Incorporating AI into a Structural Engineering Computer Lab

Dr. Allen C Estes, California Polytechnic State University, San Luis Obispo

Allen C. Estes is a recently retired Emeritus Professor who served as Head for the Architectural Engineering Department at California Polytechnic State University in San Luis Obispo for 17 years. Prior to that, Dr. Estes was the Director of the Civil Engineering Program at the United States Military Academy at West Point. Al served in the Army Corps of Engineers for 28 years, retiring at the rank of Colonel.

Dr. Peter Laursen, California Polytechnic State University, San Luis Obispo

Dr. Peter Laursen, P.E., is an Associate Professor of Architectural Engineering at the California Polytechnic State University, San Luis Obispo (Cal Poly) where he teaches courses on the analysis and design of structural systems, and conducts large scale structural testing.

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Abstract

Given rapidly increasing sophistication and wide public access to Artificial Intelligence (AI) software, the academic community is struggling with how to best incorporate this new technology into the classroom. The challenge is to use and leverage the capabilities of this new tool to enhance the student's academic experience without compromising student learning, engineering rigor or academic integrity. This paper describes and assesses the incorporation of AI into an existing computer laboratory course in an undergraduate structural engineering program.

ARCE 352 (Structural Computing I) is a one-unit computer laboratory that is a companion course to ARCE 302 (Structural Analysis) in the Architectural Engineering program at California Polytechnic State University. The students learn the theory and by-hand methods for finding forces and deflections in indeterminate structures in ARCE 302. In ARCE 352, the students use commercial software and Python programming to solve more complex problems of the same type on a computer.

After receiving classroom instruction on Python and creating the code for several assigned programs, students are required to use ChatGPT or any other AI platform to create Python code for a structural engineering application. As an embedded indicator for ABET Student Outcome 7 (Lifelong Learning), students must learn and experiment with ChatGPT on their own. As support for Student Outcome 3 (Effective communication), students write an essay about their results, their AI experience, the learning strategies they applied, and the effectiveness and limitations of using AI to write computer code. The students then use AI to rewrite their essay and comment on what they learned about the quality of their own writing.

After running this exercise over three iterations of the ARCE 352 course, this paper includes the assessment results, lessons learned, conclusions on the effectiveness and challenges of incorporating AI into an engineering computer course, and suggestions for the future. The assessment comes from student surveys, the student results on the assignments, and the collective judgement of the faculty teaching this course.

Introduction

Given rapidly increasing sophistication and wide public access to Artificial Intelligence (AI) software, the academic community is struggling with how to best incorporate this new technology into the classroom. The challenge is to use and leverage the capabilities of this new tool to enhance the student's academic experience without compromising student learning, engineering rigor or academic integrity. This paper describes and assesses the incorporation of AI into an existing computer laboratory course in an undergraduate structural engineering program.

Review of the Literature

The Architectural Engineering (ARCE) program at the California Polytechnic State University (Cal Poly) in San Luis Obispo (SLO) is an intense and comprehensive structural engineering program, arguably providing the most structural engineering content at the undergraduate level of any program in the Nation. While most structural engineers come from the 241 ABET-accredited civil engineering programs, the more prescriptive ABET program criteria prevent those programs from offering as much structural engineering content [1] and the other 26 accredited architectural engineering programs have chosen to offer a more balanced curriculum [2]. The Cal Poly ARCE program is housed in a college of Architecture, along with the disciplines of architecture and construction management, which provides graduates with a broader view of the entire design-construction process.

When the ARCE program recognized the need to integrate Artificial Intelligence (AI) into the curriculum and classroom instruction, we looked for a course that has the greatest applicability and thus the highest potential benefit. While AI has not yet mastered the ability to solve structural engineering problems, it does seem to be most frequently used to produce computer code and improve writing skills, so ARCE 352 Structural Computing I was a logical candidate.

The software development industry not only created AI platforms, but it is also one of the biggest beneficiaries of these technologies. Software developers use these products for code compilation, code debugging, and code-driven testing…even to the point that they prompt an AI product for initial coding and then augment it with their own code. Along with Machine Learning and Natural Language Processing, AI is used to automate the entire software development process, which can include software security, software deployment, planning and cost estimation, understanding user behavior, and even strategic decision making. [3]

ARCE 352 (Structural Computing I) is a one-unit computer laboratory that is a companion course to ARCE 302 (Structural Analysis) at Cal Poly. The students learn the theory and by-hand methods for finding forces and deflections in indeterminate structures in ARCE 302. In ARCE 352, the students use commercial software (RISA, ETABS or SAP2000) and Python programming to solve more complex problems of the same type on a computer. The ARCE program recently switched from MATLAB to Python for a variety of reasons, yet their prerequisite course taught by computer science is still in MATLAB.

Python is the most used language for AI programming followed by C++, Java and R [4]. Python has a readily understandable syntax, which makes it easy for students to learn. It is open source with lots of tutorials, on-line information and a large community of users. The software is free, and the students don't have to purchase a textbook. Importable libraries such as sympy, numpy, and pandas give it a great capability for numerical computations, symbolic solving of equations, import/export of files, and producing graphs and charts.

The benefits of using AI to assist in writing computer programs are enhanced efficiency, data analysis to inform decisions, personalization and customer service, risk mitigation, and fraud prevention. Today, Generative AI tools like GitHub Copilot and OpenAI's ChatGPT increase productivity in software development by producing useful lines of code. The AI platforms increase and improve at an increasingly rapid rate. They will only become better and easier to use. In fact, major breakthroughs occurred during the writing of this paper.

