Integrating Prompt Engineering into Power Electronics Contents

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Abstract

This paper presents an integration of Artificial Intelligence (AI) and prompt engineering tools into the undergraduate Electrical Engineering in Power Electronics course. It provides an analysis of students' preferences for learning from resources on semiconductor devices, converter theory, and their applications, with the objective of identifying effective resources that accommodate diverse learning needs.

The study explores how AI and prompt engineering impact student learning outcomes by examining a range of educational resources. It particularly highlights the role of prompt engineering in the field of power electronics through a review of various materials, including course textbooks, YouTube videos, Google AI, ChatGPT, and additional online educational sites. The findings suggest that emerging AI tools can significantly enhance engineering education, serving primarily as supplementary resources within a comprehensive teaching framework. Among the three institutions examined, textbooks were identified as the primary learning resource, while YouTube offered valuable visual and explanatory content. ChatGPT was found to provide moderate assistance but did not replace formal instruction. Overall, the study underscores the necessity of structured guidance to help students effectively choose resources, craft impactful prompts, and critically assess technical information.

AI tools provide students with opportunities to enhance self-directed learning and tailor their educational experiences. However, the effectiveness of these tools is heavily reliant on student engagement. Without appropriate guidance, students may face challenges in navigating misleading information regarding complex power electronics concepts. This highlights the essential role of prompt engineering as a vital skill for effective learning. By equipping students to formulate precise, well-structured questions, educators can ensure that AI tools contribute positively to engineering education. Thoughtfully constructed prompts can foster critical thinking, prompting students to clarify their assumptions, evaluate alternatives, and validate their findings, ultimately deepening their conceptual understanding.

Introduction

The emergence of prompt engineering marks a significant evolution in the field of education, transitioning the focus from mere content integration to the enhancement of learning capabilities. Once students have established a solid foundation of knowledge within a traditional classroom setting, they are positioned to engage in prompt engineering. This method not only maintains the engagement of coursework but also empowers students to move beyond the limitations of conventional learning environments. By fostering active participation in their academic pursuits, prompt engineering adequately prepares students to confront the challenges posed by emerging technologies in their engineering careers. Furthermore, it cultivates essential critical thinking skills that are vital for success in the engineering discipline.

A variety of exceptional textbooks explore the foundational principles of electrical engineering, particularly in circuit analysis, electrical power systems, and electrical machinery [1], [2], [3],

[4], [5], and [6]. These invaluable resources offer a deep and nuanced understanding of key theoretical concepts, equipping readers with the knowledge necessary for both academic study and practical application in the field.

A growing number of institutions worldwide are actively embracing AI tools as part of a strategic initiative to explore their transformative potential in undergraduate education. Ambikairajah and colleagues [7] advocated that students use ChatGPT for design solutions and seek explanations and suggestions, emphasizing the importance of disclosing any use of AI tools. The assessment process was crafted to separate between responses generated by AI and those that reflected the students' own comprehension. Their results showed 70% of the fifty students enrolled in the class turned to ChatGPT to deepen their understanding of the subject matter. Chojowski et al. [8] studied the AI-powered tools, particularly ChatGPT, on research efficiency in electrical engineering by automating literature reviews, generating code, aiding in circuit design, and providing insights for power system analysis. However, they believe the challenges, such as data reliability, ethical concerns, and the risk of over-reliance on AI content, must be addressed. Calabro, et al., [8] experienced instructors engaged with ChatGPT by generating and exploring a variety of prompts pertinent to three specific research questions. Their objective was to conduct in-depth conversations that would yield sufficient content to draw meaningful conclusions for each inquiry. Following these interactions, they undertook a qualitative analysis of the discussions, both individually and collectively. This process enabled them to identify key themes concerning the potential benefits of ChatGPT in the domains of teaching, learning, and design, as well as the associated challenges that may arise in these areas.

