

Exploring Prompt Engineering: Generative AI Applications in STEM Higher Education

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ABSTRACT

The integration of Generative Artificial Intelligence (GenAI) into daily life has shown potential benefits for assistance, entertainment, and content creation across various fields, including education. Due to the specific characteristics of the educational field, it is imperative to evaluate and verify the best forms of interaction for students to maximize benefits. In this sense, the authors applied an exploratory case study to analyze a specific GenAI, ChatGPT, aiming to answer two questions: whether students are prepared to obtain the best results when interacting with a GenAI for subjects related to their knowledge, and whether they are able to classify the answers they receive as correct or incorrect. Since the results are qualitative, we focused on the importance of prompts in obtaining better responses from GenAI in an educational context, considering a constructivist approach which led us to classify ChatGPT as an "Object-to-think-with-together". The study was conducted in higher education, specifically in an undergraduate engineering course on electronics, and the procedure was systematized to help other teachers replicate it. The analysis showed the potential of using GenAI as a diagnostic activity, providing an overview of each student's individual knowledge. GenAI can help develop critical thinking and encourage students to explore complex concepts, reflect on their understanding, and ask questions. The teacher's role is crucial in guiding the process and ensuring that interaction with the tool is appropriate.

Keywords

Education, Generative Artificial Intelligence, ChatGPT, STEM, Prompt Engineering.

ACM Classification Keywords

K.3.1: Computer Uses in Education.

INTRODUCTION

Generative Artificial Intelligence (GenAI) refers to "a class of artificial intelligence models that can create new data based on patterns and structures learned from existing data. These models can generate content in various domains (text, images, music, etc.)" [20]. GenAI became popular with the emergence of ChatGPT, which, since it began operating in 2022, has been growing rapidly and showing great potential for assistance, entertainment and content creation in various areas [1].

ChatGPT offers assistance on a wide range of possible topics [3]. These topics include: Business and industry,

Science and technology, Medicine and health care, Infrastructure, Environment and sustainability, Communication, art and culture, and also in the field of education (assistant for writing texts, preparing question banks, research assistant, etc).

Given the diversity of areas in which ChatGPT has made inroads, a number of speculations have arisen, both positive and negative about its use. Among the speculations are: fear of the unknown, issues associated with ethics, privacy and data ownership, questions about who trains the models and who decides what is right or wrong, and how this type of technology can manipulate the global landscape on issues of public interest such as education and employability [4, 15]. Other speculations concern the advantages that can be provided by GenAI, and can be defined in three categories that particularly concern education [4]:

(1) educational paradigm shift because the current educational system may restrict the use of AI in education as facilitating, (2) redefinition of human and AI roles in education and respective ownership because AI currently creates and generates content like humans, and (3) responsible use of AI so that educational effectiveness can be maximized while educational risks can be minimized and/or prevented altogether [4].

In a complementary way, it is discussed the ways in which AI should be understood in the teaching and learning process, whether as a challenge to existing pedagogies or as a tool to help teachers and students [11]. Some applications of AI in instructionist teaching and also applications used in constructivist teaching are summarized, separating them as applications to support the student or the teacher [11]. The constructivist approach presented uses the term Objects-to-think-with-together to name the objects or artifacts with which the student can interact in the construction of knowledge, and this is the approach adopted in this article. In this sense, the computer, which is widely used today, is considered to be an artifact and an object that is understood as an integrated construction platform that enables reuse and support for collaborative projects and team building [22].

With the advance of technology, a more current artifact becomes an Object-to-think-with-together, the Chatbot. It can be categorized as such because it "facilitates personalized, adaptive and collaborative learning by encouraging diverse learners to share ideas and learn

together” [24]. This author incorporates GenAI, specifically ChatGPT and Bing Chat, into STEM (Science, Technology, Engineering and Mathematics), and has verified the benefits of this artifact for cognitive development and learning, including “interactivity, personalization, multidisciplinary knowledge, critical thinking, problem solving, encouraging creativity and collaboration” [24].

Characterizing the Object-to-think-with-together used in this study, ChatGPT has its roots in the field of Natural Language Processing (NLP), “an area of AI focused on enabling machines to understand and generate human language,” [20]. In order to work, ChatGPT has undergone pre-training that “allows it to learn the patterns and relationships between words and phrases in natural language, which makes it effective at generating coherent and realistic responses in a conversation”, [20]. Unlike other GenAIs that have the specificity of creating images or animations, the ChatBot is an artifact that has its essence in NLP, so it is understood that it provides answers in text format after a request made, also in this format, thus emulating a conversation [18].

