

# WIP: Generative AI as an Enhanced Study Aid in Engineering Courses

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#### Abstract

Engineering classrooms are marked by their balance between building foundational theory and giving examples to solidify understanding. Student performance improves with increased quantity and diversity of example problems; however, faculty members, especially those early in their careers, can find it burdensome to provide enough quality example problems to accommodate student interests and learning styles. Use of Generative Artificial Intelligence (AI) can provide a novel approach to fill the gap between faculty resources and student demand.

In our work, we assess the exam performance of undergraduate mechanical engineers when taking a course covering vibration analysis, both with and without the availability of Generative AI tools. For this single course, we analyzed the performance of the students over two semesters – the first shortly prior to the public release of the ChatGPT AI chatbot; the second shortly after the release of the tool – while introducing ChatGPT as a direct learning tool in the second semester of the course. The professor showed relevant example conversations with the AI chatbot, to pursue equitable and effective usage of new AI tooling by the student population. Following the professor's example conversations, students can ask the chatbot to generate more examples, and the chatbot will also attempt to give and explain solutions. Students can also ask the chatbot follow-up questions to deepen their understanding and can interact with the AI tool when they study outside of the classroom.

During class time, students receive exams that include straightforward computing of characteristic values relevant to vibration systems. Additionally, the exams contain word problems that require determining component values from design specifications. With exams designed for similar difficulty from semester to semester, we inspect performance differences in consecutive junior-level cohorts, specifically looking at performance on direct computation and on word problems with design decisions. This ongoing work seeks to capture the effects of embedding generative AI within the classroom. As the student body begins to adopt generative AI tooling, we see a unique opportunity to characterize the effects of AI integration.

# Introduction

Recent artificial intelligence platforms provide text generation ability that is vastly more accessible to the general public, since it is deployed in the form of a chatbot. The results of these systems provide compelling ability to synthesize information – including the ability to pass difficult tests like the bar exam (Katz 2024). While there may be perils for misuse of this technology, we wish to explore beneficial aspects to using this Generative AI as a collaborative agent in learning, specifically applied to engineering courses. Generative AI has shown immense promise as a copilot for constructing computer programs; however, there remains open space for deploying AI for more theoretical content to enhance student learning.

Our work in progress report aims to present student outcomes before the advent of readily available generative AI chatbots, and after these tools became prevalent. For students with access to the novel AI systems, we provided two tools for using AI to prepare for exams. Students were given professor-crafted "prompts" and conversations with ChatGPT that would help the students to study. Additionally, students were provided ChatGPT-generated solutions to homework problems, complementing the hand solutions from the professor. Also, students were asked to submit ChatGPT examples to represent various learning objectives in the course, and compared solutions from Wolfram Alpha. In our work, we captured metrics on quiz performance for student cohorts before and after the introduction of widely available Generative AI chatbots, correlating similar problem themes, and for student feedback, we selected feedback related to example problems and usage of ChatGPT.

## **Related Work**

With respect to usage in studying, established research into Generative AI can be described through the lenses of three viewpoints: Student-focused, instructor-focused, and human computer interaction.

*Instructor-focused:* With the proliferation of generative AI tools, university faculty members, understandably, worry about plagiarism – students can ask the AI tools to construct essays and solutions to problem sets. The novelty of the current wave of AI tools lies in the difficulty tracing AI usage (Chaka, 2023) that is affordable and accessible for innumerable topics. Coupled with considerations on intellectual property and research conduct, universities from a variety of sizes and demographics continue to adopt policies for standardized and ethical AI (Kansas, 2024). Universities also support training initiatives for faculty to complement these guidelines, such as education training (Dyer, 2024) and the Ole Miss AI Winter Institute for Teachers (Watkins, 2023).