AI is already used extensively in health care, finance, manufacturing, retail, and transportation. The challenges include data availability and accuracy; ethical considerations such as privacy, bias and transparency; lack of people with technical skills and knowledge to run AI systems; and integrating AI systems into currently used systems. In many cases, it takes a highly skilled individual to prompt the AI system for a program and recognize how to efficiently an d effectively modify it. New AI programming languages and frameworks are released regularly, so these individuals must stay current and keep pace with the latest industry trends. [4]

As AI platforms have emerged over the past half-decade, the debate has raged in the academic community as to whether this new technology should be embraced or banned from the classroom. As it has become more apparent that this transformational technology will become an increasingly important part of our world, there is an obligation to introduce students to its capabilities and prepare students for the career opportunities it presents. Slimi [5] argues that applying AI in higher education should be a requirement for all higher institutions. The listed caveats are that academic faculty must be well trained in using AI to equip learners with the required skills to face future career challenges. In addition, faculty must highlight ethics and potential consequences to humanity.

Khalifa and Albadaway [6] specifically addressed the importance of teaching and using AI to improve writing, especially around academic research, to manage complex ideas and extensive information. The study examines 24 cases that demonstrated the impact of AI on academic writing and research. AI enhanced academic writing in the six areas of generating ideas, structuring content, synthesizing literature, managing data, editing, and complying with ethical issues. Grammarly and OpenAI's ChatGPT were singled out for excellence in crafting clear and original academic content through checking grammar, detecting plagiarism, and generating text. The recommendations also emphasized training, ethical usage, and transparent integration in the use of AI.

With respect to the debate on whether AI should be introduced, Ross [7] adamantly suggests that college professors should stop pretending AI does not exist, learn AI alongside the students, teach students how to effectively prompt ChatGPT, and use AI to spark student imagination. Professors should stop worrying about students cheating or not thinking for themselves, but rather reassess assignments to where ChatGPT will challenge the students.

Melo [8] supports AI in the classroom to attain the benefits of personalized experience and feedback, a deepened student understanding of this important new technology, and the

development of modern skills, such as problem-solving, critical thinking, and collaboration. The challenges include the need for technical expertise, the high cost of the AI platforms, ethical concerns and protecting the students. Best practices include starting small, finding a reliable partner with expert knowledge, and stimulating ethical and critical thinking.

Developing the AI Experience

Because of the Python programming emphasis, ARCE 352 was an ideal course to introduce an AI experience into the curriculum. The experience was enhanced by adding a writing requirement to the assignment, not something ordinarily included in a computer programming class. The ABET accreditation process facilitated the writing requirement.

Criteria 3 and 4 of the ABET general criteria [1] identify seven student outcomes (SO) that the program must demonstrate that the students have attained at the time of graduation. Programs demonstrate attainment through direct measures of student performance on assignments that reflect a particular outcome. The AI assignment in ARCE 352 was designed to measure SO7: Ability to recognize the ongoing need to acquire new knowledge, to choose appropriate learning strategies, and to apply this knowledge. It is known more succinctly as the lifelong learning outcome.

As such, the students receive no formal instruction on AI platforms and are expected to learn this assignment on their own. Student performance on the assignment is a direct measure indicator of their attainment of this outcome. Regarding their choice of appropriate learning strategies, the students are required to compose an essay on what learning strategies they applied for the assignment. The content grade on the essay measures the appropriateness of those learning strategies. The quality of writing score on the essay becomes a direct measure indicator for SO3 Ability to communicate effectively with a range of audiences which in the ARCE program encompasses speaking, writing and graphics.

The OpenAI ChatGPT platform does well at both developing Python code and assisting with writing. It can also be downloaded at no cost, so it was suggested for the assignment. Also, the instructors knew in advance that ChatGPT could seamlessly convert a MATLAB program which the students learned in their prerequisite course to a Python program.

Iteration 1: Winter 2024

This first ARCE 352 iteration of the Artificial Intelligence lesson occurred on week 9 of a ten week quarter. In laboratory courses, the final exam occurs in week 10, so this was the final lesson involving new material. Because this was an uncertain experimental lesson, the instructors did not want to address how AI might be used or authorized throughout the rest of the course and saved it until the end.

The stated laboratory objectives were:

1. Demonstrate the ability to acquire and apply new knowledge as needed, using appropriate learning strategies.
2. Demonstrate the capabilities of Artificial Intelligence (AI) to create Python programs for a structural analysis application.
3. Communicate effectively in writing.

The instructor preceded the lesson with a student exercise on how students learn engineering – an exercise given to faculty participants during the ASCE ExCEEd teaching workshop [9]. The intent was for student teams to discuss what steps they would take to learn a complex engineering topic. Because the students were about to deliberately learn on their own, the exercise forced the students to think about possible learning methodologies and discuss how they might be used in combination. The lesson slides are in Appendix B.

The assignment was worth 50 points and was divided into two separate problems.

Problem 1:

Use an AI software program to create, modify, explore and fully explain a Python script that solves a problem related to structural analysis.

(a) Create an account on an AI software package. My recommendation is ChatGPT which you can google and create an account for free.
(b) Think critically and imaginatively and choose a problem related to structural analysis that you would like the computer to solve.
(c) Use the AI program to create the Python code and run the program on Spyder just as you have done for the code you have written yourself this quarter.
(d) Continue to refine your AI request and/or modify the code until the software produces the program that you want. Create an effective output command line. You will be graded on this so if the AI program does not meet our course standards for the command line, then fix it.
(e) Document the program fully to demonstrate that you understand everything the program is doing. If the program uses any commands that we have not covered in class, investigate those commands and explain what they do.

Problem 2:

Write a short essay that describes how you learned to use ChatGPT or any other AI platform you chose to use. What was your thought process for choosing a structural analysis topic for the program? What learning strategies did you use on this assignment? Were they effective? What did you learn that you did not know before? What would you do differently?

To set the students up for success and ensure that they completed all of the steps, the following grading rubric was shared in the assignment:

Grading Rubric (50 points):

Problem 1 — 30 points

- The program runs and gives correct answers.
- Quality of documentation
- Quality of command line
- Your program topic was cool, creative, and interesting.
- Did you teach me something I did not already know?