When this conversation is mundane, the interaction is simple, but when the aim is to use the ChatBot in teaching (either by the teacher or the students), or other areas such as marketing or industry, for example, the forms of communication to obtain adequate information become important. Getting the answers you want from GenAI tools is not always an easy task. A crucial part of this process is correctly crafting a prompt, which is how the human communicates with the GenAI. A prompt is, therefore, the input provided to the GenAI tool that will initiate the preparation of a response (the output) in a given format [8], and in the case of ChatGPT, this format is text.

In this context, this paper looks at the possible uses of ChatBot in specific engineering subjects, with a focus on the student. This type of action gives teachers the chance to encourage the use of emerging tools in the classroom that complement and accompany the learning process. Bringing technological artifacts into the classroom that students feel comfortable interacting with can bring a sense of belonging, encourage dialog and also interdisciplinarity [9]. The ChatBot, which at first is only used as an artifact, can also be a stimulus for delving into specific areas of computing.

Research Questions

This paper presents an exploratory research carried out in a single case, using a constructivist approach where the object-to-think-together-with is ChatGPT. It is hoped to highlight the importance of students' critical interaction with this technology in order to obtain consistent results, i.e. given that it will be used in the classroom, the aim is to answer two research questions (RQ):

RQ1: Use of tool: are students prepared to obtain the best results when interacting with a GenAI for subjects related to their knowledge about the tool, (considering that the aim of the course is not to train them in the use of the tool)?

RQ2: Content monitoring: are students able to classify the answers they get as correct or incorrect, given that at the time of the activity they are expected to have already internalized certain specific concepts?

RQ1 will be answered by verifying the importance of the prompt in the interaction between students and the object for success in obtaining information, evaluating it in a classroom situation in a higher education subject in the area of Engineering, as well as identifying the students' familiarity with using GenAI tools. RQ2 will be answered by looking at possible contributions to the students' critical thinking, since they will need to analyze the coherence of the answers or look to other sources to confirm the correctness of the returns obtained through GenAI. The next section presents definitions and concepts of prompt engineering and a systematization of an appropriate prompt. The methodology is then detailed, followed by the results and a discussion of these, and finally the conclusions of the work in the final section.

PROMPTS FOR GENERATIVE ARTIFICIAL INTELLIGENCE

The efficiency of GenAI is not only linked to the algorithms behind the interfaces or the Large Language Models (LLM) used to train them, it also depends directly on the way in which the task is requested, i.e. the quality of the input request, since GenAI models must receive an instruction in text format, in natural language, which is called a prompt. The input prompt can give the GenAI the expected result (or even more) or it can give disappointing results, and in the worst case, incorrect results [25]. Ironically, then, while we are talking about Artificial Intelligence, the human factor can be a determining factor in the success or failure of the application of this technology, regardless of its potential or quality.

The process of studying how to execute GenAI prompts in the most correct and efficient way has been called “prompt engineering” since its importance was first noticed at the beginning of the popularization of GenAIs [7, 17]. Prompt Engineering can be defined as “the art of communicating and interacting with the GenAI” [5], or “the process of developing, refining and optimizing the input prompt to effectively communicate the user's intent to the GenAI” [7].

A well-developed prompt should preferably follow certain parameters in order to obtain satisfactory answers, according to the guidelines found in the GenAI tools themselves [14, 19, 23] and points described other works [6, 13]:

- Objective/Intention/Task: The objective is a fundamental part of creating the prompt and must clearly contain the intention, task or goal that the GenAI is to achieve. Depending on the objective, this point usually begins with a verbal inflection: Do, create, write, solve, summarize, list, identify, classify, show... The objective is the only obligatory part of a prompt, although using it in

isolation has a high chance of an inadequate response.

- **Context/details:** Providing an appropriate and detailed context is important to guide the GenAI in understanding and generating what is required, avoiding ambiguities. This includes points such as the situation in which the problem or request occurs, important information about the topic, requirements and variables that need to be considered. Contextual information will help the GenAI to generate coherent answers in line with a specific use case or situation.
- **Target audience:** Informing the GenAI of the target audience will help to formulate the response correctly. This can include end users, experts, children or any other type of audience that will interact with the response. This information can result in instructions from which the GenAI will consider the level of understanding or prior knowledge of the target audience, increasing the amount of information or adapting the type of language used in the response.
- **Desired format and tone of response:** Providing the type of response you want is important for a good result. If you're working with text, you could ask, for example, for a single paragraph or bullet point format. When working with images, you can ask for realistic or cartoon styles. You can also specify the tone of the response with characteristics such as intonation and formality.
- **Expertise/Function/Persona:** Specifying a persona or character can help the GenAI produce results with greater coherence and consistency, since the tool can adopt certain characteristics of the character mentioned, such as personality and communication style. For example, you could ask the GenAI to act as a particular professional or as a public figure (artists, athletes, famous scientists, etc.).
- **Examples:** Providing examples considerably helps the GenAI to understand the expected results, as well as reinforcing the points mentioned here. If the information provided above is not sufficient, the examples can help fill in any gaps left by the GenAI. Some GenAI models also allow for the inclusion of other sources of information to be considered when preparing the answers, such as text files, images and videos.
- **Active dialogue:** An important consideration is to let the GenAI itself consider whether your request is coherent and informative, by asking it about aspects of your prompt. As an example, you could ask the GenAI if any information is missing in order to produce a coherent and concise response.

