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The Educational Advantages/Disadvantages of ChatGPT in Relation to Engineering Classes

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The Educational Advantages/Disadvantages of ChatGPT in Relation to Engineering Classes

Abstract

This study focused on the integration of ChatGPT, a generative artificial intelligence (AI), into undergraduate education with a focus on its impact on an Embedded Systems Design Project course at a REDACTED university. Recognizing the rapid evolution of AI, ChatGPT could potentially empower students in the learning process. ChatGPT has the potential to serve as a resource for clarifying challenging concepts and brainstorming problem-solving strategies. The research questions that guided this study were: (1) What factors enable or hinder the adoption of ChatGPT in embedded systems design education contexts?, and (2) How can ChatGPT be best implemented in embedded systems design education contexts? This research employed a structured intervention that integrated pre-planned activities involving ChatGPT into the coursework, as well as allowing students to develop their own ways to use ChatGPT on assignments. Qualitative and quantitative data were collected through observations, surveys, and interviews, allowing for a review of the tool's impact on student learning. Students were given the opportunity to utilize ChatGPT for assignments, provided they reflected on their choice to use ChatGPT or not. Thematic analysis of the interviews and triangulation by additional data sources revealed key moments when students were driven to utilize ChatGPT. This work offers valuable insights into the potential adoption of ChatGPT in education and practical recommendations for its effective implementation in electrical and computer engineering coursework.

1. Introduction

As tools like ChatGPT become increasingly popular due to the potential to transform the future of work, it is unknown if it should be adopted into the classroom especially in engineering education. The nascent nature of this subject leaves a void in comprehensive research on the merits and demerits of employing ChatGPT within classrooms. This study conducts a novel small-scale exploration in a project-based learning class to explore its potential applications in educational settings, and its intersection with project-based learning in engineering. These areas can then be combined to research the gap in ChatGPT in engineering classes. The methodology section details the selection of students, the data collection process through Generative AI disclosures and interviews, and the ensuing data analysis which employs an inductive thematic approach. This study aspires to unravel the factors that either facilitate or impede the integration of ChatGPT within embedded systems engineering courses.

2. Literature Review

ChatGPT

ChatGPT is a generative artificial intelligence chatbot that allows users to insert a prompt and receive a detailed response. It utilizes pre-trained language models and in-context learning to provide a variety of answers to individuals [1]. The pre-training phase lets the model learn naturally and then it is fine-tuned by the creators [2]. Then, in-context learning uses algorithms to interpret human language to extract useful information [2]. ChatGPT can be used to answer questions, create content, program, or explain material [3].

Some students are beginning to embrace ChatGPT to complete their coursework, but there is no widespread agreement among administrators, faculty, and students on whether to embrace it or not. ChatGPT provides students with a customized learning experience allowing them to obtain new knowledge or assess their current work; whereas teachers could use it for class preparation or evaluations [4]. This provides students with their own customized learning experience since they can tailor ChatGPT to teach them content in the style they prefer [5].

However, ChatGPT should not be relied upon but utilized as a tool to aid in the brainstorming or revision process due to its inaccuracy and risks of plagiarism [6]. According to other students, "the top three obstacles to using ChatGPT included 'unable to examine quality and reliability of sources', 'unable to replace words and use idioms wisely', and 'inability to measure the value of difficult mathematical formulas'" [7]. Professors are concerned about students learning false information on ChatGPT and not using other sources to verify its output [8].

Project-Based Learning

Project-based learning is a commonly used teaching method in engineering due to its hands-on approach. Project-based learning is centered around the learner and allows them to investigate topics through experimentation [9]. Therefore, students have the flexibility to tailor their approach to a project according to their preferred learning preferences. Project-based learning helps students with hands-on technology experience, the ability to work autonomously and take responsibility, and fosters inclusion and teamwork [10]. These are important attributes when it comes to working in industry since most projects are assigned and given a specific deadline [11]. Some students might face challenges when switching from a traditional classroom to project-based learning [12]. Students often encounter a heavy workload and limited time to complete tasks meaning training is absent in this new learning method [12]. Students may fall behind since they lack the knowledge needed to excel in a different learning environment [13]. However, project-based learning helps increase mathematical representation and communication skills, higher-order thinking, and academic rigor [13]. With project-based learning, students can break down harder concepts and communicate them to others, think more critically, and achieve academic excellence through intellectual demands.