Elwakil and Emami [9] investigated the outcomes of teaching prompt engineering in two courses: Introduction to Databases (DB) and Electric Energy and Machines (EEM). Prompt engineering, essential for crafting inputs for AI models, is gaining importance across fields. Findings showed that students in both courses improved their understanding of AI and prompt engineering. DB students, focusing on computational skills, gained confidence in applying these techniques to tasks such as automating processes and optimizing queries. In contrast, EEM students progressed but approached AI integration with caution, expressing concerns about its reliability and safety. They applied it in their workflows. Farahmand and Mathapathi [11] introduced CAPCHAT, a domain-specific generative AI system designed to support undergraduate engineering capstone projects by providing structured, course-aligned mentoring rather than open-ended AI assistance. In their study, CAPCHAT was deployed across multiple capstone offerings and used by student teams to refine technical requirements, develop marketing and stakeholder analyses, and iterate on early design decisions. Student interactions with the system, along with course artifacts and feedback collected over multiple years, were analyzed qualitatively to examine how AI-mediated guidance influenced students' research strategies, clarity of requirements, and reflective thinking. The results indicate that when carefully constrained and monitored, CAPCHAT can enhance student metacognition and project planning while preserving the central role of faculty mentoring, highlighting both the pedagogical value and the implementation considerations of GenAI in capstone design environments.

The current paper illustrates that prompt engineering does not serve to replace foundational teaching; rather, it enhances students' learning outcomes. This approach aids students in:

- Breaking down complex engineering problems into clear, structured questions.
- Exploring subjects that cannot be comprehensively addressed within the limited time of a classroom setting.
- Receiving immediate feedback and alternative explanations that reinforce their conceptual understanding.
- Cultivating lifelong learning skills, which are essential in the rapidly evolving field of engineering.

Electrical Energy and Machines (EEM) is an elective course [12]. This course is designed to deliver essential knowledge through engaging in-person instruction, ensuring that students are not only informed but also develop critical thinking skills. One of the course's focuses is power electronics, which is covered in four lectures and a hands-on laboratory exercise that bridges theory and practice. While a theoretical foundation in power electronics topics, such as diodes, transistors, MOSFETs, converters, and switching devices, can be covered in a small number of lectures, it is not feasible to deeply cover the theory and applications, design variations, or emerging developments. In this context, we designed a project that helps students use prompt engineering to deepen their learning in these topics. This method offers a practical and pedagogically valuable complement to traditional instruction. Once students have learned the fundamental principles, they are prepared with the conceptual framework needed to explore more advanced topics. Prompt engineering enables students to interact with Artificial Intelligence (AI) tools to ask precise questions, analyze equipment, and validate their understanding.

This paper presents an overview of the educational goals and final project results from a pilot study at the U.S. Coast Guard Academy. It includes quantitative data collected from the Coast Guard Academy as part of their final project, along with data from Sonoma State University and California State University San Marcos, gathered after students completed at least one course in power electronics or electronics. The analysis evaluates student assessments across these three institutions.

Educational Objectives

The final project for the EEM course is designed to prepare students with essential skills for independent research, critical thinking, writing, and presenting a professional technical report. This project focuses on the use of Artificial Intelligence (AI) prompts and explores how these tools can enhance the learning experience in power electronics. It aims to integrate the principles of prompt engineering into the study of power electronic devices, highlighting both theoretical understanding and practical application. Specifically, students learn how AI-assisted prompt design can deepen their comprehension of power electronics concepts and improve learning outcomes by exploring various reference sources.

In this project, students worked individually and in teams, with multiple deliveries throughout the semester. Each section requires the student to write a professional report. The report includes students' prompt designs, labeled diagrams, mathematical derivations, and proper citations of students' understanding of the prompt responses.

The learning objectives of this project are to develop targeted prompts, learn about power electronic devices, identify their essential components, present basic types of power converters, apply theoretical knowledge to real-world applications, and improve communication skills by writing technical reports, delivering presentations, and collaborating in a team.

Project Delivery

In the first delivery of the report, students work individually to build a solid foundation in power electronics through prompt-based learning and content creation after learning the foundation in a traditional in-person classroom setting. They create a list of prompt tasks and online resources for studying this field. They have been tasked to learn about five significant aspects of power electronics devices in industry and modern technology. Then they create a circuit diagram and perform theoretical and mathematical derivations of voltage, current, and power for diodes, transistors, and MOSFETs. They were also tasked with learning about circuit diagrams and theory, as well as the mathematical derivations of different types of power conversion (DC–AC, DC–DC, AC–DC, AC–AC). A summary of the project's first delivery is shown in Table 1.