The amount of information required for a satisfactory response will depend on the type and complexity of the request. Simple questions may yield satisfactory results

with just the objective or task indicated. More complex questions, which require reflection and contextual analysis, will certainly need more information.

It is therefore defined that the appropriate structure of a prompt, with the aim of obtaining the most satisfactory result possible, is:

“Task - Context - Examples - Target Audience - Format - Persona - Active Dialog”

It is important to note that it is not necessary to follow this particular order of the elements when setting up the prompt, but rather to consider the presence of as many elements as possible.

Some points are mandatory, others are important to consider and others are optional, as shown in figure 1:

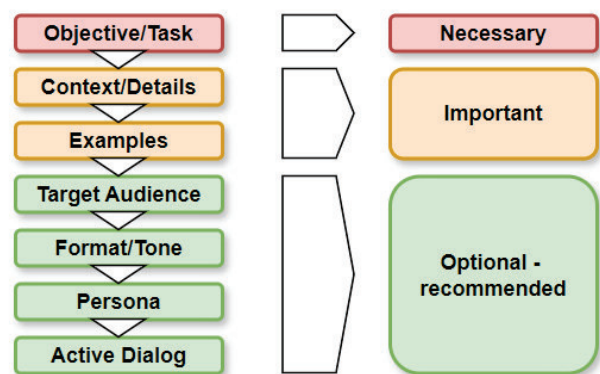


Figure 1: Recommended proper structure of a prompt (source: authors).

METHODOLOGY

To answer the RQs, the importance of the prompt in obtaining better responses from the GenAI in the educational context and possible contributions to the critical thinking of higher education engineering students will be analyzed, applying an exploratory case study, to understand through the data collected how students interact with the GenAIs, analyze these interactions and then confront them with responses resulting from prompts that follow the instructions of the developers.

This work proposes the study of ChatGPT as Object-to-think-with-together in a constructivist approach applied in higher education, in the subject “Electronic Devices”, in undergraduate engineering courses at Federal University of ABC in Brazil. In this subject, semiconductor materials, diodes, transistors are studied, and the analysis of circuits that consider this type of device is studied in depth. In traditional courses, the subject is called Analog Electronics.

The use of the artifact was proposed to the students as an extra-class activity, and with an extra grade, it was part of the teacher's didactic strategy, since the contents are abstract, and the path between analytical results,

computational results and experimental results is not always easily traversed by students, due to the need to know how to interpret what is being calculated or measured.

The experiment was applied to a class of 30 students, with an average age of 22, 26.6% of whom were women. The activity was proposed to be carried out over 10 days in order to follow the teaching plan. In the classroom, the students were informed and instructed to use the resource to solve some of the proposed problems. The students were presented with three situations, each with different characteristics and objectives, in which they had to ask for ChatGPT's help to solve them, but none of them consisted of mathematical operations.

In order to create a systematic process in this activity, the students were instructed to use ChatGPT in its free version, and to use the Portuguese language for interaction, since the paid versions are not accessible to everyone, especially to economically disadvantaged populations, and can also generate different responses due to their more advanced and up-to-date models. In addition, ChatGPT is the most popular and widely used GenAI tool at the time of this research. It is not part of the objectives of this study to analyze the functioning of ChatGPT, which is used as a "black box", i.e. the type of data model used or the way in which the GenAI is trained will not be considered.

The stages of this exploratory case study are:

1. Checking students' familiarity with ChatGPT.
2. Interaction with ChatGPT (Object-to-think-with-together).
3. Checking the correctness of the ChatBot's answers, carried out by the students themselves. This stage aims to create a sense of analysis and criticism.
4. Drawing up prompts that take into account all the requirements suggested by the developers for better interaction with the GenAIs.
5. Analyzing the responses resulting from appropriate prompts against those of the students' prompts.

For stages 1 to 3, the students completed a questionnaire on Moodle, initially classifying their familiarity with using ChatGPT (stage 1), and then they were asked to indicate, for each situation, which prompt they had given to the GenAI, without modifying it and without making any further attempts to obtain a more appropriate or coherent response than the first one, as the aim was to observe their knowledge of how to create prompts, and for this purpose it was necessary to have access to the first interaction (stage 2). The same was asked of the tool's responses (step 3). The students were also asked to briefly reflect on their answer, considering whether it was correct, coherent and sufficient for the objective proposed in each situation, given that they were aware of situations 1 and 2 and, in situation 3, they were shown a video on the subject. This request was made to check the students' current knowledge of the content

already studied in the subject and to see what they thought about using the tool.