Problem 2 — 20 points

- Content
- Format
- Quality of writing (spelling, grammar, sentence structure)

The students were given a week to complete the assignment, and the instructor was not available to assist. They were allowed to use any other sources and methods.

The students' topics came predominately from their statics or mechanics of materials courses taken previously or from the structural analysis and structural systems design laboratories that they were currently taking.

Sample topics chosen by the students included:

- Shear moment diagrams for a beam in bending
- Creation and analysis of a determinate truss
- Performance of a simply-supported timber beam
- Solving a class quiz on indeterminate axial structures
- Base shear on a single-story building using seismic response coefficient
- Deflections on a beam-column
- Response of composite plates under an axial load
- Response of a fixed-fixed composite column to temperature effects

Some students managed to get a working program quickly while others struggled mightily. The learning was a highly iterative process of continued prompts and effective communication. The students who chose to have the AI platform create Python code that solved one of their homework problems encountered the most difficulty. Most of those problems had a diagram that ChatGPT could not read or understand, so the student had to communicate the information on the diagram such as forces, dimensions, topology, and restraints using prose. Most students found that they needed to break the problem into smaller steps and teach Chat GPT the problem-solving method (force method, slope-deflection, virtual work, etc.) they wanted the code to use. For some, this required tens of iterations, exact instructions, and a lot of wrong answers before attaining a satisfactory program.

Other students were more successful creating a more versatile and general type of program and allowing the AI platform to decide how to do it. While the students were used to solving problems by hand using a specific technique, the computer often surprised them by using symbolic integration, approximate methods and core principles to solve the problem. The AI platform was very good at creating graphs and charts that reflected results. It seemed incapable of drawing a free-body diagram and a deformation diagram or any kind of sketch that are key to many structural engineering problems.

The items in the grading rubric were scored using sub-rubrics for each of the categories. The student performance is shown in Table 1.

Iteration 1: Winter 2024																					
Rubric	**Student**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**Average**	**Percent**
Problem 1:	Value																				
Program runs and gives correct answers	8	1	8	6	7	6	6	8	8	5	6	6	6	8	8	6	6	2	8	6	6.16	77.0%
Documentation quality	8	4	7.5	8	8	7.5	3	6.5	7	6	7.5	7.5	5	8	6.5	8	8	0	7	6.5	6.39	79.9%
Command Line quality	8	5	8	8	8	7.5	2	8	7.5	7.5	8	6.5	4	7	7.5	8	7.5	2	8	5	6.58	82.2%
Cool, creative, and interesting	6	2	5	6	6	4	3	4	3	4	4	4	4	2	3	4	5	2	4	4	3.84	64.0%
Problem 2:																						
Writing content	8	5	8	8	8	8	7	7	7	8	8	7	8	8	6	8	6.5	1	8	5	6.92	86.5%
Prescribed format	4	3.5	4	4	3.5	4	4	4	4	3.5	4	4	4	4	4	4	4	4	4	3	3.87	96.7%
Quality of writing	8	3	7.5	8	8	8	4	6	7	5	6	8	7	6	6	8	8	3	8	8	6.55	81.9%
Student score	50	23.5	48	48	48.5	45	29	43.5	43.5	39	43.5	43	38	43	41	46	45	14	47	37.5		

Table 1: Student Performance Result on the Iteration #1 AI Assignment

Except for two students, the class did a good job in submitting the Python code that ran and performed as intended. Many lost points for not being able to verify that the answers provided by the program were correct. The students were not explicitly required to submit sample calculations to compare their own computations with the computer output. Students realized through their iterations that ChatGPT produces answers confidently and quickly, but they are often wrong, because the AI platform does not understand what is being asked. The next iteration requires sample calculations to be submitted.

The documentation requirements include a few sentences at the beginning of the programming code that describe what the program is supposed to do. Comment statements follow throughout describing the steps that the computer is taking to solve the problem. The AI platform used a lot of code statements that the students had not learned in class. A requirement of the assignment was to investigate and explain any code that had not been previously taught. This was an important learning opportunity that many students did not take seriously enough. The explanations were facile or pasted directly from a web search.

The standard for the command line was to provide the input data to the problem, avoid extraneous intermediate step values and provide clear and complete results with descriptive variable names, answers to an appropriate number of decimal places and inclusion of units. The

ChatGPT-generated results were reasonable but needed extra prompts to provide input data and more complete output results. The student was expected to provide additional prompts or supplemental code to meet the course standards.

Many of the programs were unimaginative or simplistic. Cool and creative may have been an unrealistic expectation given that this was a first attempt at using AI and students needed a good command of the material to be able to detect wrong answers and create appropriate prompts. Nevertheless, this portion of the rubric was intended to reward students who were more intellectually curious or ambitious in their choice of topic.

The content of the student essays was quite good overall. The prose met the requirements of the assignment and described the learning methods used along with their journey through the problem. Some gave a detailed account of their fits and starts in communicating effectively with the AI platform. Most importantly, the essays were sufficient to confirm that students used "appropriate methodologies" in their self-learning experiences. The quality of the writing, on the other hand, was quite bad overall. Many students rambled in a stream-of-consciousness manner using more sentences than necessary to tell their story. The students either have not learned to write well, or more likely, don't take it seriously on an engineering assignment, because it is not usually graded. Reading them was painful but the content, once deciphered, was solid. The best essays were created when the students wrote the essay themselves and then asked an AI platform to rewrite it for them. The worst essays resulted when students relied on AI to write the specific content of their essay and they never proofread it. This was such an important consideration that we chose to require that AI be used in a specified manner to assist with writing in the second iteration. The format portion of the rubric was of almost no value and eliminated in the next iteration.