This study combines ChatGPT and project-based learning to address the gap in the adoption of ChatGPT in engineering education with the following research questions:

1. What factors enable or hinder the adoption of ChatGPT in embedded systems design education contexts?
2. How can ChatGPT be best implemented in embedded systems design education contexts?

3. Methods

Context

Participants were recruited for a study on ChatGPT in the classroom from a third year/ junior-level Embedded Systems Design Project class taught in the Fall of 2023. This is a project-based learning course for electrical and robotics engineering students. Using the engineering design process, the students were instructed to design a wearable robotic device for

children with cancer. The product had to include one linear voltage regulator, one analog sensor, one motor/linear actuator, and board-to-phone duplex communication over Bluetooth using the CY8CKIT-142 (BLE) microcontroller [14]. Students could use ChatGPT on any part of the project.

Data

Generative artificial intelligence (AI) disclosures were collected from all students where they would answer the following free-response questions:

- If you used AI, how did you use it and how did you improve the output of the tool?
- If you did not use AI, why not?

Students were asked to submit a text entry or media recording to Canvas answering one of the questions above. Multiple submission methods were used to reduce the barrier of completing the discourse and allow for more responses. Interview participants were selected based on their responses to the Generative AI disclosures and their willingness to participate. Each person was interviewed over Zoom for approximately thirty minutes utilizing a semi-structured interview method. A total of fifteen people were interviewed to learn about their opinions on and experiences with ChatGPT. The explorative interview protocol (seen in **Table I**) was grounded in Flanagan's Critical Incident Technique [15] to ground discovery in the experiences of participants. Questions were purposely structured to get an understanding of students' views on ChatGPT, where they chose to use it, and how and when they used it in a specific engineering class. The classroom use of ChatGPT questions was repeated for multiple types of assignments: a classroom assignment, a homework assignment, a coding assignment, and a project/team assignment. This was to help guide students in answering the questions.

Table I.
ChatGPT Interview Protocol

Interview Sections	**Questions**
Overview of ChatGPT	1. What are your general views on ChatGPT? 2. Have you used it in a class besides EGR 304 *(Embedded Systems Design Project)*? a. If so, what did it help you accomplish? 3. Have you seen your peers use ChatGPT? a. What did they use it for?
Classroom ChatGPT Use	Next, let's talk about a [classroom, homework, coding] assignment where you used ChatGPT. 1. What were your primary goals or objectives when using ChatGPT for this assignment? 2. Were there any challenges you encountered while integrating ChatGPT into this assignment? a. How did you overcome these challenges? 3. Did you refine your inputs into ChatGPT to obtain a better result? a. If so, how did you refine the prompt?

	4. Do you believe using ChatGPT in your assignment had a positive or negative impact on the quality of your work? 5. How did it contribute to your understanding of the subject matter or the overall effectiveness of your assignment? 6. What did you learn from the experience?
Synthesis and Closing	1. What do you imagine the educational future of ChatGPT will be in 5 years? a. In industry? 2. What improvements to ChatGPT would you suggest for better usability? 3. Do you have anything else I didn't ask that you'd like to share?

The data from the Generative AI disclosures and interviews were analyzed using an inductive thematic analysis as described by Larson et al [14]. Inductive posteriori approaches to thematic analysis allow codes to be discovered in the data during the analysis process by using the perspectives of the individuals within the study [14]. This helped find commonly appearing themes within the interviews.

4. Findings and Discussion

The codebook containing the codes discovered during the interviews can be seen below in **Table II**. The first code was "errors in result" and contained four subcodes. Many students expressed how ChatGPT is often inaccurate in its answers and people should take that into consideration when using it. The subcodes "not accurate in coding" and "not trustworthy in writing" were used since students also explained how ChatGPT sometimes gives code that does not work and its writing often sounds robotic. Several students said they tried using ChatGPT for complex math problems and found it would frequently provide the wrong answer so the code "trouble doing math problems" was created. The code "answers require small edits" surfaced when multiple students expressed that ChatGPT did not give precisely what they were looking for which meant they had to edit the answer.

The second main code was "ChatGPT integration in class" which comes from the specific ways students used it in the embedded systems class. Subcodes were then created to capture the most popular ways students used it in class. The first, "aiding to complete work" referred to students using ChatGPT in a multitude of ways to help them finish assignments. "Answering a variety of topics" emerged after students explained how ChatGPT can be used to answer any topic and has no limitations. It also helped them "learn new things" they could leverage in assignments. Another frequently appearing code was "provides brainstorming examples" where many mentioned how they used ChatGPT to help get them started on certain work. The final two were "used for coding" and "used for writing" and were used when someone mentioned how they used ChatGPT for coding or writing support.

