics. Machine learning algorithms, particularly deep learning, are increasingly integrated into adaptive filter design to enhance their adaptability and efficiency.
- 2. AI and Machine Learning in Filter Design:**
- 4. Quantum Filtering:**
  - With the advent of quantum computing, research into quantum filtering aims to exploit quantum mechanics principles to achieve filtering at speeds and efficiencies beyond the capabilities of classical filters.
- 5. Nanotechnology and Microelectromechanical Systems (MEMS):**
  - On the hardware front, nanotechnology and MEMS are being used to create ultra-compact, high-performance filters for use in integrated circuits and biomedical devices. These technologies enable the production of filters with features at the nanoscale, offering unprecedented precision and miniaturization.
- 6. Environmental and Biomedical Applications:**
  - There's a significant interest in developing filters for environmental monitoring and biomedical applications, such as wearable health monitoring devices, where filters must be highly selective, sensitive, and capable of operating in noisy real-world

**You**  
Find recent research papers on quantum filtering for biomedical applications

**Databases and Platforms for Research Papers:**

- PubMed:** Focuses primarily on biomedical literature. Using search terms like "quantum filtering in biomedical applications" could yield relevant results.
- IEEE Xplore:** A great source for engineering and technology papers. Searching for "quantum filtering in biomedical" might bring up research on the application of quantum filtering in biomedical engineering.
- Google Scholar:** A broad platform that can help you find research papers across multiple disciplines. Use specific search queries like "quantum filtering biomedical applications."

**Quantum machine learning applications in the biomedical domain: A systematic review**  
D Maheshwari, B Garcia-Zapirain, D Sierra-Sosa - IEEE Access, 2022 - IEEE Xplore. IEEE.org

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AI lists databases to search research papers

Research papers on filtering

(PDF) IEEE.org

(HTML) nature.com

(PDF) Wiley.com Full View

(HTML) sciencedirect

(PDF) IEEE.org

Figure 3: Research-based learning with AI: A query recent advances in filtering technology was posed to GPT 4.0 which produced a list of state-of-the-art filtering techniques for various applications including biomedical. On further query such as "find recent research papers on quantum filtering for biomedical applications", GPT listed databases where relevant papers could be accessed. One such database, google scholar shows relevant research papers.

## Innovative project-based learning

Project-based learning represents a natural progression from research-based learning, focusing on the practical application of theoretical knowledge to develop and construct innovative technology. In this methodology, students are tasked with identifying the limitations of existing technologies and, rather than inventing entirely new solutions from scratch, they are encouraged to adapt and enhance these technologies for novel applications. An illustrative example of this approach can be seen in the field of telerobotics that is undergoing rapid advancements for medical applications, yet relatively unexplored in the context of power line maintenance<sup>17</sup>. Through project-based



learning, students might engage with AI to gather and analyze information on telerobotics and haptics technology, drawing upon AI-generated codes and system designs to conceptualize a telerobotic haptic robot tailored for the maintenance of transmission lines, as demonstrated in Fig. 4. This project would address a significant gap, as robotic arms designed specifically for this purpose do not currently exist. Students would use existing technology of finger gripper design, haptic wearable glove, and haptic interface development. They would also learn to calibrate sensors, simulate, assemble, and test circuits, ultimately integrating all components into creating a comprehensive telerobotic system. In general, students could refer to G-AI databases that generate conceptual ideas and instructions for systems design, embedded programming, coding, and circuits design and simulation to name a few, and adapt these techniques for their specific projects. This process fosters collaboration between students and AI and teaches them with a diverse skill set, enabling the customization and development of new products for various industries. By incorporating this open-ended problem-solving approach into the curriculum, educational programs, especially those in robotic engineering technology, can significantly enhance student learning outcomes.