Iteration 2: Fall 2024

This second ARCE 352 iteration of the Artificial Intelligence lesson occurred on Week 8 of a ten-week quarter. The learning objectives for this assignment were not changed from the first iteration. The directions for **Problem 1** were augmented to specifically require sample calculations and a record of the prompts needed to solve the problem:

(f) Getting ChatGPT to provide you with the desired program may take multiple prompts. Keep a record of the prompts and how you successively revised them to get the program you wanted
(g) Include sample hand calculations to verify that your program provides the correct answers.

Problem 2 was modified as follows:

(a) Write a short essay that describes how you learned to use ChatGPT or any other AI platform you chose to use. What was your thought process for choosing a structural analysis topic for the program? What learning strategies did you use on this assignment? Were they effective? What did you learn that you did not know before? What would you do differently?
(b) Use the AI platform to rewrite your essay for clarity, grammar, spelling and sentence structure.
(c) Assess the result and comment on how your own writing can be improved.

The grading rubric was changed to accommodate these changes and to implement the lessons learned from the first iteration:

Grading Rubric (50 points):

Problem 1 — 30 points

The program runs and gives correct answers.
Iteration of prompts
Sample calculations
Quality of documentation and describe unfamiliar code
Quality of command line
Program topic was cool, creative, and interesting.

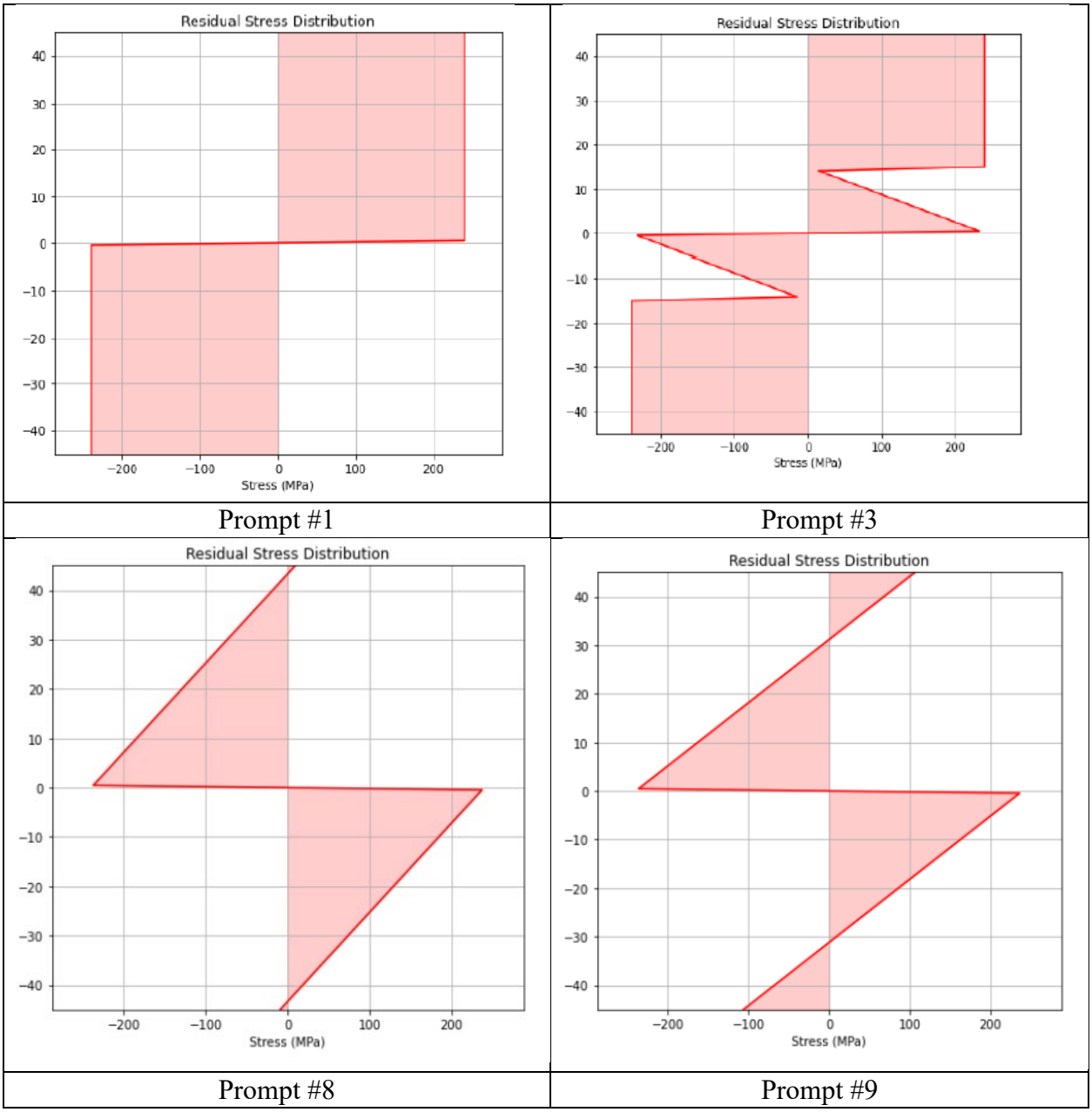
Problem 2 — 20 points

Content
Quality of writing (clarity, grammar, sentence structure)
AI revision of the writing
Assessment of how writing improved

Sample topics chosen by this group of students included:

- Find and graph the residual stresses on a beam with a hole in the cross-section after loading to the plastic moment capacity and releasing the load.
- Choose the best W-shape cantilever beam from an imported excel spreadsheet based on an allowable deflection limit of 0.4 inches
- Draw shear, moment and deflection diagrams for a fixed-fixed loaded beam.
- Solve for the reactions in a specific indeterminate loaded beam using virtual work to compute the deflections.
- Draw the moment diagram for a fixed-pinned indeterminate beam loaded with a point load at any point along the beam.
- Find the unit shear in a roof framing plan supported by shear walls and subjected to a specific wind load.