The three situations presented to the students are described in table 1.

Situation 1	Your electronics teacher has asked you to do a final project on a guitar pedal circuit. Since you don't know anything about the subject, you've decided to ask ChatGPT for help with the assignment.
Situation 2	You've attended your teacher's lesson on how JFETs work and she's asked you to write a summary of the topic. You forgot to do the activity and won't have time to write it up. Use ChatGPT to generate this summary.
Situation 3	You're excited about your electronic devices lessons and have decided to brush up on the content, so you've used ChatGPT to find out about the next topic, which is MOSFET operation. After your interaction with the AI, watch the following video and comment on ChatGPT's response.

Table 1. Situations presented to students.

In situation 1, the project was in fact required at the beginning of the course and made up a percentage of the final grade. The aim was to implement a circuit for a sound effect device for electric guitars.

In situation 3, a video was provided which adequately explained the requested topic.

Once we had the students' answers, we moved on to step 5 to make a comparison of the answers provided by GenAI when using the prompt format suggested in the previous section (step 4).

RESULTS AND DISCUSSION

This section details the results obtained at each stage of the methodology.

Stage 1: When asked about their familiarity with ChatGPT on a scale of 1 to 5, 1 for never used (uninitiated) it before and 5 for someone with experience using it (advanced), no student marked advanced use. The answers, see Figure 2, indicate that the majority of students use it sporadically, which suggests that they lack knowledge of prompt techniques due to a lack of experience with the tool.

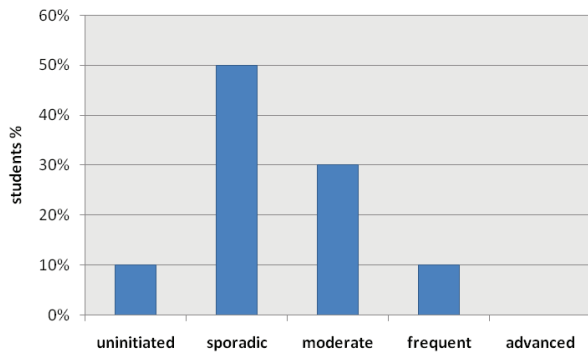


Figure 2: Percentage of students' prior knowledge of the GenAI tool.

Stage 2: The situations presented to the students (Table 1) include three types of interactions with the GenAI, and some hypotheses are considered about how the tool will respond:

In situation 1, students were asked a question involving at least 3 phases: planning, costs and execution. At this point the students were already in the process of finalizing the project, so they would already be able to assess the quality of the answer provided by GenAI. Here, an answer involving at least these 3 phases was expected, but incomplete when the appropriate prompt is not used, given the specificity. In this particular situation, the graphical representation was important, which is a limitation of the tool.

In situation 2, a simpler case, since it deals with a topic already known to the students, where it is expected that the deficiency of the answer is due to a lack or deficiency of context when formulating the prompt. The way the result is displayed is also important here, as it is a summary of the lesson they attended.

In situation 3, students were asked to respond to a topic they hadn't seen in class, so they were sent a video explaining this topic (here in an appropriate way), so that they could evaluate the GenAI's response on a topic they didn't know before. In this situation, the lack of prompt elements is expected to cause fewer inconsistencies or errors, as there was no requirement for anything that implied format, complex context or particularities of the other prompt elements.

Figure 3 shows an analysis of the prompt elements that the students used when making their requests to the GenAI. It can be seen that, although the 3 situations demand certain priorities in the prompt, the result was similar in all of them. As noted above, the task is a mandatory item in the preparation of prompts, and this is confirmed by the fact that 100% of the students, in all 3 situations, included the task, so that its absence would imply that the GenAI would not provide answers. It can be seen that the only points used other than the mandatory one were the format of the answer and the context.

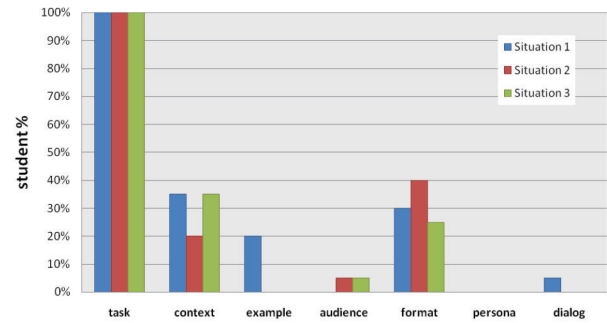


Figure 3: Percentage of suggested points used by students in the prompts.

Some examples of prompts prepared by the students will be presented in stage 3.