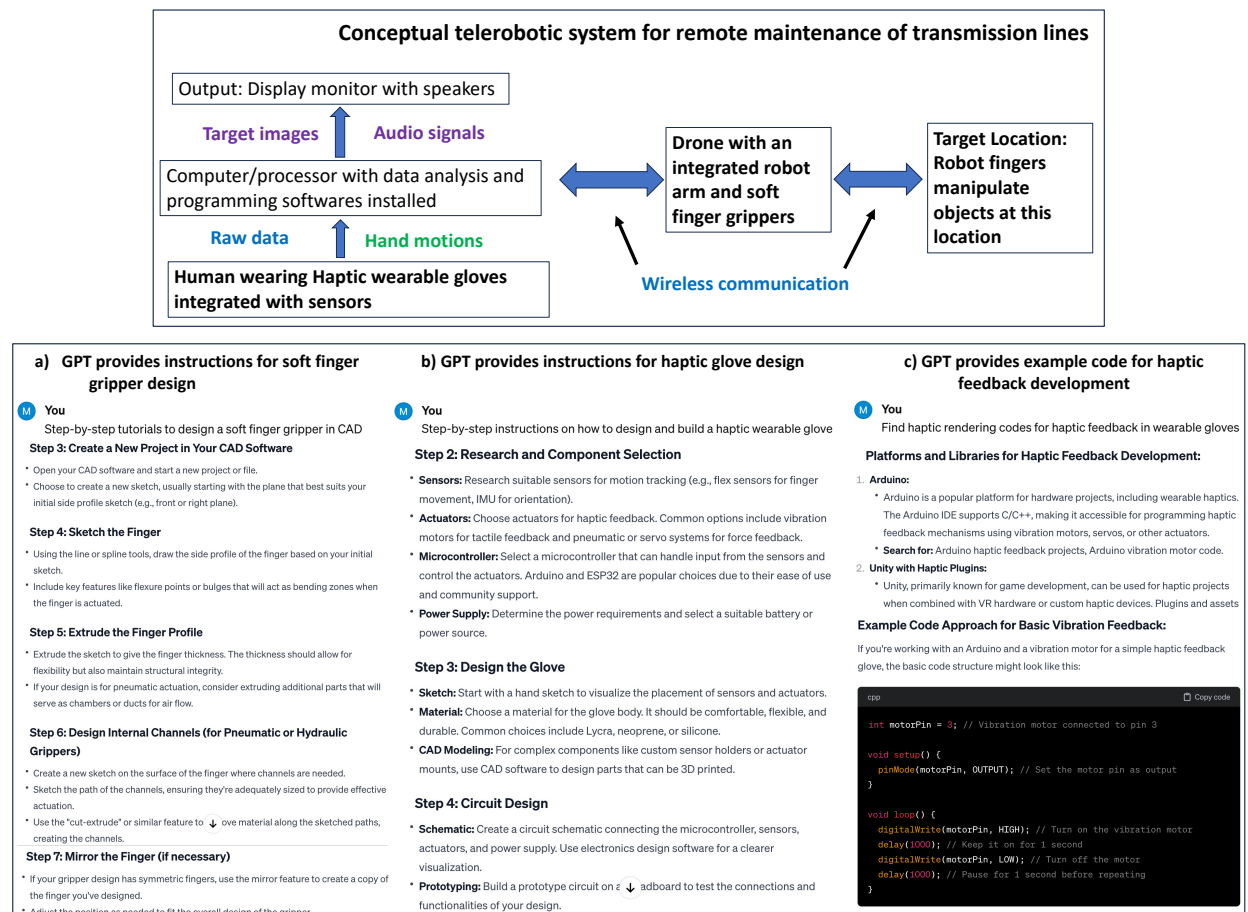


Figure 4: Project-based learning: Customization of GPT-provided methodologies for gripper design, fabrication of wearable haptic gloves, and haptic feedback programming for remote drone operation, offering an innovative approach to powerline maintenance.

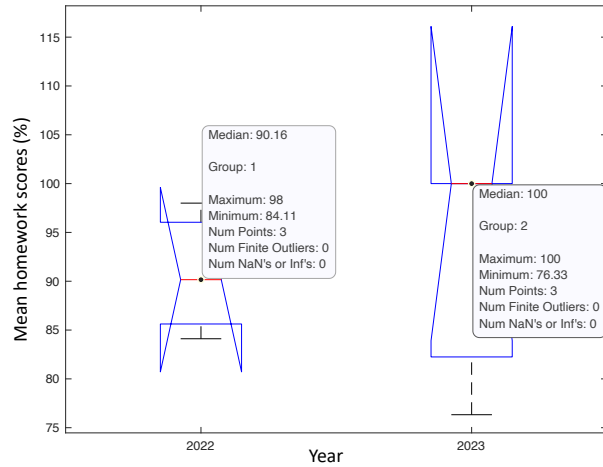
Table 1: Student Performance: Average course scores for 2022 and 2023