The third was "ChatGPT improvements" which became a major code because students had many things to say when it came to how ChatGPT could improve usability. Next was the "importance of prompt engineering" which came up several times throughout the interviews because students expressed they had to be very specific with their prompts in ChatGPT or else

they would not receive the answer they wanted. The code “improved work quality” referred to those who believed ChatGPT had a positive impact on the quality of their work. The final code was “referred to other resources” which also became a main code since students explained how they would use other websites first before going to ChatGPT for help.

Table II.
Codebook

Code Name	Definition	Example
Errors in result	ChatGPT outputs inaccurate or misleading information	“I always take it with a grain of salt because sometimes it's not as accurate.” - Alexander Wood
● Not accurate in coding	Is not sufficient in coding and does not give code that fully works	“So I would have an error in my code, I would just copy the code and paste it in chat and say “Can you fix it for me?” If I specify the language, then it would make new variables that don't exist or try to find libraries that don't exist, and it just wouldn't work. So it would just give me more errors and just completely break the code.” - Maou Zhang
● Trouble doing math problems	Can not do complex math calculations because it often gets the wrong answer	“ChatGPT was giving the wrong answer for sines and cosines and stuff like that and every time I would ask it to retry solving the equation, it would come up with a different way to do it, and it would get a different answer every single time and every single answer was wrong.” - James Goldfinch
● Not trustworthy in writing	Sounds robotics when writing, using unusual words and does not cite sources	“The paragraph was definitely good, but it had some words that were used frequently, certain words that I think ChatGPT has liking too, uses it really frequently and it had that robotic tone to it until we asked it to make certain changes.” - Maou Zhang
● Answers require small edits	Does not give precisely what the user is looking for requiring them to make changes to ChatGPT’s answer	“Most of them were good, I would say they did need a little bit of tweaking, but sometimes they weren't completely related to what we were trying to say but we would just kind of adjust them a little bit, and then it would fit into our concepts that we were kind of thinking.” - Christian McCarthy
ChatGPT integration in class	How students used ChatGPT specifically in an embedded systems design class	“So I used it to help me find other sources to learn about better methods of the Bluetooth application things because without ChatGPT, I wouldn't have found out how to do a color wheel through the Bluetooth thing that we used and that was like a huge part of what my team needed.” - Tyler James
● ChatGPT as a guide	Allowed students to complete work	“I use it more as a search browser because it pulls up more accurate results. I find, especially for assignments that are more about a specific topic instead of general knowledge.” -

	by solving issues on assignments	Christian McCarthy
● Answering a variety of topics	Can answer diverse questions from any subject matter	“So in terms of certain questions on any variety of topics it is pretty competent at figuring out the answer with reason, and it gives evidence as well which is good” - James Goldfinch
● Learning new things	Allows the user to learn new information quickly	“Yeah, I'd say it definitely helped me learn especially what to look for when designing speaker circuits but also helped me read data sheets better like what I should be looking for and the lateral characteristics and all that” -Alexander Wood
● Provides brainstorming examples	Helps users get started on assignments by giving them ideas to work off of	“Just for basic idea generation and getting the groundwork for what the user needs could be given good examples and then we would build off them based on our specific use case” - James Goldfinch
● Used for coding	Used to help code in any language given certain instructions	“Some of them use the newest version of ChatGPT, which is GPT 4.0, and it's a paid version. According to them, it's really good at coding. It can write massive amounts of code and it's perfectly fine working. It doesn't break anymore.” - Maou Zhang
● Used for writing	Can be used to write sentences or paragraphs as well as check for grammar mistakes	“I would say it's really helpful, for grammar checking, and not only grammar checking, it helps in finding information to put in my essay as well. It's really helpful at that point.” - Derek Smith
ChatGPT improvements	Users suggest usability improvements to ChatGPT	“I think what would be pretty cool is that they give you reference links from what they're basing their information on so that you can double check, or read more into it from the source.” - Alexander Wood
Importance of prompt engineering	The use of prompt engineering determines how well ChatGPT will respond to a question	“If I want it to produce certain results then you have to ask the question in a certain way.” - Christian McCarthy
Improved work quality	After using ChatGPT, the quality of the student’s work improved	“I'd say it had a positive impact on my work because I was able to successfully design the speaker circuit and it came out really great.” - Alexander Wood
Referred to other	The student	“I would go to the assignment details and if there was a video

resources	referred to a different resource other than ChatGPT to complete coursework	walkthrough, I would try to utilize that and if none of that worked, I would normally Google it instead of going to ChatGPT." - James Goldfinch

The main themes deduced from the codes included Errors in Result, ChatGPT Integration in Class, and Importance of Prompt Engineering. Out of the fifteen students interviewed, based on their overall perspective of ChatGPT, seven had positive responses, six had neutral responses, and two had negative responses. ChatGPT Integration in Class aligns with students' positive responses, Importance of Prompt Engineering incorporates neutral reviews, and Errors in Result highlights the negative views of ChatGPT. All student names used below are pseudonyms to maintain privacy.