Stage 3: As the aim of this activity is for students to interact with the Object-to-think-with-together in order to build knowledge, it was mandatory to ask for an evaluation or critique of the answers provided by ChatGPT. In their comments on the GenAI answers, the students noted that the information was deficient in some respects. All the observations and considerations made by each student were summarized by assigning four categories to the ChatBot's answers: Incorrect, Incomplete, Generic and Satisfactory, and this categorization was the result of the analysis of each of the students' notes. The result is shown in figure 4.

In situation 1, in addition to the task, the students used the example parameter. As this was a work in progress, they used the circuits they were working on as an example. The students who indicated that they had moderate or frequent knowledge of the tool were the ones who used the most elements in drawing up the prompts. As expected, due to the specific nature of the subject, 60% of the answers were classified by the students as incomplete and none as satisfactory. 45% pointed out that the circuit's electrical diagram was missing and 55% felt that they had obtained an insufficient answer to carry out the activity.

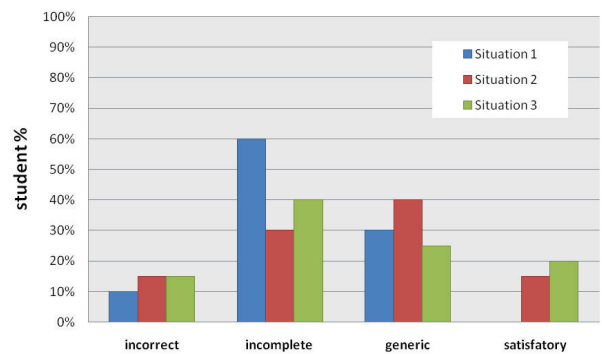


Figure 4. Classification of ChatGPT responses by the students themselves.

Tables 2, 3, 4, 5, 6 and 7 show examples of the prompts executed by some students.

Tables 2 and 3, referring to situation 1, show, respectively, examples of a simple prompt and another that considered more elements for its formation. In Table 2, in addition to what was presented, the student made many technical notes and comments related to the project in her critique.

Prompt: <i>"Electric circuit of the overdrive guitar pedal"</i>
Criticism: <i>"The introduction provided by ChatGPT is coherent but way too simple [...]"</i>

Table 2: Example of a prompt that only considers the task.

Prompt: <i>"Chat, help me with the final project for the subject "Electronic devices", in which a tremolo pedal needs to be made. You'll need to write a report and assemble your circuit on the protoboard, so you'll need both theoretical and practical knowledge. In this context, please provide information about the tremolo pedal for this project."</i>
Criticism: <i>"[...]It can be said that this response to the chat provided an initial "guideline"/roadmap for the realization of the project. However, it would be necessary to look for more information."</i>

Table 3: Example prompt for the same situation that considers task, context and form.

In Situation 2, where a summary format was explicitly required, we observed a slight increase in the use of this prompt element, though not sufficient. Ideally, the GenAI should always be informed about the desired output format (e.g., summary). This situation yielded responses closest to the expected, with only 15% incorrect and 30% incomplete.

Table 4 presents a prompt for Situation 2 that produced an acceptable result despite having few elements (only task and format). Notably, the "format" element was crucial for this type of task (summarization).

Prompt: <i>"Chat, could you please give me a summary of how a JFET works?"</i>
Criticism: <i>"I think it was a good answer, Chatgpt tends to be very theoretical, which is good for learning purposes and consolidating concepts, but for a more practical part, I believe it lacks a little explanation"</i>

Table 4: Example of a simple prompt for situation 2, but including the form of the output (summary).

Prompt: <i>"Hey 'Xét', today at college I missed the electronic devices class on how JFET works. Could you give me a summary of the topic?"</i>
Criticism: <i>"For a superficial understanding of the JFET, it is an ok summary. ChatGPT makes a very generalized theoretical summary, which does not include the different JFET configurations [...]. Due to its limitation of not generating images, it does not present any type of graph [...], or the circuit schematics. [...]"</i>

Table 5: Example of a prompt with more elements for situation 2 (task, context and form).

In Table 5, it can be seen that the student deeply internalized the knowledge of the subject, and was therefore able to perform a more in-depth analysis of the response provided by the tool. The student also noted that the impossibility of generating visual material (images and videos) ends up harming the quality of the response for this specific case.

In situation 3, even with few or no prompt elements used, more satisfactory responses were presented than in the other situations (20%), since in this topic no contexts, formats or other elements were required for the response. 40% were classified as generic, since the subject in question is better understood with visual elements such as animations or videos.

Prompt: <i>"How does a MOSFET work?"</i>
Criticism: <i>"The answer does not distinguish between a depletion and an enhancement MOSFET implying that the two are the same device in different operating ranges, there is no mention of the threshold voltage for enhancement and the pinch off voltage for depletion. "</i>

Table 6: Prompt for situation 3 considering only the task.

In Table 6, the student's criticisms were technical, but it can be seen that the very vague prompt leaves the tool prone to broad and generic responses, since no details of the desired output or contexts were specified.

