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Assessing ChatGPT 4o for AI-Assisted Problem Solving in Electric Circuits Teaching

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Introduction

Electric Circuits is a core course in Electrical Engineering and serves as a prerequisite for many advanced courses. The second half of the Electric Circuits course typically covers key topics such as Laplace Transforms, Filters, Fourier Series and Fourier Transforms, and two-port circuits. The process of solving problems generally involves following a structured sequence of steps. Using Laplace Transforms as an example, students usually need to go through the following steps to solve a problem:

1. Examine the circuit diagram and identify the circuit elements, and note the initial conditions.
2. Convert the circuit to the s-domain using Laplace Transforms by replacing all time-domain elements with their Laplace equivalents, and transform time-domain sources into the s-domain.
3. Apply circuit analysis methods correctly, such as Ohm's Law, Kirchhoff's Voltage and Current Laws, Node Voltage, Mesh Current Analysis, Thevenin/Norton equivalents etc., to write equations for the circuit in the Laplace domain.
4. Combine and simplify equations in s-domain through algebraic steps, including the calculation of transfer functions.
5. Perform partial fraction decompositions to simplify the equations into a form suitable for inverse Laplace Transform.
6. Apply the inverse Laplace Transform to transform the solution back to the time domain using the standard transform pairs.
7. Interpret the solutions and perform following steps such as determining the initial and final values depending on the requirements.

One of the key teaching and learning methods in this course is providing a detailed, step-by-step demonstration of how to solve circuit problems manually. When students face challenges in class or with homework, the most effective teaching method is to walk them through problem-solving steps to help them understand the material through an application. This approach helps students gain a deeper understanding of complex concepts and strengthens their problem-solving abilities. However, this process is time-intensive. Instructors or teaching assistants (TAs) can only assist a limited number of students in a given time, making it challenging for all students to get the help they need due to resource constraints.

Simulation software like Multisim and SPICE is widely used in electric circuits course teaching [1-2]. Some textbooks have integrated these tools into course materials and problems. These tools allow for real-time simulation and visualization of circuit behavior to help students better understand theoretical concepts and to become familiar with industry-standard tools. Additionally, simulation software enables students to validate their solutions quickly. However, these tools often lack step-by-step guidance and explanation of the approaches and formulas used to solve the problem because these tools are not originally designed for education. Students can find results without fully understanding the foundational concepts, which hinders students from developing critical analytical, problem-solving, and mathematical skills.

Artificial Intelligence (AI) has made significant strides in various fields, including education. Generative AI tools powered by Large Language Models (LLMs) have demonstrated remarkable capabilities in answering questions, generating ideas, writing code, providing technical assistance, and retrieving information [3-5]. ChatGPT, one of the most well-known AI chatbots, is trained extensively with internet-based materials and exhibits human-like language understanding and generation. The latest version recommended by OpenAI for most tasks is ChatGPT-4o [6].

While the use of AI in education remains a topic of debate in academia, many students already turn to AI tools for help before seeking assistance from the instructor or TAs. Based on observations, most students do not copy AI solutions directly. Instead, they ask AI for help with specific concepts or steps they find challenging. When the AI's answers appear reasonable, students often adopt its suggested approaches. In this way, AI acts as an easily accessible and responsive assistant, similar to a classmate, TA or instructor. Therefore, it is essential to evaluate the strengths and limitations of AI in teaching and learning, particularly in engineering where numerical accuracy and conceptual understanding are of importance. AI can provide quick and accessible guidance, but it may also introduce biases, errors, or oversimplifications [7-8].

This study selected the Electric Circuits course as a testbed to evaluate the integration of AI into classroom teaching. The primary reason for this choice is that the problem-solving process in Electric Circuits follows a well-defined and systematic approach. It is a long-established course with relatively stable instructional materials and topics that have remained consistent over many decades. Additionally, the abundance of online resources for Electric Circuits provides a robust training foundation for AI models. Secondly, we sought to analyze the impact of AI in engineering education and pedagogical theory under the frame of social constructivist paradigms built upon the ideas of theorists including Lev Vygotsky, Jean Piaget, and John Dewey [9]. Social constructivism in terms of educational pedagogy refers to a theory of learning that emphasizes the role of social interactions and collaborative activities in the construction of knowledge. The core assertion is learning is a social process where individuals construct meaning through their interactions with others rather than passively receiving information. Social learning is social-centered where collaboration leads enhanced learning when students work together, share ideas, discuss concepts, and solve problems in group settings.