Table 1: Theory, Mathematical Derivation, Diagram

Delivery 1	**Foundation (Individual)**
Work Mode	Individual Work
Focus	Theory, Mathematical Derivation, Diagram
Tasks	Explain five aspects of a power electronics device Diodes, Transistors, MOSFET analysis (Voltage, Current, Power) Switching devices (2 types) Power conversions (DC–AC, DC–DC, AC–DC, AC–AC) List of prompt engineering tasks and online resources
Outcome	Individual Report with diagrams and derivations

The second delivery of the report, shown in Table 2, has students work in groups to create a list of prompts that describe two types of converters and explain how they work in real-world applications. Each group connects their theoretical concepts of the converter to a real-world application, such as a laptop, computer, electric vehicle, mobile charger, blender, mixer, coffee maker, refrigerator, microwave, or fan speed control, etc. Each group chooses one of the following topics. Group 1 focuses on AC–DC Converter (Rectifier) and DC–DC Converter (Buck/Boost), and Group 2 focuses on DC–AC Converter and AC–AC Converter.

Table 2: Apply Theory to Real-World Applications

Delivery 2	**Converter Applications (Group)**
Work Mode	Group Work
Focus	Apply Theory to Real-World Applications
Tasks	Group 1: AC–DC (Rectifier) and DC–DC (Buck/Boost) Group 2: DC–AC and AC–AC converters Create Prompts to learn about the theory and application of converters to real devices
Output	Group Report + Case Study

In the third section of the delivery report, students work in groups to prepare a 20-minute presentation, including an oral component. Oral presentations are one of the tools for assessing students' learning outcomes, such as presenting their projects to technical audiences. The presentation's content is similar to the research paper, with a focus on clarity, teamwork, timing, and confidence. This assessment aims to improve communication skills by requiring presentations and team collaboration. A summary of the First part of the project delivery is shown in Table 3.

Table 3: Communication and Presentation Skills

Delivery 3	Presentation (Group)
Work Mode	Group Work
Focus	Communication and Presentation Skills
Tasks	Prepare a 20-minute presentation Oral explanation, clarity, teamwork, timing, and confidence Team discussion and Q&A
Output	Group Presentation

The final delivery for the project is a comprehensive individual report that combines the first and 2nd deliveries. Each student shares their analysis and learning outcomes from this project in the conclusion. This assessment aims to improve communication skills by requiring students to write technical reports individually. The final delivery of the project is shown in Table 4.

Table 4: Technical Writing Report

Final Delivery	Comprehensive Report (Individual)
Work Mode	Individual Work
Focus	Technical Writing Report
Tasks	Analyze learning outcomes Write a conclusion and reflection Technical Writing Report
Output	Final Individual Technical Writing Report

Student Feedback and Responses

Figure 1 presents the average student-reported effectiveness of five learning resources across four aggregated topic categories, using combined survey data from the U.S. Coast Guard Academy, Sonoma State University, and California State University San Marcos institutions. The categories are Diode, Transistor & MOSFET Theory, Transistor & Diode Applications, Converter Theory, and Converter Applications, with an additional Overall average. Scores are reported on a 0-10 scale, where higher values indicate greater perceived usefulness for learning. In this figure, each cluster compares Textbook, YouTube, ChatGPT, Google AI, and Other Websites within a category, allowing direct comparison of how students across the three institutions distributed their reliance on different resources.