Prompt: <i>"The next topic in my class is MOSFET. I would like to be prepared for the class. So, I would like an introduction to the subject."</i>
Criticism: <i>"The answer presents the subject well, but it is not as didactic as the video. Therefore, I believe that as an introduction to a new subject of electronic devices, the</i>

best option is to watch a short video like the one provided.”

Table 7: Example prompt for situation 3, adding context.

In situations 2 and 3, the use of an example is not specifically necessary. An example in situation 2 could be a report similar to the one you want to run. If the GenAI supports it, large texts can be provided as an example. In situation 3, an example could be a type of presentation or class for which the teaching method is previously known and is considered satisfactory by the user who makes the prompt.

For Stage 4, the authors developed the appropriate prompts for each situation, following the suggested structure. The prompts created are presented in Table 8, highlighting in brackets the prompt parameter that each part of the text represents.

Situation 1	Consider that you are an electronics teacher [persona]. The electronics teacher has asked the students to assemble an effects pedal for electric guitars as a project [context]. You have to describe the steps for assembling an overdrive pedal circuit step by step [task], as if you were teaching your students [audience]. Explain in tutorial format what needs to be done, taking into account that the assembly will be done on a protoboard, so there is no need for soldering or encapsulation, and also listing the components used for assembly [form]. Consider a BOSS SD-1 overdrive pedal [example]. Do you need any more information to answer this question [dialog] coherently?
Situation 2	Consider that you are an undergraduate student studying electronic devices [persona]. You need to generate a summary [task] in the form of a report, of a class you attended on the subject of “JFET operation”[context]. This summary should have a formal tone, but without exaggeration and too many complex terms, considering that it will be done by someone who is not an expert on the subject. In any case, you can use some equations [form]. This summary will be assessed by your teacher [audience]. Avoid artificial and “forced” expressions, try to have a more natural tone, without exaggerated excitement, like a summary in the form of a report. I'll tell you some important points that the teacher mentioned in class [dialogue], please

	consider them in the summary: Choke voltage, ohmic and saturation region (but not to be confused with TBJ saturation), high impedance, VGS and polarization [dialogue]. Do you need any additional information for this assignment? This summary should be no more than two pages long [form].
Situation 3	Consider that you are an undergraduate lecturer in the electronic devices subject that you teach [persona] with Boylestad's book as a reference [example]. The next topic in class is the operation of the MOSFET, specifically the physical description and modes of operation [context]. Summarize [task] in topic format on this topic [form]. Consider that your target audience is undergraduates who don't yet know about the topic [audience]. Use accessible language, considering that the students are not experts on the subject [format/tone]. Start by talking about the structure and flow of electrons in this device [form]. Do you need more information to generate this response [dialog]?

Table 8. Appropriate Prompts for each situation presented to the students.

Two important notes about the texts presented in the prompts in Table 8: In situation 1, the students were shown examples of pedal circuits that are widely known by their users. The BOSS SD-1 is an example of the overdrive type. In situation 3, the author referenced (Boylestad) is the author of the book Electronic Devices and Circuit Theory, used as the basic bibliography in the course.

Stage 5: Finally, the analysis of the answers obtained to the prompts in Table 2 is presented. For Situation 1, all of ChatGPT's responses to the students' prompts considered the list of components. Half of the responses suggested assembling on a board with solder (which was not requested for the students' project), i.e. the instructions were one step ahead of what the students should do (which could confuse a beginner). One point to note is that 35% of the GenAI responses recommended that students check electronics forums, DIY sites or be careful with soldering and using electricity.

The response to the appropriate prompt was more consistent, and indicated: Electronic Components, Component Positioning, Connections on the Protoboard, Tests and Adjustments. However, it should be noted that it is not possible to assemble a circuit with these prompts alone, as it is necessary to have an electrical diagram, a point mentioned by ChatGPT. When confronted with the

answers obtained by the students, we can see that there is no redundancy in some components, there is no mention of the soldering stage (as this is not expected), and the assembly sequence is very close to what it actually is. In any case, although this answer gives an idea of what needs to be done, it is not enough in itself to carry out the action.

In Situation 2, more appropriate responses to the students' prompts were expected, due to the fact that it was a summary, and due to the classification made by the students. However, it was observed that 45% of the answers came in topic format and not as a summary in the form of a report. As for the information provided by the GenAI, it was found that it confuses some concepts of the device studied (the JFET device is being studied and the GenAI responds with some incorrect concepts that are valid for another device known as TBJ). It should therefore be noted that a percentage of the criticisms cataloged by the students as incomplete (10%) or generic (10%) should in fact be classified as incorrect. On the other hand, 55% of the answers did not include an important concept of this device (high input impedance of the FET). There were 10% of answers that, due to the prompt being more specific, included more information related to calculations in the circuit, showing that the students were concerned with directing the answer.