Under this pedagogical theory teachers are encouraged to serve not as repositors of knowledge, but guides-on-the-side facilitating learners' educational attainment as they scaffold new ideas into prior understandings refining concepts over time. Learners are viewed as active participants in their learning process, constructing understanding based on their prior knowledge and experiences. This approach often involves hands-on, inquiry-based learning. As such, one's knowledge is influenced by their cultural background, social environment, and prior experiences. These factors influence and shape how students understand and interpret new information.

AI as a new ideology is quickly emerging and stands to greatly impact how humans seek out new information and learn. While social constructivism has until now fostered a pedagogical environment where students are encouraged to engage in dialogue, problem-solve, and reflect thereby promoting deeper understandings and critical thinking skills, AI now offers an entirely new modality of information gathering. Current AI models are normally trained by the materials generated by human. We believe effective use of AI in educational paradigms must be based on a human centric theory where human inputs, interactions, and feedback drive learning as they co-

train AI agents in the pursuit of knowledge building. In this study, we use Electric Circuits as a testbed to find the key principles to ensuring an effective integration of educational AI tools in future pedagogical practices. We call this blending of the use of AI tools within an established human-centered educational paradigm Social Constructivist Artificial Intelligence Learning (SCAIL). Application of SCAIL in classroom settings will allow for improvement of AI's outputs via corrective feedback from instructors and TAs over time.

Methods

The objective of this study was to assess the performance of OpenAI's ChatGPT-4o in assisting students' understanding of course materials in the context of students following a step-by-step method of Electric Circuits problem solving. The evaluation of ChatGPT-4o focused on the following five categories:

Category 1. Ability to read and understand circuit diagrams presented in images

Category 2. Ability to break down problem-solving procedures into clear, logical steps

Category 3. Ability to select appropriate formulas and conduct calculations

Category 4. Ability to analyze circuit configuration and conduct calculations

Category 5. Accuracy in the use of equations and numerical calculations.

The study was designed and conducted with the following steps in class:

1. The instructor taught the course materials and concepts required to solve the selected problem.
2. The instructor presented a sample problem and demonstrated the solution step-by-step, helping students understand the methodology and logical flow of solving problems.
3. A similar problem was then given to students to solve independently or in groups. This approach allowed the students to apply the concepts and steps taught be the instructor.
4. Students were provided with ChatGPT-4o solutions for the same problem. They were tasked to:
   - review the AI-generated solutions.
   - identify any errors in the solutions.
   - compare the AI's methods and solutions with their own solutions.
   - evaluate the performance of AI in solving the problem.
5. The instructor reviewed the AI solutions and pointed out any errors, providing additional comments to help students better understand the strengths and limitations of AI-generated solutions.
6. Students completed a survey to share their opinions on AI's effectiveness and the potential of the use of AI as a teaching and learning tool.

The problems for the study were selected from the 12th edition of "Electric Circuits" by Nilsson and Reidel, a widely-used textbook in the field [10]. The problems were presented to ChatGPT-4o using text to define the question, and images to define the circuit diagram and/or source waveforms. To ensure consistency in the results, all the problems were presented to ChatGPT-4o using the same prompt.

Results

The study evaluated ChatGPT-4o's performance in solving Electric Circuits problems based on the five defined criteria. The results for each category are as follows:

Category 1. Ability to read and understand circuit diagrams presented in Images

ChatGPT-4o demonstrated 100% accuracy in extracting information from circuit diagrams presented in images and in text. It accurately identified and understood circuit element symbols, numerical values, and units. It appears that ChatGPT can handle formatted text input in Markdown, HTML, JSON, CSV and mathematical expressions in LaTex. Here is one of the examples:

Question to ChatGPT4o:

What is the output v_0 if the input v_g is a square wave with the amplitude of 12.56 V and an angular frequency of 100 rad/s?"

The circuit diagram image uploaded to ChatGPT-4o is shown in Figure 1.

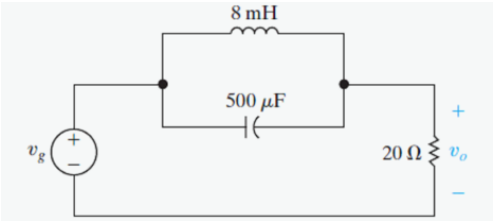

Figure 1: The circuit diagram provided to ChatGPT 4o.