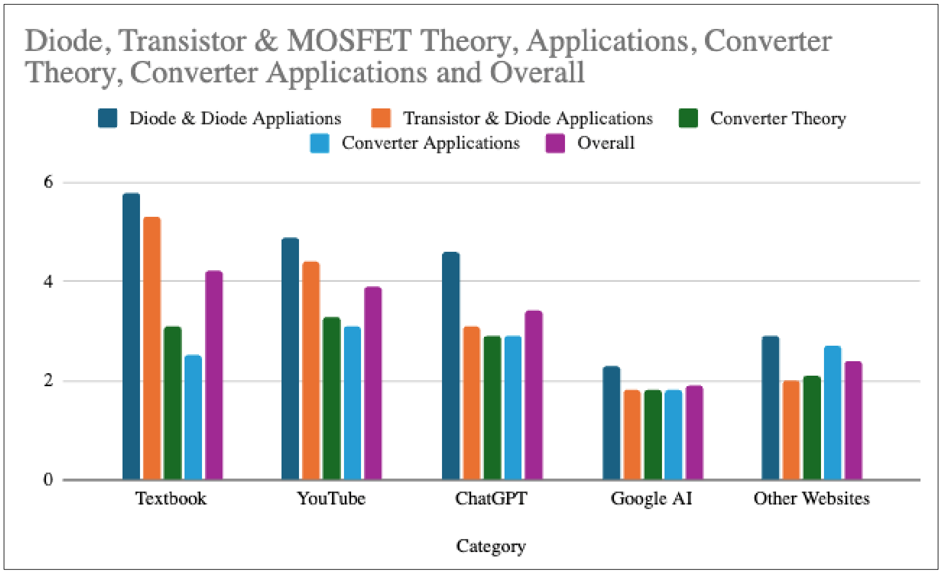

Figure 1. Student-reported effectiveness of learning resources across specific power electronics topics.

Figure 2 provides a topic-level heatmap table of the same multi-institution dataset, summarizing the average student-reported use of each learning resource for specific power electronics topics. The rows list individual topics, including diodes, transistors, MOSFETs, electronic switches, converter theory topics, and converter application topics, while the columns correspond to Textbook, YouTube, ChatGPT, Google AI, and Other Website. The numerical values in each cell show the exact average score for that topic-resource combination across students from the three institutions, and the color shading highlights relative intensity so that higher- and lower-scoring resources can be identified quickly.

Reference Source Usage by Topic - Average Scores (N = 40 students, Scale 0 - 10)

Scores represent the average self-reported reliance on each reference source (0 = not used, 10 = exclusively used)

Topic	Textbook	YouTube	ChatGPT	Google AI	Other Website
Component Devices					
Diodes	5.8	4.9	4.8	2.3	2.8
Transistors	6	5	4.5	2.2	3
MOSFET	5.6	4.9	4.6	2.4	2.8
Electronic Switches	5.3	4.4	3.1	1.8	2
Converter Theory					
DC-DC Converter Theory	2.9	3.4	3	1.6	1.9
AC-DC Converters Theory	3.4	3.4	3	2.1	2.3
DC-AC Converters Theory	3.3	3.6	3	1.9	2.1
AC-AC Converters Theory	2.9	3	2.5	1.8	2
Converter Applications					
DC-DC Converter Apps	2.4	3	2.7	1.6	2.5
AC-DC Converter Apps	2.8	3.3	3	1.9	2.8
AC-AC Converter Apps	2.4	3.1	3	1.8	3
DC-AC Converter Apps	2.5	3.1	2.9	1.9	2.7
Color Scale:	0–2 Low	2–4 Below Avg	4–6 Moderate	6–8 High	8–10 Very High

Figure 2. Heatmap of student-perceived effectiveness of learning tools by topic.

Qualitative feedback from students across the three institutions revealed several common themes regarding how they used the available learning resources. Many students emphasized that no single resource was sufficient on its own and instead described combining multiple tools depending on the task. Across responses, traditional resources, especially textbooks and instructor-guided materials, were viewed as particularly important for establishing foundational understanding and checking technical accuracy.

YouTube emerged as a valuable resource for visualizing circuit behavior and understanding applications, particularly for topics such as transistor switching and converter operation. Students frequently referenced the usefulness of visual demonstrations, animations, and real-world examples. At the same time, some noted that the quality of online videos can vary, so students still needed to judge credibility carefully rather than assuming that all video explanations were equally reliable.

Feedback regarding AI-based tools such as ChatGPT and Google AI was mixed across the three-institution dataset. Many students valued these tools for quick overviews, terminology support, summaries, and follow-up explanations. However, students also raised repeated concerns about technical reliability, especially in mathematical derivations, circuit interpretation, and detailed engineering explanations. Several comments indicated that AI-generated responses could sound confident even when they were incomplete or incorrect.
Other websites and general web resources were primarily described as supplementary sources. Students used them to locate datasheets, application notes, academic papers, worked examples, and alternative explanations. Although these resources were usually not treated as the main learning tool, they played an important role in verification, cross-checking, and filling gaps left by textbooks, videos, or AI tools.