*Student-focused:* Universities also make efforts to provide students with concrete roadmaps of what to do and what not to do in education (Latrobe, 2024). For career focused usage upon entering the workforce, companies provide services for understanding how to use AI (LinkedIn, 2024). The ability for companies in EdTech to deploy generative AI for tutoring (Kshetri, 2023) is viable, with examples in writing tutors (Kim, 2023) and software tutors (Prather, 2023). Whether tutoring provides a desired tool or is deployed well remains up for debate (Engle, 2023). The overall risk-benefit analysis affects policy making (Office of Ed Tech, 2024), but there is promise for increasing educational equity (Sylvestre, 2023).

*Human-Computer Interaction:* The general area of best practices for interacting with a chatbot is termed "prompt engineering" (Reynolds, 2021). Prompt engineering entails users tailoring their questions to the chatbot to task-specific domains, such as medicine (Heston, 2023), engineering (Velásquez-Henao, 2023), science education (Cooper, 2023) and image generation (Liu, 2022). Overall, prompt engineering provides another aspect to example-based learning (Huang, 2017), in which the student initiates the examples.

Additionally, the authors would like to describe an additional use of ChatGPT from their own teaching:

ChatGPT may be used to generate code – an ability which makes it a useful tool for engineers, while also presenting challenges in evaluating student performance in coding, while students have access to the tool within or outside of the classroom. Code generation is not a new phenomenon – for example, machine language like assembly code is commonly generated from

standard programming code like Python – however, ChatGPT and other AI tools continue to improve reliability and accuracy for code from user prompts.

To evaluate the performance of this AI in code development, ChatGPT was asked to generate MATLAB code by students in a core undergraduate Mechanical Engineering course, "Computer Programming for Mechanical Engineers," in Spring 2023. Students were offered an extra credit opportunity at the end of the semester, wherein they were to ask ChatGPT to solve previous assignments and exams which the students themselves had completed throughout the semester. Students were asked to generate and refine prompts, optimizing phrasing to encourage the AI software to produce the correct solutions to these problems. Afterwards, the students were asked to grade ChatGPT to evaluate its performance. The students found that, while ChatGPT performed substantially better than original student performance (which was in part due to the fact that, during the extra credit assignment, students had access to solutions such that they could tailor prompts to guide the AI to correct answers), the software nevertheless did not provide consistently accurate, correct responses and MATLAB code.

# Methodology

Due to the evident potential for ChatGPT to be used as a tool to increase student understanding, the authors aimed to evaluate whether the incorporation of this AI platform as a study resource would affect student performance on technical exams.

Students were introduced to the concept of interacting with ChatGPT during class, with a description of prompt engineering. While the in-class examples were not standardized, an example would be: "Can you generate examples of second order linear constant coefficient ODEs? Use a mix of homogeneous and non-homogeneous examples." After reviewing how ChatGPT can generate a set of questions, the instructor followed up with a prompt asking ChatGPT to, for instance, "Solve the second example." ChatGPT would respond with a set of steps to be taken to solve the problem, which should prove useful for students. See Figure 1 for typical chatbot responses to these prompts.

Of course! Here are some examples of second-order linear constant coefficient ordinary differential equations (ODEs), both homogeneous and non-homogeneous:	Absolutely! Let's solve the examples one by one: Homogeneous Equations:
Homogeneous Equations:	1. $y'' + 4y' + 4y = 0$
1. $y'' + 4y' + 4y = 0$ 2. $2y'' - 3y' + y = 0$ 3. $y'' + 9y = 0$	The characteristic equation is $r^2 + 4r + 4 = 0$ , which factors into $(r + 2)^2 = 0$ . This gives a repeated root $r = -2$ . The general solution is then: $y(x) = (c_1 + c_2 x)e^{-2x}$
Non-Homogeneous Equations:	1. $2y'' - 3y' + y = 0$
1. $y'' + 2y' + y = e^x$ 2. $y'' - 5y' + 6y = 3x^2$	The characteristic equation is $2r^2 - 3r + 1 = 0$ , which factors into $(2r - 1)(r - 1) = 0$ . This gives roots $r = \frac{1}{2}$ and $r = 1$ . The general solution is: $y(x) = c_1 e^{\frac{r}{2}} + c_2 e^x$
3. $y'' + 4y' + 5y = \sin(2x)$	1. $y'' + 9y = 0$
In these equations, $y$ represents the unknown function of $x$ , and $y'$ and $y''$ represent its first and second derivatives with respect to $x$ , respectively. The coefficients in front of the derivatives are constants, and the right-hand side of the equations may contain functions of	The characteristic equation is $r^2+9=0$ , which has complex roots $r=\pm 3i.$ The general solution is: $y(x)=c_1\cos(3x)+c_2\sin(3x)$
<i>u</i> .	Non-Homogeneous Equations:
Keep in mind that the solutions to these equations would involve finding the complementary (homogeneous) solution and the particular (non-homogeneous) solution. The general	1. $y'' + 2y' + y = e^x$
solution of the complete equation would be the sum of these two solutions. $$\odot_{\rm Reg}$$	For the homogeneous part, the characteristic equation is the same as in Example 1. For the