ChatGPT-4o Output:

This circuit consists of an inductor ($L = 8mH$), a capacitor ($C = 500\mu F$), and a resistor ($R = 20\Omega$) in series with a voltage source (v_g) that provides a square wave with an amplitude of $12.56\ V$ *and an angular frequency of 100 rad/s.*

Category 2. Ability to break down problem-solving procedures into clear, logical steps

ChatGPT-4o provided well-structured, logical step-by-step solutions that aligned closely with the problem-solving sequences taught in class. See Figure 2 for ChatGPT-4o's output of the above example problem.

To solve this problem, we can break it down into the following steps:

1. **Analyze the circuit:**
   - This is a second-order RLC circuit where the inductor and capacitor are in parallel, and this combination is in series with the resistor.
   - The output voltage v_o is taken across the resistor.

2. **Calculate the impedance of the RLC network:**
   - The impedance of the inductor is $Z_L = j\omega L$.
   - The impedance of the capacitor is $Z_C = \frac{1}{j\omega C}$.
   - The equivalent impedance of the parallel LC circuit is given by:

$$Z_{LC} = \left(\frac{1}{Z_L} + \frac{1}{Z_C} \right)^{-1}$$

   - Once you have Z_{LC}, add it in series with the resistor to get the total impedance.

3. **Use voltage divider to find v_o:**
   - Use the voltage divider formula to find the output voltage across the resistor:

$$v_o = v_g \times \frac{R}{R + Z_{LC}}$$

   - Since the input v_g is a square wave, it can be represented by its Fourier series components. The fundamental frequency component can be used to approximate the response.

Figure 2: The solution breakdown provided from ChatGPT-4o was well aligned with the problem-solving sequences used in class.

Category 3. Ability to select appropriate formulas and conduct calculations

ChatGPT-4o successfully selected relevant formulas after analyzing the circuit and provided detailed calculation steps. ChatGPT also excelled in answering follow-up questions, as shown in Figure 3, where it identified that the circuit filtered out the frequency at 500 rad/s due to

The filtered Fourier series components, after accounting for the RLC circuit's effects, are:

1. Amplitude = 15.98 V at frequency $\omega = 100\,\mathrm{rad/s}$
2. Amplitude = 5.24 V at frequency $3\omega = 300\,\mathrm{rad/s}$
3. Amplitude = 0.00 V at frequency $5\omega = 500\,\mathrm{rad/s}$ (filtered out due to resonance)
4. Amplitude = 2.19 V at frequency $7\omega = 700\,\mathrm{rad/s}$
5. Amplitude = 1.75 V at frequency $9\omega = 900\,\mathrm{rad/s}$

The third harmonic at $500\,\mathrm{rad/s}$ is effectively filtered out due to resonance, while the other harmonics are attenuated based on the impedance of the RLC circuit. Let me know if you need further analysis!

Figure 3: Part of output of the follow up question: “Provide Fourier Series after filtering.” ChatGPT pointed out 500 rad/s was filtered out due to resonance, even though this information was not explicitly required by the question.

resonance. It is impressive because the following up question did not explicitly ask for this information.

Category 4. Ability to analyze circuit configuration and conduct calculations

ChatGPT-4o struggled with circuit interpretation. When errors occurred during the analysis of the circuit, the errors propagated through the rest of the solution, leading to incorrect formulas and answers. This category was the weakest, and incorrect analysis was the primary cause of inaccurate results. For example, a question shown in Figure 4:

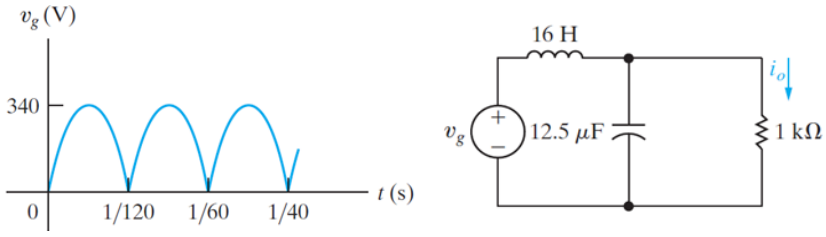

Figure 4: Prompt to ChatGPT: The full-wave rectified sine-wave voltage is applied to the circuit. Find the first five nonzero terms in the Fourier series representation of i_o. Provide step-by-step calculations.