As for the appropriate prompt, because it contained more parameters, it provided a report in the format of a story, with a well-defined beginning, middle and end. The answer mentioned all the important concepts of the device, did not confuse concepts and used a neutral and serious tone as expected for a text of this type. However, it was necessary to make the natural tone explicit without exaggeration by using two sentences, because in past experiences it has been found that ChatGPT has a tendency to use expressions of excitement that are not common in student language.

In Situation 3, the answers to the students' questions presented coherent and complete information, but it should be noted that 25% presented more detailed information than expected, due to the students interacting using more specific terms such as "what is the difference between this device and another", "insert equations" and using some technical terms that they had learned for other devices and assumed that they also applied to this one, which is totally correct. It was also found that when the students used the phrase "how it works", or "teach me", instead of "how to do it", the ChatGPT answers were better organized and summarized the operation of the device.

With regard to the appropriate prompt, there is a possibility that some students don't have the vision to narrow down the answer precisely because they were beginning their studies on this subject, and it was found that using the phrases indicated in the previous paragraph could have improved the answer. However, the answer was well organized and covered the main concepts related to the subject.

Finally, with regard to ChatGPT's responses to the prompt, it should be mentioned that if identical prompts are written on different computers at the same time and under the same conditions, the response generated is expected to be the same in theory, given that the users are using the same version of ChatBot. However, it should be noted that, in practice, there may be small variations, which are due to factors such as the randomness introduced in certain processes within the model, the way the model is being run, or even small differences in the internal states of the model at the time of generation. Another important issue is that ChatGPT remembers previous inputs, so when it asks a second time, using the same input, it changes the output, possibly in the expectation that the user is asking again because they weren't satisfied with the first answer.

Research Questions Answers

In order to answer RQ1, some observations from the analysis carried out in the previous section stand out.

Looking at the answers provided by the GenAI, when comparing the answers to the students' prompts with the prompts in Table 8, it can be seen that the prompt with more parameters provides better answers in Situations 1 and 2. In Situation 3, due to its simplicity, the GenAI responses to the simple prompts are very close to the prompts in Table 8. Although the GenAI results for the appropriate prompts are more consistent, this does not mean that there is no need for more iterations to improve the response. As for the best way to correct the response, ChatGPT itself recommends rewriting the prompt with the improvements.

Another factor to highlight is the fact that each person has their own particularities when interacting with other people, which also translates into interaction with the artifact. In Situation 1, there was diversity in the styles of the prompts, in Situation 2, 65% used imperative terms. In Situation 3, 5% used a neutral tone, 10% asked using the word "how", 85% asked for information directly (as mere information or as help).

With these considerations in mind, RQ1 can be answered as follows: students have their own ways of communicating in interactions with humans, and these are repeated in interactions with the Chatbot. Since they intend to use this technological tool in the learning process, they must be trained in the use of the artifact in order to obtain better responses. Translated into the terms of constructivist methodology, students need to adopt an advanced language when interacting with the object-to-think-together-with. Another important issue is that this ChatBot does not include the use of figures, which can be a limiting factor in the specific subject of this discipline.

Generally speaking, in all three situations it can be seen that in order to define the parameters in the prompt, it is necessary to have more knowledge of the subject, which produces a difficulty in the educational context in which the student is seeking this knowledge, so critical thinking should be strongly encouraged, thus covering RQ2.

To answer RQ2, stage 3 analyzed in detail the criticisms made by the students according to the teacher's perception. The criticisms and comments made by the students did not follow a template as they were open questions and the intention was for them to compare the information provided by ChatGPT with their own knowledge.

Some important points should be made about the comments made by the students:

- In situation 1, the majority of comments classify the response as an initial path and indicate that even with an adequate response from ChatGPT, it is necessary to look for other information, mainly in graphic or video format, which is consistent with the task.
- In situation 2, it was where the students best explained what they missed or liked about the answers, probably because it was a summary, they considered the most important concepts about the FET device.
- In situation 3, both the prompts and the students' comments showed what each one understood about the term "operation of the MOSFET device", with some considering the device as such (movement of electrons) and others considering the device within the circuit, which showed a confusion on the part of some students between the term "operate" and the term "polarize".
- Some students wrote long texts. These texts generally presented technical terms used in the subject, explanations, concepts or equations they missed, comparisons between what they know and the information they received. In a few cases, the students were very succinct.

In general, the students said very little about ChatGPT itself, and their comments focused on the subject content. This made it possible to check which concepts had been internalized by the majority. It was observed that the more the student internalized the concepts, the less complete the tool's response seemed to them. The notes show that, even in the absence of a correct answer template, they are able to identify errors or inconsistencies, whether textual or conceptual, in the GenAI's answer.