Figure 1: ChatGPT provides well-structured example problems (left) and provides solutions to these same problems, when asked (right).

#### Exam Preparation

Prior to each exam, students were given a prompt that asked ChatGPT to provide help in preparing for an upcoming example. The prompts are listed in Table 1.

Assessment	Prompt(s)
Quiz 1	"Can you give me some examples problems to prepare for a quiz on spring- mass-damper systems?"
Quiz 2	"Can you give me some examples problems to prepare for a quiz on harmonic forcing in spring-mass-damper systems?" Follow-up: "Yes, please solve problem 3."
Quiz 3	"Can you form example equations of motion using second order ODEs that can be solved via the Laplace transform? Please use specific initial conditions and external forcing functions."

Table 1: Listed are the Prompts Provided for Students before each Quiz.

Besides the prompts for the exam topics, students were provided ChatGPT-generated solutions to homework problems. These solutions were verified by the professor, who provided hand solutions, as well. In general, this comparison between AI generated answers and expert-provided solutions raises interesting questions for students on their way to demonstrating proficiency.

#### Generative AI Verification

While the chatbot generated results generally looked good, it was important to note that ChatGPT could get things wrong, and that it was crucial to check ChatGPT's steps and solution (e.g., with Wolfram Alpha) before relying on it. The class was encouraged to verify results with ChatGPT, and to practice their verification methods through an extra credit assignment.

In the course, the extra credit facilitated building a custom database to encourage students to utilize the AI tools available to them. Building a catalog helps others to improve the utilization ability for students interacting with AI chatbots (White, 2023). For the extra credit assignment, students were asked to pick a topic from a list of learning objectives and form a prompt that made ChatGPT reply with an example problem for the course. Given the example problem, students were asked to solve the problem using Wolfram Alpha and by hand – important to ensure that students continued to hone their problem-solving skills without the AI tool.

# Evaluation

To evaluate the utility of ChatGPT as a study tool for engineering and technical courses, students from two subsequent iterations of a core undergraduate junior-level Mechanical Engineering course, Dynamic Systems II, were presented with similar exams during the Fall 2022 and Fall 2023 semesters, for similar student populations (primarily juniors majoring in Mechanical Engineering). The students were taught by the same faculty member, who taught three sections (approximately 80 students total) in Fall 2022, and two sections (approximately 60 students total) in Fall 2023.