ChatGPT broke down the problem into:

1. **Determine the Fourier series of the input voltage $v_g(t)$.**
2. **Find the transfer function $H(\omega)$ of the circuit.**
3. **Calculate $i_o(t)$ by applying the transfer function to each harmonic component.**

In Step 1, ChatGPT showed calculations with easily noticeable errors in algebra shown in the highlighted areas below:

Given that $V_m = 340$ V, we have:

$$A_1 = \frac{2 \times 340}{\pi(1 - 1^2)} = \frac{680}{\pi},$$

$$A_3 = \frac{2 \times 340}{\pi(1 - 3^2)} = \frac{680}{\pi \times 8},$$

The circuit consists of an inductor in series with a parallel combination of a resistor and a capacitor. However, ChatGPT-4o misinterpreted the configuration, incorrectly identifying the circuit as a series RLC circuit. (ChatGPT-4o had similar errors of treating parallel circuits as series circuits for multiple times in this study.) All the rest of calculations were followed with the incorrect circuit analysis.

Step 2: Transfer Function $H(\omega)$

The circuit is an RLC circuit, and we need to find the transfer function $H(\omega) = \frac{I_o(\omega)}{V_g(\omega)}$. For an input $V_g(\omega)$ and output current $I_o(\omega)$, the impedance $Z(\omega)$ of the circuit is:

$$Z(\omega) = j\omega L + \frac{1}{j\omega C} + R, \quad \text{A}$$

where:

- $L = 16\,\text{H}$,
- $C = 12.5\,\mu\text{F} = 12.5 \times 10^{-6}\,\text{F}$,
- $R = 1\,\text{k}\Omega = 1000\,\Omega$.

Calculating $Z(\omega)$:

$$Z(\omega) = j\omega \cdot 16 + \frac{1}{j\omega \cdot 12.5 \times 10^{-6}} + 1000. \quad \text{B}$$

Figure 5: ChatGPT interpreted the circuit as LRC in series, and calculated the equivalent impedance in series by substituting numerical values with appropriate unit conversions (See A and B). The error in circuit analysis was propagated down throughout the calculations.

Category 5. Accuracy in the use of equations and numerical calculations.

Table 1 shows the performance of ChatGPT-40 measured by the percentage of correct answers provided by ChatGPT-4o in each category. The results of the study indicate that ChatGPT-4o performed exceptionally well in:

- Reading and understanding circuit diagrams (Category 1).
- Breaking down procedures into steps (Category 2).
- Selecting formulas and calculations (Category 3, with limitations due to analysis errors).

ChatGPT-4o performed poorly in circuit analysis (Category 4) and calculation accuracy (Category 5).

ChatGPT-4o also did the final exam of the course in Fall 2024 and received a "C" in letter grade using the same rubric as human students.

Table 1: ChatGPT 4o performance

Evaluation Categories	ChatGPT 4o
Identify elements, values and units in an image of circuit diagrams	A+
Circuit analysis	C
Laplace transform	A
Transfer function	B
Problem breakdown and decomposition	A

Alignment of generated contents with the problem	A+
Correctness of all calculations including algebraic steps	B
Filter design and calculation	B
Fourier series and transforms	C
Two-Port circuit	A

- A+: 100% correct rate; A: 80% - 100%; B: 60% - 80%; C: <60%;
- Only source errors were counted. Errors propagated in calculation chain were not repeatedly counted as errors.

Survey Results

A survey with 7 multiple choice questions and one open ended question was conducted in class with 11 students in Fall 2024 when ChatGPT's answers were provided. Students' feedbacks were positive in general. The students found ChatGPT's step-by-step explanations and detailed responses particularly helpful for understanding the material and in clarifying concepts. Table 2 shows the average score of Question 1 to 6. Question 7 "In what areas do you think ChatGPT was most beneficial for your learning? (Check all that apply)" had 4 choices of

- Understand difficult concepts
- Get quick answers to questions
- Explain homework problems
- Review for exams

"Understand difficult concepts" received the highest votes followed with "Explain homework problems"

Table 2: Survey questions and results

	Survey Question	Average Score
1	How would you rate the quality of the answers provided by ChatGPT?	3.0
2	How clear and easy to understand were the answers provided by ChatGPT?	3.3
3	Did ChatGPT's responses help you understand the concepts covered in the course?	3.2
4	How well did ChatGPT's responses align with the course material and topics discussed in class?	3.5
5	Do you feel that using ChatGPT could enhance your learning and understanding of Electric Circuits?	3.3

6	Would you like to see more integration of ChatGPT in this course to assist with studying, problem-solving, and understanding difficult concepts?	3.3
7	In what areas do you think ChatGPT was most beneficial for your learning? (Check all that apply)	• Understand difficult concepts • Get quick answers to questions • Explain homework problems • Review for exams

- Four choices for each survey question with scores of 1 to 4 from low to high except for Q7.