In the teacher's experience, engineering students tend to be less interactive, both verbally and in writing, and the characteristics of the subjects often perpetuate this type of behavior. So, in this activity, she observed that one way of encouraging critical thinking was by using object-to-think-together-with, because since in the classroom sometimes these interactions are not possible, outside of class, without the gaze of other students, they externalized their thoughts on the subject and classified the answers.

Finally, we observed the potential of this systematized activity, i.e. the student presenting a prompt, an GenAI response and a critique, to be used as a diagnostic activity, since analyzing the students' critiques gave the teacher an overview of each student's individual knowledge, and it was

also possible to see who was most interested in the subject matter.

CONCLUSION

Setting up the prompt is often considered a trivial part of the process, but it is essential for good results and can completely ruin the experiment when done incorrectly [2]. The importance of knowing how to ask the tool, i.e. how to set up the prompt, is considered in many different areas, such as computer programming code development [16], linguistic studies [10], medical education [12], pharmacological data analysis [21], among others. It is therefore important to know whether or not students are able to operate the tool before using it in class or extra-class activities, and some training may be necessary.

It is important to note that this work differs from others found in the literature on some points, listed below:

- The focus of the study was the student, not the teacher;
- The tool was not used to provide lesson plans or to prepare quizzes or other materials;
- This study was not used to teach the student content;
- The aim of this study was not to train students to use the tool, but it was noted that this step is necessary;
- The subject studied does not include skills related to writing or interpreting text, the content is more related to abstract thinking, numerical analysis, the operation of electrical and electronic components and the functioning of circuits, so in addition to verifying the importance of the prompt, it was hoped to see if ChatGPT could also be used in some way to study this type of subject.

This study provided important insights into the dynamics and way in which students interact with GenAI, particularly ChatGPT, as well as providing a guide for drafting prompts. It was observed that users with no experience of the tools tend to provide simple prompts, using the analogy with communication between humans, from the point of view of the GenAI it is as if a child with little vocabulary were making a request. It should be noted that in the process of communicating with GenAI, the right prompt is the equivalent of speaking the same language, communicating efficiently.

There is the possibility of using ChatGPT in teaching areas such as STEM, where the subjects are often not restricted to interpreting and constructing ideas. However, there are limitations related to both the input provided, i.e. the prompt, and the type of GenAI output, i.e. the text format. As far as the input is concerned, the more the user knows about the subject, the better the prompt can be, which is a difficulty for students who are still learning. As for the output provided by the GenAI, i.e. the response to the prompt, one would hope that as well as common images it could also provide circuit diagrams, as suggested by the students themselves, for the particular case of subjects in this specific area of STEM, which is outside the scope of ChatGPT.

The teacher's role is important in guiding this process and ensuring that interaction with the tool is appropriate, as well as recommending other objects-to-think-with-together. In addition, by observing the way in which students interact with the tool, it is possible to identify the extent to which the student is internalizing the content, since, as discussed in the previous section, those who have advanced knowledge of the subject in relation to other students will be able to identify different aspects and will be more likely to discuss the answers provided by the GenAI, while students who are still building their knowledge will eventually have more doubts about the correctness and coherence of the answers, or will even be able to validate the answers even if they are incorrect or incomplete.

One of the GenAI's strengths is that it helps develop critical thinking, since it can be used as a space for interaction that is sometimes not possible in the classroom, where students are generally less comfortable expressing opinions or doubts. The students' own criticisms showed that they were able to identify differences in the answers provided by the GenAI, compare the information obtained and point out what was missing. And some students indicated that they could have improved their question, i.e. the prompt, showing that they were concerned about interaction with the artifact.

Using these tools in class can encourage students to search for complex concepts, reflect on their understanding, ask questions, receive instant feedback and explore different perspectives. Thus, rather than being seen as an element that can hinder learning, GenAI can help teachers create a more inclusive and creative learning environment, promoting exploration, innovation, self-reflection and engagement among students.

These expectations about GenAI were superficially observed in the classroom, where there was the opportunity to participate in interactions between students about the ChatGPT activity. They commented on issues related to faulty answers and the iterations they had after the first answer. In future offerings of the course, the activity could be applied synchronously to encourage discussion between peers or as a diagnostic assessment between one subject and another within the course itself.

Other future work could cover the numerous research possibilities in the area of GenAI in education. We would highlight the development of specific experiments on the use of prompts for certain subjects or themes, comparison of responses between available GenAI tools, including commercial ones, and tests with NLP models trained in different ways and with specific material for each subject tested, using third-party tools or those allocated internally to educational institutions.

Finally, it is hoped that this work can serve as a roadmap or suggestion for using prompts in any GenAI, since this systematic experience can be replicated and improved without major technical or pedagogical difficulties. It

should also be pointed out that educators and users can often neglect an essential part of interacting with GenAIs (the prompt) and this can compromise the whole experience of using technologies in education.

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