For this iteration, fewer students chose to complete a specific problem from the textbook or a homework problem. Multiple students chose to draw shear, moment and deflection diagrams for loaded determinate and indeterminate beams. Choosing a specific beam to accommodate a specific load case was also developed by several students. The record of successive prompts provided a vivid picture of how some students struggled to communicate with the AI platform.



Prompt #1	Prompt #3
Prompt #8	Prompt #9

Figure 1: The residual stress diagrams for a beam with a rectangular hole in the cross-section loaded with the fully plastic moment and released provided by ChatGPT after successive prompts from a student

The results for each prompt were more visible when a graph was being modified after each prompt. Figure 1 shows changes in the residual stress graph after four different prompts. The correct answer was obtained after the ninth prompt.

The comments from students that a problem had to be broken down into component parts and solved using progressively simple prompts formed a consistent thread through this assignment as well. It was surprising to see how polite many students were in their interactions with the AI platform.

Again, using a series of sub-rubrics for each element of the overall grading rubric, the results are shown in Table 2:

Iteration 2: Fall 2024																	
Rubric	Student	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
Problem 1:	Value																
Program runs and gives correct answers	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	4.64	92.9%
Describe iterations	5	5	5	3	5	5	5	3	2	5	5	5	5	4.5	5	4.46	89.3%
Sample calculations	5	0	4.5	4	4.5	5	5	5	0	4.5	5	0	5	5	2	3.54	70.7%
Documentation quality	5	3.5	2.5	2	4.5	0	5	4	3.5	5	4.5	2.5	5	4	3.5	3.54	70.7%
Command Line quality	5	4.5	4	3	3.5	3	5	4.5	3	5	5	3.5	4	3.5	4	3.96	79.3%
Cool, creative, and interesting	5	4.5	4.5	4.5	4.5	4.5	3.5	3	2.5	4.5	4.5	2.5	4.5	2.5	3	3.79	75.7%
Problem 2:																	
Writing content	5	4.5	3.5	4.5	4	4	3.5	4	3	5	5	4.5	4.5	4.5	3.5	4.14	82.9%
Quality of writing	5	4	3.5	3.5	3.5	3.5	3.5	3	2.5	3.5	5	3	3.5	3.5	4	3.54	70.7%
AI version of essay	5	5	0	5	0	5	5	0	5	5	1	0	0	5	5	2.93	58.6%
Describe writing improvement	5	5	4.5	4.5	0	4	4	0	3	3.5	3.5	0	0	3.5	3	2.75	55.0%
Student grade	50	41	37	39	34.5	39	44.5	31.5	29.5	46	43.5	26	36.5	41	33		

Table 2: Student Performance Result on the Iteration #2 AI Assignment

Again, the students did a great job of using an AI platform, on which they had no formal instruction, to produce working Python code for a specific structural analysis application and produce correct answers. Only one student failed to submit the code, but it was apparent from her documentation that she created a working program. The records of the prompts required to solve the problem were illuminating and offered real insights into the challenges the students faced, and the degree of effort required for the assignment. Three of the 14 students neglected to submit sample calculations. For those that did, the calculations provided proof that the program gave correct answers, although it took many iterations to get those correct answers. Wrong answers are a real problem with the current versions of ChatGPT. The other elements of the rubric for problem 1 produced similar performance results as Iteration 1. Students still did an incomplete job of identifying and explaining any new code commands that had not previously been taught. The students tended to use whatever command line and comments that the AI platform provided, which in many cases was quite adequate. It was hard to tell how effective it was to improve commenting and documentation through additional prompts.

The results of the writing assignment in Problem 2 were far more effective with the changes made to the assignment. The writing content was similar to Iteration 1 where students answered the questions posed by the assignment. The students chronicled their step-by-step experience

with the AI platform quite well, but gave short shrift to identifying the methodologies used to learn on their own…. which was a big part of the ABET portion of the assignment. For the most part, they did not state whether they read a book, searched online, sought help from another professor, consulted with classmates or watched a You-Tube video to learn the AI capabilities. This needs to be asked more explicitly in future iterations.

The quality of the student writing was disappointing as with Iteration 1 for all the same reasons….maybe even more since they knew that AI would be improving their writing. More disappointing was that six of the 14 students did not use AI to improve their writing as the assignment required. For those eight students that did follow the directions, the results were very revealing. In all cases, the AI platform greatly improved the student writing and made it far easier to read and understand. This was done with little to no change to the content. In six cases, the AI revision shorted the length of the essay and in the other two it remained about the same. The total number of words in the student composed essays was 3,487 and the number of words in the revised essays was 2,756, representing an overall reduction in length of 21%.

In addition, the students were quite insightful about how the AI platform improved their writing. Some student comments included:

- Improved clarity and flow
- Produced concise and direct sentences
- Refined the transitions
- Enhanced the formality of tone
- Improved sentence structure and word choice
- More polished and professional
- Essay more readable and engaging
- Smoother flow, cleaner, more refined
- Better verb choice
- Improved grammar
- Technical explanations more precise
- Avoided repetition of words and thoughts
- Eliminated unnecessary words
- Ensured each sentence added value
- Consistency of grammar and tense
- Created new paragraphs to separate thoughts
- Made writing more formal, less colloquial.

These are not comments provided by a professor. The students deduced these by examining the differences in the two writing samples.

Iteration 3: Winter 2025

The third ARCE 352 iteration of this lesson occurred in late February on Week 8 of the ten-week Winter quarter of 2025. The assignment objectives, the specific requirements, and the grading rubric remained the same. The directions were augmented to ensure students provided sample calculations, commented on any Python commands not previously learned in class, and included their learning methodologies in the essays. The enhanced comments increased the student participation and in some cases performance in those areas.