Course name (class sizes)	Year 2022			Year 2023		
	Homeworks Mean% (SD)	Final exam Mean% (SD)	Course GPA	Homeworks Mean% (SD)	Final exam Mean% (SD)	Course GPA
Circuits Analysis (14 '22 ; 19 '23)	90.16% (4.73)	72.51% (9.59)	<b>2.67</b>	76.33% (4.90)	88.32% (10.22)	<b>3.35</b>
Signal Processing (7 '22 ; 4 '23)	84.11% (4.81)	89.97% (1.17)	<b>3.05</b>	100% (0.00)	93% (3.32)	<b>3.37</b>
Intro to Robotics (6 '22 ; 8 '23)	98% (1.21)	100% (0.00)	<b>3.37</b>	100% (0.00)	100% (0.00)	<b>4.00</b>
Control Systems (25 '22 ; 12 '23)	75.99% (5.19)	81.22% (4.43)	<b>2.64</b>	78.52% (5.62)	77.54% (7.57)	<b>2.58</b>
Instrumentation (22 '22 ; 19 '23)	89.10% (2.45)	92.50% (4.50)	<b>3.48</b>	87.30% (3.66)	94.30% (3.44)	<b>3.56</b>
Robotic Systems (12 '22 ; 14 '23)	85.00% (2.35)	90.20% (3.67)	<b>3.23</b>	88.60% (4.27)	87.50% (3.67)	<b>3.12</b>

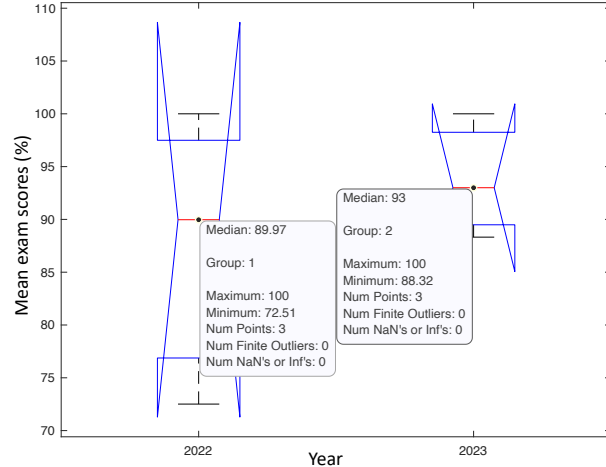
number 'yy indicates class size in the year yy. For example, 14 '22 ; 19 '23 indicates class size of 14 students in year 2022 and class size of 19 students in year 2023.

## Results and Discussion

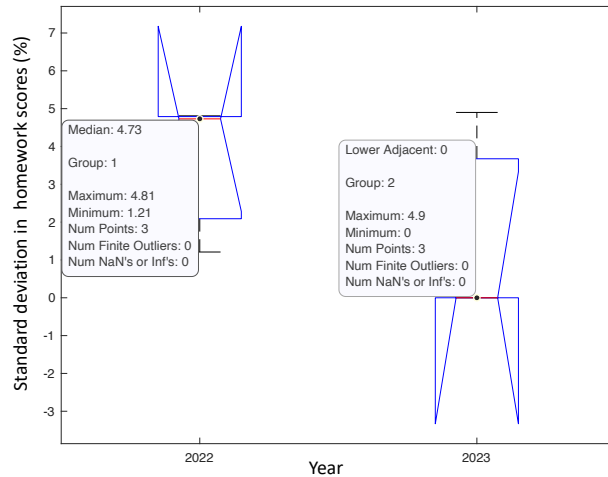
This section reports on the academic performance of students in electric circuits, signal processing, control systems, and introductory robotics courses from the years 2022 to 2023. We observed an improvement in the average course grades calculated on a 4-point scale, as shown in Table 1. The AI strategies were implemented for all the listed courses in the year 2023. By comparing homework and final exam results, we noticed a pattern: students generally did well on homework in 2022 but scored lower on final exams. This discrepancy might stem from students collaborating or seeking external assistance for homework, including online tutoring or AI tools, which didn't necessarily translate to independent problem-solving skills in a closed-book exam setting. This pattern is observed using the standard deviation scores in homework as shown in Fig. 5. In 2023, we adopted the proposed teaching strategies that encouraged students to study concepts on their own, using any external resources they preferred. In-class activities then focused on applying these concepts through quizzes and assignments, with these tasks being graded as homework. This method led to a slight drop in homework scores, indicating more individual effort, but an improvement in final exam performance and overall course GPA, suggesting a better understanding and confidence in the material. For the signal processing course, which was delivered online due to the geographic spread of students, we applied the same learning approach. Despite the small class sizes (7 students in 2022 and 4 in 2023), the personalized teaching format contributed to enhanced learning outcomes. The robotics course also benefited from a similar one-on-one instructional approach, with project-based assessments fostering better student performance. This is evidenced through zero standard deviations in student scores, as every student performed well in project-based assignments and exams.