While no AI platforms were presented as student tools during the Fall 2022 iteration of the course, ChatGPT was specifically integrated as a study tool during the Fall 2023 semester. Students were advised to use ChatGPT to generate example problems for topics including Laplace transforms and forced response for mass-spring-damper systems and were provided with specific examples of ChatGPT prompts used to generate such examples; a sample of which is provided in Figure 2, related to Laplace transforms for second-order ordinary differential equations (ODEs).

```
Anonymous
                                                                                                  Anonymous
    Can you form example equations of motion using second order ODEs that can be
                                                                                                       Can you solve example 2 with initial position of 1 meter and initial velocity of 2 meters
    solved via the Laplace transform? Please use specific initial conditions and external
                                                                                                      per second?
    forcing functions.
                                                                                                  ChatGPT
ChatGPT
                                                                                                                                ~
                                                                                                        Used unknown plugin
    Certainly! The Laplace transform is a powerful tool for solving linear ordinary
                                                                                                      I apologize for the oversight. Let's solve the differential equation step by step using
    differential equations (ODEs) with constant coefficients, especially when initial
                                                                                                      the Laplace transform.
    conditions and external forcing functions are specified. Here are three example
    equations of motion using second-order ODEs:
                                                                                                      Given the equation of motion for a mass-spring-damper system:
                                                                                                      mrac{d^2x(t)}{dt^2}+crac{dx(t)}{dt}+kx(t)=F_0e^{-lpha t}
    1. Mass-Spring System without Damping
                                                                                                       with initial conditions:
    A mass m is attached to a spring with spring constant k. The equation of motion is:
                                                                                                       x(0) = 1
    m\frac{d^2x(t)}{dt^2} + kx(t) = F(t)
                                                                                                       \frac{dx(0)}{dt} = 2
    where x(t) is the displacement of the mass and F(t) is an external forcing function.
                                                                                                      To solve this using the Laplace transform, we'll follow these steps:
    Initial Conditions: x(0) = x_0 and \frac{dx(0)}{dt} = v_0
    Forcing Function: F(t) = F_0 \cos(\omega t)
                                                                                                     1. Take the Laplace transform of both sides of the equation.
                                                                                                     2. Use the properties of the Laplace transform to handle the initial conditions.
    2. Mass-Spring-Damper System
```

Figure 2: Sample ChatGPT prompts, as well as chatbot responses, provided to students during preparation for Quiz 3 in ME3102 Spring 2023.

During both iterations of the course, students were tested with three 50-minute quizzes and a final exam; the quizzes covered comparable material during both semesters. Students in the Fall 2022 iteration of the course were not introduced to ChatGPT or other AI tools; whereas students in the Fall 2023 iteration of the course were encouraged, as described above, to use ChatGPT as a study tool. ChatGPT was not allowed as a resource during the quizzes. In comparing student quiz performance between the two semesters, the authors aimed to evaluate whether the use of ChatGPT as a study tool affected student understanding of course material.

The authors recognize that there are natural differences between course iterations, which may affect the results of this work. For ME3102, we specifically note that, while students Fall 2022 and Fall 2023 were taught by the same faculty member, the exams during the semesters contained different problems (although comparable in subject matter), and the faculty member gained experience between the 2022 and 2023 semesters (the faculty member taught the course for the first time in 2022), and recommended an additional textbook for reference during the Fall 2023 iteration of the course. The course also spent additional time (approximately two class periods) on Laplace transforms during Spring 2023, related to the material in Quiz 3. Additionally, exam policies differed slightly between the two semesters; in Fall 2022, students were allowed to reference page-limited notes during Quizzes 2 and 3 (no notes during Quiz 1), whereas in Fall 2023, students were allowed to reference their notes and textbook during all quizzes. No computer or internet resources (including ChatGPT and other AI tools) were allowed during quizzes in either semester.

#### Results

Students in ME3102 (Dynamic Systems II) during the Fall 2022 and Fall 2023 semesters were evaluated in their understanding of course material during three quizzes and a final exam. In Fall 2023, ChatGPT was presented as a study tool (as previously described); whereas no AI tools were presented in Fall 2022. Quiz results between the two semesters are shown in Figure 3, which presents total scores (labeled "Total") for the three quizzes in Fall 2022 (blue) and Fall

2023 (red), as well as, when possible, direct comparisons in performance between problems with similar subject matter (labeled "P1," "P2", "P3"). The average score for each quiz (and individual problem, where possible) is indicated with a shaded square, and a line extends above and below indicating the standard deviation of the score across the student population.