Overall, the structural engineering topics chosen by this group of students were less complex and more prosaic. Most programs used a single specific structure. With some additional prompts, many of these programs could become more robust and handle an entire category of structures, but most students did not pursue this. Some topics included:

- Find the shear, moment, maximum shear, maximum moment and maximum deflection on a specific determinate cantilever beam
- Find the area moment of inertia for some common shapes where the user inputs the dimensions
- Use symbolic Python (sympy) to find the equations for the shear, moment, slope and deflection for a uniformly loaded determinate beam and plot their graphs
- Find the maximum moment and plot the moment diagram for a uniformly loaded simply supported determinate beam where the user enters the beam length, depth, moment of inertia and factor of safety
- Use Scientific Python (scipy) to compute the midspan deflection of a uniformly loaded simply supported determinate beam using virtual work

Using the same grading rubric as for Iteration 2, the student results for Iteration 3 are shown in Table 3.

Iteration 3: Fall 2025													
Rubric	**Student**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Average**	**Percent**
Problem 1:	Value												
Program runs and gives correct answers	5	5	5	5	5	5	5	5	5	3	2.5	4.55	91.0%
Describe iterations	5	5	2	5	4	5	5	0	5	1	1	3.3	66.0%
Sample calculations	5	5	5	0	5	5	5	5	5	3	0	3.8	76.0%
Documentation quality	5	5	5	4	4	5	3.5	3.5	4.5	4.5	4.5	4.35	87.0%
Command Line quality	5	4	5	3.5	4	5	4.5	4	5	4.5	5	4.45	89.0%
Cool, creative, and interesting	5	1	2	2	3	2	3	4	3	3.5	4	2.75	55.0%
Problem 2:													
Writing content	5	3	3.5	4	5	4	3.5	3	5	4	2.5	3.75	75.0%
Quality of writing	5	4	3	2	2	4.5	3	3	2	4	2.5	3	60.0%
AI version of essay	5	5	5	5	5	5	5	3	5	5	5	4.8	96.0%
Describe writing improvement	5	4	5	3.5	5	5	5	3	5	3.5	3	4.2	84.0%
Student grade	50	41	40.5	34	42	45.5	42.5	33.5	44.5	36	30	38.95	77.9%

Table 3: Student Performance Result on the Iteration #3 AI Assignment

While the scores for "cool, creative and interesting" were lower than for past groups, the student grades on the assignment were slightly higher. With simpler problems, the students were better able to meet the other elements in the grading rubric. With additional emphasis in the assignment guidance, more students followed all the instructions and included their learning methodologies into their essays and all used ChatGPT to improve their writing.

The biggest development in the third iteration was the sudden improvement in the ChatGPT software. With the recent release of ChatGPT-4o, the software demonstrated the ability to interpret figures which represents a substantial upgrade in capability for solving structural engineering problems. Only a handful of students recognized and used this new capability.

One remarkable student uploaded a document with the figure below and a problem statement that read, "Analyze the frame below. Compute all reactions. Also, $I_{BC} = 200$ in^4 and $I_{AB} = I_{CD} = 150$ in^4. E is constant."

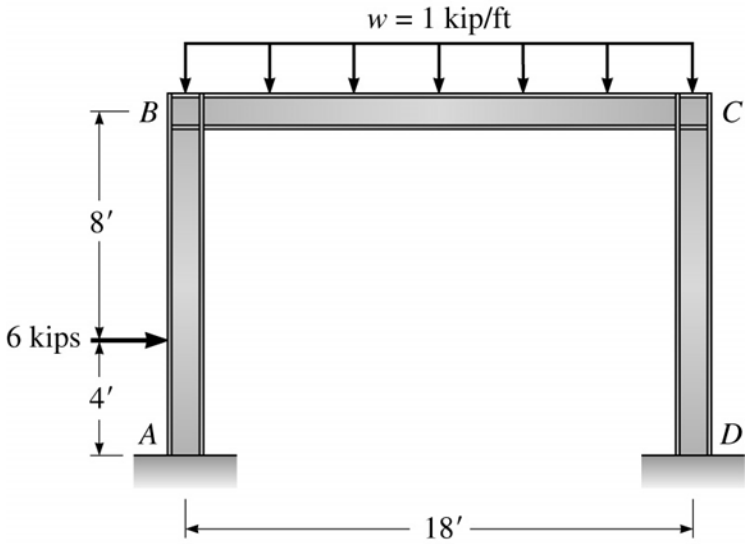


Figure 2: A drawing uploaded into ChatGPT-4o which has figure interpretation capability.

The AI platform responded with a complete written description of the figure and created a Python code that provided the stiffness matrices for the individual members, assembled them in a global stiffness matrix, reduced the global matrix by applying the boundary conditions, and applied the assumed loads to solve for the free displacements. From there, it solved for the reactions.

The platform did not initially recognize the prescribed loads on the structure, so it assumed 10 kip lateral loads at points B and C. With several additional prompts that described the actual loading and other details, the program provided correct answers. With additional prompts the code was expanded to a more general-purpose structural analysis program where the user inputs information on the location of nodes, material properties, type of connections, loading conditions, and even topology of the structure. The upgraded version of ChatGPT also provides

better internal commenting throughout the program, making the coding and algorithm much easier for the user to follow. This improvement also helps explain the increase in student scores in this area of the rubric during this iteration.

With respect to the writing portion of the assignment, the scores on the initial essays were the lowest of the three iterations in both content and writing quality. All students loaded their initial essays into the AI platform and the students made insightful comments on the improvements in their writing. The total number of words in the student composed essays was 4145 and the number of words in the revised essays was 3230, representing an overall reduction in length of 22.1%, which is almost identical to iteration #2.