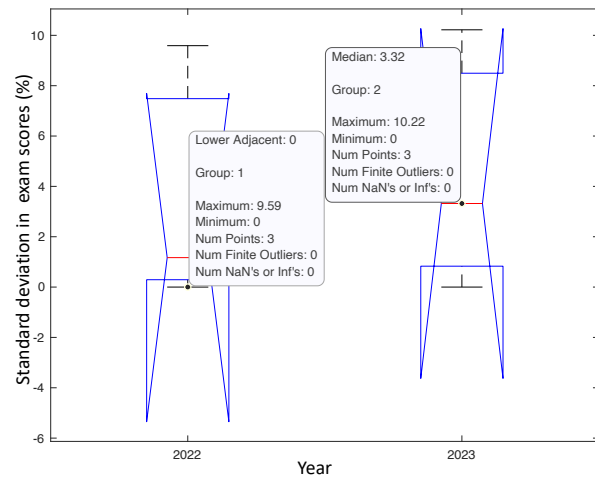
(a) Comparing mean homework scores between 2022 and 2023



(b) Comparing mean exam scores between 2022 and 2023



(c) Comparing standard deviations in homework scores



(d) Comparing standard deviations in exam scores

Figure 5: Statistical analysis of the effect of proposed AI strategies on student performance between years 2022 (AI strategies not implemented) and 2023 (AI strategies implemented). (a) The median of average homework percentage scores of students for all listed courses in 2023 was higher than in 2022. (b) The average exam percentage scores for all listed courses in 2023 was slightly higher in 2023, showing better overall student performance. (c). The standard deviation in homework scores was less in 2023, meaning every student performed well in homework assignments showing possible plagiarism. (d) The standard deviation in exam scores was higher in 2023 showing plagiarism was less likely during exams conducted in classrooms.

Overall, the mean percentage scores of students in homework is higher in 2023 by 11.1% because of learning with AI and potential plagiarism by copying AI answers to homework questions. These homework assignments were intentionally assigned for students to openly learn with AI. These assignments were graded to motivate and prepare students for mid-term and final exams. The mean exam scores were better in 2023 by 4.45% and higher standard deviation (SD) scores, showing better student learning and less plagiarism issues.

A key limitation of our study is that formal plagiarism detection methods were not used to

differentiate between students using online tutoring, AI platforms, or collaborating with peers. While we propose solutions to address AI and tutoring-related plagiarism, peer-to-peer copying remains a challenge for future investigation. Even though Kruskal Wallis analysis shows acceptance of the null hypothesis that the AI strategies do not affect the student scores significantly ( $p > 0.05$ ); however, slight improvements in student performance in the year 2023 indicate usefulness of the proposed AI strategies in classroom teaching. More data needs to be collected from these courses in the following years to track the significance levels of the effect of AI strategies on student scores. Further research is needed across more courses and larger student groups to fully assess these educational strategies. Future studies should also include student feedback on their learning experiences with AI to better gauge the effectiveness of these approaches. Adopting these strategies could also ease grading workloads for instructors, as AI can support practice assignments at home, allowing teachers to focus on evaluating in-class work and comprehensive final projects.

## **Conclusion and Future work**

This paper introduced innovative teaching strategies for electrical engineering and robotics technology courses, aiming to leverage AI for educational purposes while addressing the challenge of plagiarism, often resulting from the dependency of students on online tutoring platforms or generative AI tools like ChatGPT for completing assignments without genuine comprehension. We proposed four specific strategies designed to enhance student learning outcomes while reducing the effects of plagiarism. These strategies were applied to three distinct courses, allowing for an analysis of student performance through course GPA comparisons between the years 2022 and 2023. The analysis showed that the student learning outcomes were better in 2023 when the proposed teaching strategies were implemented, compared to the year 2022 when the strategies were not implemented. The authors did not intend to substitute current educational methods but to complement them with AI to improve learning efficiency and streamline tasks such as organizing texts and editing language in technical writing. For example, the language in this paper was structured and refined by GPT 4.0 using the foundational content, ideas, and drafts supplied by the authors following the educational approach<sup>14</sup>. Similarly, engineering students can be motivated to employ AI for straightforward tasks such as report writing. Integrating the suggested teaching strategies with traditional approaches can enhance learning efficiency for both teachers and students, by delegating routine tasks to external platforms and concentrating on core concepts.

Future work will explore the effectiveness of these strategies in a wider array of educational contexts, including other engineering technology and traditional courses, as well as graduate-level programs. This will also involve collaborative efforts with faculty members from various departments and universities to assess and refine the proposed approaches.

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