Overall, the written feedback suggests that students from the three institutions were becoming more aware of the relative strengths and limitations of each resource and were adjusting their learning strategies accordingly.

Analyzing Student Feedback

The quantitative results shown in Figures 1 and 2 indicate clear differences in how students from the three institutions used learning tools across topic types. At the category level, Figure 1 shows that Diode, Transistor & MOSFET Theory received the strongest support from textbooks (5.8), YouTube (4.9), and ChatGPT (4.6), indicating that students relied on a mix of traditional, video-based, and AI-supported resources when studying foundational semiconductor topics. For Transistor & Diode Applications, textbooks (5.3) and YouTube (4.4) remained the most used resources, while ChatGPT was lower (3.1). In the converter-related categories, overall scores decreased, suggesting that students reported less reliance on outside resources for these topics or found them more difficult to support effectively with the available tools.

Figure 1 reinforces this pattern at the topic level. Within the component-device topics, diodes, transistors, MOSFETs, and electronic switches generally received moderate-to-high scores for textbooks, with YouTube and ChatGPT also contributing meaningfully in several cases. In contrast, converter theory and converter application topics show lower and more uneven averages, with occasional stronger use of YouTube or ChatGPT in specific subtopics but less consistency across the full set of converter topics.

An important observation from the qualitative feedback concerns prompt formulation when students used AI tools. Students repeatedly noted that the usefulness of AI responses depended strongly on how questions were posed. Prompts that were clear, specific, and structured tended to produce more helpful explanations or comparisons, whereas vague or leading prompts often produced incomplete, inaccurate, or misleading responses. This suggests that effective use of AI requires metacognitive skill in both question design and answer evaluation.

Students also demonstrated a cautious approach toward AI-supported learning. Rather than treating ChatGPT or Google AI as authoritative sources, many students described using them to clarify, summarize, or interpret information they had already encountered in textbooks, class materials, or technical references. They frequently emphasized the need to verify AI-generated information with reliable sources such as textbooks, datasheets, and peer-reviewed literature. Taken together, the results suggest that students across the three institutions were learning to match tools to task complexity. Foundational device theory showed the highest overall resource use, with textbooks remaining central and YouTube and ChatGPT serving meaningful supporting roles. Converter topics, especially when considered across theory and applications, showed lower averages overall and more uneven tool use. This pattern suggests that students were more selective and possibly more cautious when using external tools for advanced or less familiar topics.

Overall, the figures and written feedback indicate that emerging AI tools can support engineering learning, but primarily as complementary resources within a broader instructional ecosystem. Across the three institutions, textbooks remained the strongest overall resource, YouTube served as an important visual and explanatory aid, and ChatGPT functioned as a moderate support tool rather than a replacement for formal instruction. These findings point to the value of structured guidance that helps students choose resources strategically, formulate effective prompts, and verify technical information critically.

Conclusions

This paper presented an integration of Artificial Intelligence (AI) and prompt engineering tools into the undergraduate Electrical Engineering curriculum, with a focus on a few topics in Power Electronics. It analyzed students' preferences for learning resources on key topics, such as semiconductor devices and converter theory, to identify effective materials that meet diverse learning needs. The study evaluated the impact of AI and prompt engineering on student outcomes, highlighting their role in power electronics by reviewing various resources, including textbooks, YouTube videos, Google AI, ChatGPT, and educational websites, to enhance active learning.

AI tools can enhance self-directed learning and personalize educational experiences for students, but their effectiveness relies on student engagement. Without proper guidance, students may face misleading information on complex concepts in power electronics. This underscores the importance of prompt engineering for effective learning. By teaching students to create precise inquiries, educators can ensure that AI tools enrich engineering education, promote critical thinking, and deepen conceptual understanding.

The findings indicate that emerging AI tools, while beneficial for enhancing engineering learning, serve best as complementary resources within a broader instructional framework. Across the U.S. Coast Guard Academy, Sonoma State University, and California State University San Marcos, textbooks were identified as the most effective educational resources. YouTube emerged as a valuable visual and explanatory tool, whereas ChatGPT was recognized as a moderate support mechanism rather than a substitute for formal instruction. These insights highlight the importance of structured guidance, which can help students strategically select resources, craft effective prompts, and critically verify technical information.

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