The Student Experience

The student essays provided detailed feedback on the students' immediate experience with the AI platforms on creating a Python program and improving their writing. Appendix A shows a survey that was administered to all three iterations of students. The survey was voluntary and anonymous and had 25 respondents. The survey attempts to get some less immediate, more reflective responses to questions about the capabilities of the AI platform, how easy or valuable it was to use, their likelihood of experimenting further, and their opinion on the degree to which AI should be included in future iterations of the course.

AI Platform Tasks	**Stated Ability**
Convert MATLAB code to Python	3.38
Create new code in Python based on your prompts	3.52
Assist with syntax errors and debugging your Python code	4.08
Add the comments and documentation to support your program	4.13
Produce high quality graphs and charts	3.19
Improve the quality of your writing	4.32
Improve the content of your writing	3.68

Table 4: Student Survey Results on AI Capability

The students were asked to rate the capability of their AI platform on a series of tasks. For each capability, a Likert scale was used with the following descriptive indicators: 1= horrible, 2= not good, 3 = fair, 4=good, and 5=outstanding. An N/A (not applicable) option was offered. 48% of the students answered N/A for the first capability which makes sense because the students were never explicitly asked to convert MATLAB code, even though the instructors knew this was a strong capability. All other capabilities received very few N/A responses. As shown in Table 4, the students gave the highest ratings to debugging their programs, adding documentation, and improving the quality of their writing. Producing high quality graphs and charts was rated the lowest.

Table 5 rates the student experience with respect to how much they liked the AI platform, learned from it and found it easy to use. The Likert scale options for rating these positive statements were: 1=totally disagree, 2=moderately disagree, 3=no opinion, 4=moderately agree, and 5=strongly agree. The student results were overwhelmingly positive and surprisingly, very few students chose the neutral no opinion option on any of the statements. Students felt most strongly that ChatGPT was easy to use and they learned a lot. Some had doubts as to how effectively it worked.

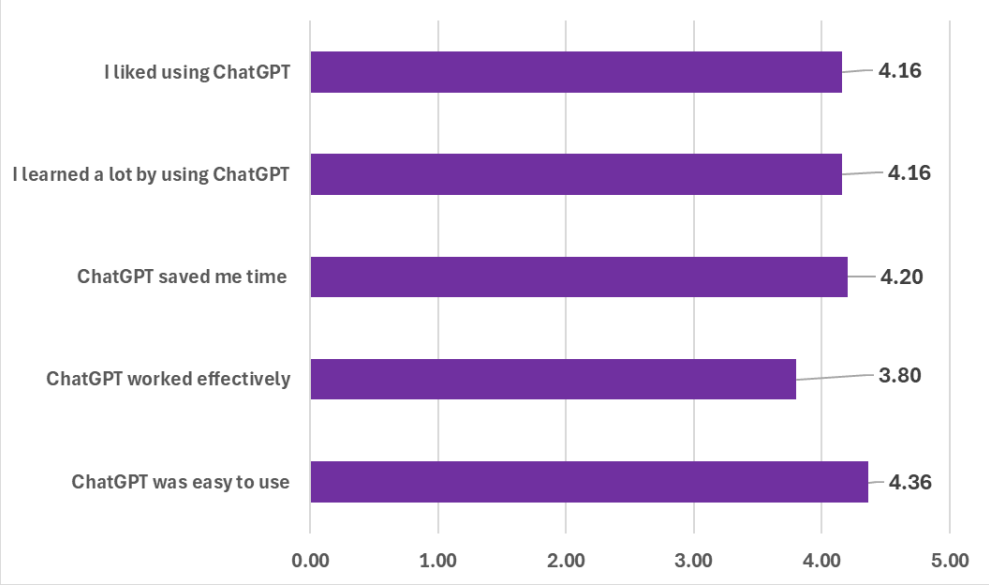


Table 5: Student Survey Results on their own Experience with AI

Students were asked to recommend whether the inclusion of AI into the ARCE 352 course should be eliminated, continue with a single experience, or expand. Figure 3 shows that almost nobody recommended elimination. Beyond that, the students were evenly split on the degree to which it should be included in the future.

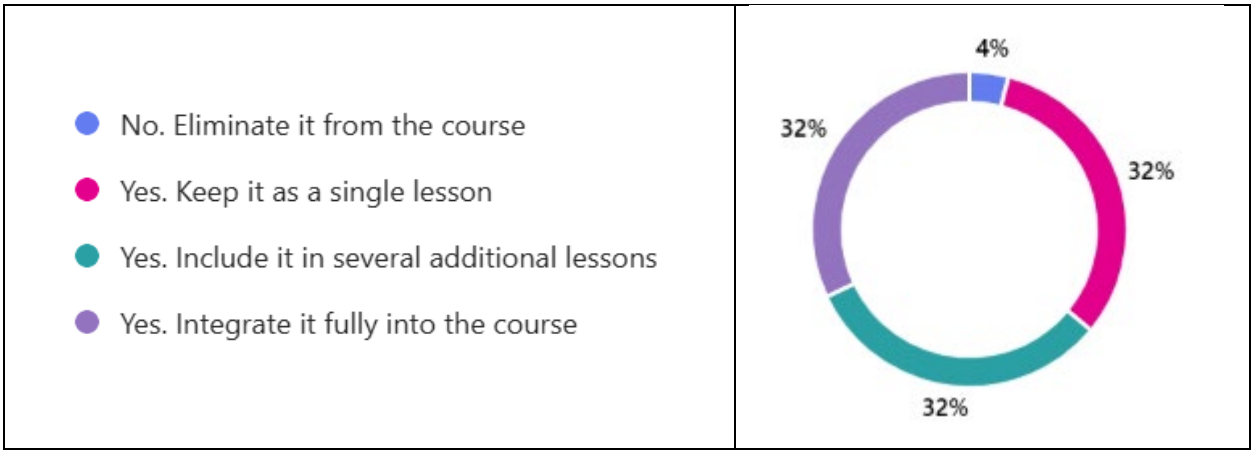


Figure 3: Student recommendations on the future of AI in ARCE 352

Conclusions and Recommendations

Without any classroom instruction, the students in ARCE 352 demonstrated that they could successfully access an AI platform (specifically ChatGPT), learn how it works and create a working Python computer program that solves a structural engineering problem. They wrote essays that reported the appropriateness of their learning strategies. The AI platform rewrote the student essays offering immediate, personalized and effective feedback on the quality of the writing.