Discussions and Conclusions

The survey results and student feedback has demonstrated that ChatGPT might be an effective tool for quickly retrieving relevant materials, formulas, and structured approaches to solve problems in Electric Circuits. ChatGPT's ability to break down problems into logical steps is particularly beneficial for students struggling to identify an appropriate problem-solving approach. ChatGPT-4o tends to include background knowledge and closely aligns its responses with the context of the question. Students can use it to clarify concepts and gain a better understanding of the topics they find challenging. ChatGPT-4o also allows students to quickly obtain sample solutions and approaches and may act as a "study partner" that can address specific questions rapidly.

However, if ChatGPT's circuit analysis is incorrect, the rest of its solution, including formula selection and calculations, is also incorrect. The survey indicates that AI's detailed explanations and comprehensive background materials make it challenging for students to identify errors in circuit analysis. Many students tended to use ChatGPT's methods and analysis when they did not know how to solve a problem. They often struggled to verify the correctness of the analysis without external support from the instructor or TAs.

ChatGPT-4o is more suited for students seeking a general understanding or who wish to reference sample solutions, similar to consulting a knowledgeable classmate student. According to the survey and class observations, ChatGPT-4o was less effective as a primary learning tool for developing advanced problem-solving and critical-thinking skills. However, this limitation will lessen over time as instructors and TAs SCAIL feedback into ChatGPT bettering the correctness of future outputs.

This study highlights the importance of guiding students in the appropriate use of ChatGPT. Students should be advised not to rely on AI-generated solutions blindly and need to understand ChatGPT's capabilities and limitations. This awareness helps them use the tool effectively while remaining cautious of potential errors.

AI tools are quickly evolving and improving. OpenAI announced on 09/12/2024 that its new large language model with reasoning, o1, "ranks in the 89th percentile on competitive programming questions (Code forces), places among the top 500 students in the US in a qualifier

for the USA Math Olympiad (AIME), and exceeds human PhD-level accuracy on a benchmark of physics, biology, and chemistry problems (GPQA)." [11-12]. o1's reasoning and calculation capabilities address some of the shortcomings observed in ChatGPT-4o. This capability would enhance AI's reliability in solving circuit problems and would make it a more powerful tool for supporting Electric Circuits instruction. Shortly after, OpenAI previewed the o3-mini model in December 2024 and released it in January 2025. According to OpenAI's report [13], o3-mini and o3-mini-high have demonstrated superior performance across nearly all categories and standard test sets compared to the o1 model. With enhanced reasoning capabilities, we anticipate that future AI models with increased SCAIL feedback will significantly reduce calculation errors and become a more reliable source for learning, particularly in the area like engineering where precise information and accuracy in understanding, mathematics and numerical computations are essential.

References

1. Multisim. http://ni.com
2. SPICE: http://ni.com
3. Jacob Devlin, Ming-Wei Chang, Kenton Lee, Kristina Toutanova. BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding. https://arxiv.org/abs/1810.04805. 2019.
4. Rishi Bommasani, et al. On the Opportunities and Risks of Foundation Models. https://arxiv.org/abs/2108.07258. 2021.
5. Wayne Xin Zhao, et al. A Survey of Large Language Models. https://arxiv.org/abs/2303.18223. 2023
6. https://chatgpt.com
7. Alvarez, J.M., Colmenarejo, A.B., Elobaid, A. et al. Policy advice and best practices on bias and fairness in AI. Ethics Inf Technol 26, 31 (2024). https://doi.org/10.1007/s10676-024-09746-w
8. Valerio Capraro, et. al., The impact of generative artificial intelligence on socioeconomic inequalities and policy making, PNAS Nexus, 3, 6, (2024), pg191, https://doi.org/10.1093/pnasnexus/pgae191
9. Dewey, J. Experience and Education. United Kingdom: Macmillan (1938).
10. James Nilsson, Susan Reidel. Electric Circuits. SBN-13: 9780137648375. 2023
11. Learning to Reason with LLMs. https://openai.com/index/learning-to-reason-with-llms/
12. Tianyang Zhong et al. "Evaluation of OpenAI o1: Opportunities and Challenges of AGI", 2024, https://arxiv.org/pdf/2409.18486
13. https://openai.com/index/openai-o3-mini/