Errors in Result

One main theme was how ChatGPT sometimes has errors in its results. This was then broken down into four subcategories however two were more frequent than others. The codes Not Accurate in Coding and Trouble Doing Math Problems were brought up by eight and ten students respectively during the interviews.

Not Accurate in Coding

ChatGPT was considered inaccurate in coding by some students due to its code output not functioning correctly. When asked about the challenges encountered when coding using ChatGPT, Ben responded, "when I would tell it something isn't working or to do it in a different way, it would… then do it the same exact way… and when I try to say, change it again, it still doesn't work." Even after telling ChatGPT the code was wrong, it still would not change it so the student could not obtain working code. Another student expressed "it would start writing the code in a completely different language... and if I specify the language, then it would make new variables that don't exist or try to find libraries that don't exist, and it just wouldn't work." In this situation, Maou could not get ChatGPT to give a useful code snippet which resulted in not using ChatGPT to help in this situation. Other researchers found similar issues saying "ChatGPT-generated code is prone to various code quality issues, including compilation and runtime errors, wrong outputs, and maintainability problems" [16]. Therefore, ChatGPT can be flawed when it comes to the quality of code it gives to users.

Trouble Doing Math Problems

Another problem students found was that ChatGPT can not do higher-level math. Derek explained how he will " use ChatGPT to calculate some math or physics problems, but actually, the thing is when they calculate math or physics they sometimes get the wrong answer." ChatGPT was consistently wrong when performing math problems which makes students less likely to use it for calculations. Another example was from Josh who said, "while it got the steps right, it got the numbers wrong… so these are the right steps but when we actually evaluate it we get a different number." Again, it got the wrong answer even though the approach to the problem

was correct. Since the student was a math tutor, he knew that the steps were correct and even proved ChatGPT wrong by telling it the correct answer. Both students believed that ChatGPT is not ready to solve higher-level math problems given its current outputs. This is consistent with a finding by Frieder et al, who said that "(Chat)GPT is not yet ready to deliver high-quality proofs or calculations consistently" [17]. Therefore, ChatGPT should not be relied upon for its accuracy in calculations.

ChatGPT Integration in Class

Another main theme was how students used ChatGPT to complete embedded systems assignments. There were six subcodes but three captured the majority of student uses. Those included ChatGPT as a Guide, Used for Coding, and Used for Writing.

ChatGPT as a Guide

When participants described their experiences with ChatGPT, several students explained ChatGPT is a useful guide but should not be heavily relied upon. Tyler described, "if you take what it gives but you further develop it into what you specifically need, then that's a pretty good resource to use." Alexander highlighted, "I think it's a useful tool, I really like it when I have vague questions or very specific questions to ask it but I always take it with a grain of salt because sometimes it's not as accurate." Both of these quotes suggest that ChatGPT is a good guide for answering questions in a simplified manner. However, Alexander takes what ChatGPT outputs with a grain of salt knowing its information is not always accurate. This can also be seen in another student's discussion where James emphasized, "I think it can be a useful tool for basic computations and idea generation but I don't know it is good for complicated tasks yet." Alexander and James shared similar ideas in that ChatGPT can do some basic things but the more complex questions it tends to provide incorrect answers. The students' discoveries echo et al [18] stating "ChatGPT may be a helpful tool for online learners, it should not be depended upon as the only source of knowledge or assistance." However, to extend the students' possible tools, et al [18] suggests ChatGPT can be a "tool to help students with their studies by creating relevant content and sources on a specific subject."