The following lessons-learned and recommendations are summarized:

- Artificial intelligence, while still in its infancy, is already making a huge change in how businesses operate and people learn. It is a transformational tool that will only get better. ChatGPT improved greatly over the three iterations of this assignment. Employers that hire college graduates expect and value those with skills in the latest technology. It would be irresponsible not to incorporate AI into a college curriculum, if part of the university experience is to set students up for success in their working careers
- The advice of starting small and learning alongside the students [7] worked well on this assignment. The opinion that the professor must become an expert on the new technology before incorporating it into the curriculum [5] is unrealistic and counterproductive. Everyone is better served if the faculty show some humility and are willing to learn from the students who are often more tech savvy and more flexible in learning the newest developments. This was an ideal assignment to ask the students to learn on their own.
- The obligation to protect the student [8] was poignant. Once students use AI in ARCE 352, they will likely use it in other classes. They need to be warned about how AI should be documented if used elsewhere and encouraged to consult with the faculty members of those other courses before using it.
- AI platforms are quickly becoming more adept at solving standard structural engineering problems. ChatGPT-4o can now interpret drawings that provide information such as structural loads, cross-section shape and dimensions, restraints and topology. Students in the next iteration of this assignment should be able to make far greater use of this capability. The AI platform cannot yet interpret create visual aids such as free body diagrams or deformation diagrams that are key to solving and understanding the problem. AI was helpful in producing charts and graphs. One question to answer is whether the challenge lies with AI or the programming capability of Python.
- Conversely, the difficulty in solving structural engineering problems may have provided a richer learning experience for the students. One of the desired skills needed for AI is the ability to effectively prompt the AI platform to get the best results in the most efficient manner. The students had to display that skill to a greater degree for those structural engineering problems, which might make them more marketable for using AI to solve more commonplace problems

- A purported benefit of AI in the classroom is more personalized instruction. That certainly occurred when ChatGPT rewrote each student's essays. It would take substantial time and effort for a human instructor to provide that type of feedback. The student comments on how their writing can be improved were revealing and insightful.
- Even after a single experience, the students had many good answers and suggestions for what they would do differently next time. The most common theme was to break prompts into small clear steps and build the program sequentially. They also recognized the need for sample calculations because the AI platform often misunderstands the prompts or gives wrong answers.
- This exercise was deliberately left until the end of the course to avoid addressing how AI might be used during the rest of the course. These results form a basis for discussing how AI might be integrated into the rest of the ARCE 352 course and the follow-on courses in terms of debugging code, program documentation and getting more proficient at prompting the AI platform.

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Appendix A: Student Participant Survey

ARCE 352 Survey on incorporating Artificial Intelligence (AI) into the Course

1. Based on your own use, please rate the ability of an AI platform with respect to each the following:

	Horrible	Not good	Fair	Good	Outstanding	N/A
Convert MATLAB code to Python	◯	◯	◯	◯	◯	◯
Create new code in Python based on your prompts	◯	◯	◯	◯	◯	◯
Assist with syntax errors and debugging your Python code	◯	◯	◯	◯	◯	◯
Add the comments and documentation to support your program	◯	◯	◯	◯	◯	◯
Produce high quality graphs and charts	◯	◯	◯	◯	◯	◯
Improve the quality of your writing	◯	◯	◯	◯	◯	◯
Improve the content of your writing	◯	◯	◯	◯	◯	◯

2. Should we continue to include Artificial Intelligence in the ARCE 352 course?

- ◯ No. Eliminate it from the course
- ◯ Yes. Keep it as a single lesson
- ◯ Yes. Include it in several additional lessons
- ◯ Yes. Integrate it fully into the course

3. Mark the degree to which you agree with the following statements:

	Totally disagree	Mildly disagree	No opinion	Mildly agree	Strongly agree
ChatGPT was easy to use	◯	◯	◯	◯	◯
ChatGPT worked effectively	◯	◯	◯	◯	◯
ChatGPT saved me time on my assignment	◯	◯	◯	◯	◯
I learned a lot by using ChatGPT	◯	◯	◯	◯	◯
I liked using ChatGPT	◯	◯	◯	◯	◯

4. How likely are you to experiment further with ChatGPT and other AI platforms?

0	1	2	3	4	5	6	7	8	9	10

Not at all likely — Extremely likely

5. Do you have any insights either good or bad that you would like to share on Artificial Intelligence

Enter your answer

Appendix B: Student Exercise on Learning [9]

A Design Project

- Given:
  - A complex engineering concept, with a variety of important applications
  - You know *nothing* about it
- Resources:
  - A textbook that covers the topic
  - 6 hours:
    - 2 one-hour blocks of classroom time with a subject-matter expert
    - 4 hours on your own, outside of class
- Required: Design a sequence of activities that will help you learn the *concept* and its *applications* most effectively.

You have 7 minutes

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Some *Possible* Activities

- Read the textbook.
- Receive a lecture on the concept from the expert.
- Watch the expert solve an example problem.
- Describe your own understanding of the concept to the expert, and get feedback on how well you really understand it.
- Discuss the concept with your peers.
- Solve a practice problem with assistance from the expert.
- Solve a practice problem on your own, then get feedback from the expert on how well you did.
- Solve a practice problem with your peers.

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