Figure 3: Quiz scores from ME3102 students over subsequent years, without ChatGPT (2022; blue) and with instruction in use of ChatGPT prompts to create custom example problems as a study aid (2023; red). For Quiz 1 (left), the total quiz score is shown ("Total"); for Quiz 2 (center), one problem ("P1") and the total quiz score ("Total") are shown; and for Quiz 3 (right), three problems ("P1," "P2," "P3") and the total quiz score ("Total") are shown. For each, the mean score is provided with the shaded square, and the lines extend +/- one standard deviation.

In particular, we note the results of the total score for each quiz: For Quiz 1, the Fall 2022 students scored an average of 67% (with a standard deviation of 16%), compared to the Fall 2023 average of 72% (with a standard deviation of 15%); for Quiz 2, the Fall 2022 average was 60% (with a standard deviation of 13%), compared to the Fall 2023 average of 57% (with a standard deviation of 15%); and for Quiz 3, the Fall 2022 students scored an average of 62% (with a standard deviation of 13%), compared to the Fall 2023 average of 74% (with a standard deviation of 13%).

Between the Fall 2022 and Fall 2023 iterations of ME3102, these results corresponded to a score increase of 5% for Quiz 1, a score decrease of 3% for Quiz 2, and a score increase of 12% for Quiz 3. Overall, the authors observed that, based on quiz scores, student performance increased between Fall 2022 and Fall 2023, which correlates positively to the incorporation of ChatGPT as a study tool.

The participation rate for students submitting extra credit to build up the library of prompts for the dynamics course was 57%. While this does not give direct evidence of utilization rate of ChatGPT for exam preparation, it does give a rough indication of exposure to the tool. In the future, surveys will be conducted for students to self-report usage of ChatGPT in preparing for exams. Additionally, students would be given the opportunity to provide subjective feedback on the accuracy and usefulness of ChatGPT, compared to by-hand methods and computational tools like Wolfram Alpha and MATLAB.

## Discussion

Based on the outcomes of this work, the authors recommend the following "AI-Conscious" future teaching approach for engineering education:

- 1. When possible, student understanding should be evaluated using in-person, analog methods; i.e., written exams (including in code-centric classes), oral evaluations, and inclass projects.
- 2. External assignments (primarily homework) should carry little or no weight in student grades. The focus of homework should be shifted towards a tool for student preparedness, with students aware that their completion of assignments will significantly impact their readiness for in-person, heavily-weighted exams and other evaluations.
- 3. Given that student grades will depend on demonstration of understanding without the use of ChatGPT or other AI tools, students should be made aware of the abilities of these platforms as tools to aid in learning and future engineering applications (to the extent to which they are appropriate within the students' future employment). For example, the authors recommend student familiarity with Wolfram Alpha and its associated tools (Wolfram Alpha, 2024), along with other platforms with similar purpose to ChatGPT, including Microsoft Copilot (Microsoft, 2024) and Google Gemini (previously Bard) (Google, 2024).
- 4. There is a huge potential for student-led learning after amassing sets of example prompts. In future years, students can be given a library of prompts from the instructor and from peers of previous years.

Opportunities for the continuation of this project include the continuation of ChatGPT use in future semesters of ME3102 to increase data collection related to the impact of AI on student performance, as well as to fine-tune the use of AI within the course. Additionally, the authors intend to expand Generative AI use in their own technical courses, while providing recommendations for similar use in others, whether as a study tool, problem-solving assistant (to mimic the potential for appropriate AI use in industry or academia in students' future careers), or in the incorporation of exercises which demonstrate the abilities of AI related to course subject matter (as in the MATLAB extra credit assignment in Computer Programming for Mechanical Engineers, as previously described).

The authors expect Generative AI to eventually become ubiquitous in engineering and technical education (much like calculators and search engines), regardless of the specific platform used. Therefore, we look forward to continuing to seek out opportunities for its productive use to aid and engage students in their learning.

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