Used for Coding

ChatGPT emerged as a valuable resource in coding by offering code snippets and debugging help for people seeking programming assistance. When students were asked if they used ChatGPT to help with coding, Juan stated "I feel like if I had used ChatGPT for those coding assignments it would have helped a lot especially for the final project… to help me have a speaker that actually makes sound and not just a monotone pitch or beep." Juan struggled to get his speaker to make any other sounds but eventually got it to work. He realized if he had asked ChatGPT he may have been able to get the speaker working faster. Hannah said in regards to coding, "I can ask ChatGPT to play a tune using certain frequencies so I don't have to find the frequencies myself and it played twinkle twinkle little star." Hannah implemented the code she had written into ChatGPT and asked it to make changes and the changes it suggested enabled the speaker to work successfully. Therefore, Hannah was able to code her speaker using ChatGPT so if Juan thinks they would have done the same it would have worked for him as well. Other recent

findings by Nikolic et al. [19] also explain how ChatGPT is proficient in entry-level code with some fine-tuning and giving detailed explanations for each step.

Used for Writing

ChatGPT can be used as a writing aid, facilitating the creative process, providing instant feedback, and offering versatile support in creating ideas. Students were asked about writing using ChatGPT, where James mentioned using it "for basic idea generation like getting the groundwork for what the user needs could be given good examples then build off of them given our specific use case and our product requirements." This aligned with what Alexander said as well that he used it "for product requirements and interview questions to get us going or to provide examples for us". Both students utilized ChatGPT to help them generate ideas and were able to edit them slightly to better fit the assignment. For some students, "lack of direction and scaffolding, particularly at the outset of a problem- or project-based learning intervention, can be highly frustrating" [20]. Therefore, students can utilize computer software for idea generation since it does not impact self-efficacy and can be more appealing to students [19].

Importance of Prompt Engineering

ChatGPT can be rather useful when given a good prompt. Although students were not asked specifically about prompt engineering, many expressed how ChatGPT needs very specific information to give better results. "Prompt engineering plays a vital role in bridging the gap between user intent and the models' understanding, thereby significantly impacting the quality of generated replies" [21]. Christian explained, "if I want it to produce certain results then you have to ask the question in a certain way." This is similar to what Sean said, "you have to be really specific with what you were asking, it was really accurate and precise with giving me the information that I needed with the information that I put in." These students both agreed that in order to produce a certain answer one has to be clear and concise with what is given to ChatGPT. This is why prompt engineering is so important because users influence the output and that can lead to "more precise, reliable, and contextually appropriate results" [22].

Outliers

There were two students in particular who did not use ChatGPT at all during the course. The first student talked about other resources he used instead of ChatGPT. Jim stated, "I mostly referenced YouTube videos just going over the system we were using; in addition to the references section on each of the homework assignments to get the gist of what I'm supposed to be doing for them." Jim preferred to look at YouTube or the assignment instructions for help in lieu of ChatGPT. Anna answered similarly when asked about what resources she used saying, "predominantly, the Internet, mainly YouTube because I need step by step." Jim and Anna preferred to get their information from YouTube since it gives a more in-depth explanation and visuals that the unpaid version of ChatGPT can not do [23].

Another reason why these students did not use ChatGPT was because they had negative views of it. Jim explained, "I don't feel that excessive uses of it are necessary…it's easy for it to hallucinate answers." Jim does not trust the validity of ChatGPT which is why he uses other resources instead. Anna has a negative view as well where she explains that "my opinion of it

becomes more negative when you are using ChatGPT to do your entire assignment… you're not proving your skill set, you're having a computer AI prove their skill set." She believes that students should do their own work rather than having ChatGPT do everything for them. Students should not rely heavily on ChatGPT because it could weaken their critical thinking skills.

5. Limitations

Despite the lead researcher being a teaching assistant for this class, recruitment proved difficult, resulting in only conducting interviews with fifteen participants. Several students had unique responses to the Generative AI disclosures but did not want to be interviewed. The embedded systems course was selected for its need to leverage supplemental materials and resources and was recently taken by the main researcher. The main researcher is new to qualitative research but is guided by the second and third authors.

6. Future Work and Conclusion

Through generative AI disclosures and student interviews, this study found that ChatGPT can be an assistant to students for basic questions, coding, and writing. More research should be conducted on specific interventions where ChatGPT is implemented in the classroom. Interventions should vary in their implementation, rules, and other constraints. ChatGPT holds promise for future educators, students, and researchers. ChatGPT could be used in many more classrooms but would require more in-depth research. Educators should receive an overview of ChatGPT, its risks and merits, and ways to leverage ChatGPT in the classroom as a supplement. For students, there needs to be a new form of media literacy on AI and critical thinking where students should be taught how to evaluate ChatGPT results and adapt them to their needs.

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