Integration of Generative AI into a Project-based Learning Activity in a Microcontrollers Course

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Abstract. The use of generative artificial intelligence by students has increased since the launch of powerful natural language processing tools such as ChatGPT. Several works have highlighted the strengths, weaknesses, opportunities, and threats of this technology in education, but there is a reduced amount of empirical research of its application in real academic scenarios. This work proposes the use of ChatGPT as a tool that could help engineering students solve highly complex problems more efficiently and accurately. In order to test this hypothesis, an experience with a group of students from a mechatronics engineering microcontrollers course was carried out using the project-based engineering approach. The results highlight the necessity of finding a balance between a learner's previous knowledge and the complexity of a new task and educating students about proper prompt engineering techniques and the use of ChatGPT and any other GAI only as a complement to their own knowledge and skills.

Keywords: ChatGPT, Engineering, Education.

1 Introduction

The exponential massification and diversification of artificial intelligence (AI) around the planet have brought applications of this technology in all fields of human activity, including education. In this area, those applications include administrative work, instruction or instructor support, and student's learning [1]. In the latter of these subareas, these applications include customizable learning platforms, chatbots, machine translation tools, and intelligent tutoring systems [1]. More recently, generative AI (GAI) platforms such as ChatGPT, Bing Chat, and Bard, have gained increasing popularity among students.

Since its release on November 30, 2022, the GAI ChatGPT has raised a myriad of reactions from all those involved in education. In fact, experts from this realm have highlighted both the benefits and drawbacks of this new technology when applied to the different dimensions of the education system at all levels, including teaching, learning, assessment, and curriculum. On one hand, ChatGPT brings many benefits into these areas, including its vast knowledge from all disciplines, flexibility in the

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content generated, speed, low cost, and availability [2]. Conversely, the main weaknesses in the application of this technology include its possible generation of incorrect, false, or biased content difficult to identify by the user and the potential use by students to commit different forms of fraud in assignments [2]–[4]. Because of this diversity of possible outcomes, experts have also recommended a series of actions to deal with the many challenges that this new tool will bring into classrooms. Regarding faculty and educators' actions, experts suggest the application of activities where students need to integrate their personal experience, consult multiple sources, apply creativity and critical thinking, and complete their work without exclusive reliance on GAI [3], [4]. In the field of higher education, specifically engineering, reception from academics has been similar. For example, the author of [5] mentions various forms in which ChatGPT and other language models can be helpful for engineering education for both students and teachers, including language editing, tutoring, and generating and solving technical and non-technical questions. However, the author also highlights the false or incorrect information provided by these tools, making necessary the creation of standards and guidelines for proper use [6].

The rest of this article is organized as follows. The next section summarizes previous experimental results obtained in the integration of ChatGPT into engineering courses of diverse disciplines. Further, the research design proposed in this paper is detailed in all its steps, and the results obtained from the experiment are presented and discussed. Finally, conclusions and areas of future work are proposed, as well as the limitations contained in the proposed design.

2 Related Work

In engineering, there is some limited evidence of the impact of using ChatGPT in real-life educational scenarios. For example, software engineering students and professionals have provided positive feedback on the potentialities of this tool in coding activities despite its drawbacks [6], [7]. Research has also shown ChatGPT's capabilities for answering questions and generating code in a cybersecurity course [8] as well as generating code for the construction of a finite state machine [9], but in both cases, human expertise has been needed to properly evaluate and use the provided information. In the field of assessment, the authors of [10] noted ChatGPT's capabilities for the generation of biomedical engineering diagnostic exams, remarking that, however, the quality and reliability of each question should be evaluated. Similarly, the authors of [11] showed the implicit benefits when testing ChatGPT's support in the design of distillation columns for undergraduate chemical engineering education, highlighting the necessary verification of the provided information. Synthesizing, it is evident for most authors that ChatGPT and any other GAI will make sense as a learning and teaching tool only in conjunction with proper human skills and knowledge coming from users.

3 Research Design

3.1 Students' Background

This experiment was carried out with 24 mechatronics engineering students of an eight-semester microcontrollers course at Universidad de Sonora, in Hermosillo, Mexico. At the beginning of the term, they were divided into four groups to carry out a series of project-based learning experiences, where the third of these activities was controlling the behavior of a robot to follow the route given by a thermal footprint. Fig. 1 shows one of the groups working on this project, which included building an electronic circuit and programming an STM32 NUCLEO board. The robot consisted of a crawler unit whose movement depended on two motors controlled by the NUCLEO board according to temperature measurements obtained from two thermistors. Through a Bluetooth module as part of the circuit, the students were also able to monitor the robot's behavior from their cellphones.

Fig. 1. A group of students working on the previous project.

3.2 Experimental and Control Groups

Because of the proven effectivity of project-based learning in engineering courses [12]–[14], a fourth activity based on this paradigm was planned for the students to carry out. This project would be based on the already completed project described in section 3.1.

The same four groups would have an hour to solve a complex problem that required the application of abilities of the highest level according to the most recent version of Bloom's Taxonomy. This problem would be related to the activity mentioned previously, but the groups would be separated to work under different conditions: Two groups (experimental group) would be allowed to use ChatGPT and digital online resources, and two groups (control group) would be allowed to use only the latter—with the use of ChatGPT and any other GAI forbidden.

Some days before the experience, all of the students watched two short videos covering the basics of digital literacy and prompt engineering when using ChatGPT, followed by answering a multiple-choice test that assessed their understanding of both topics. In the area of digital literacy, the video covered two main topics: a methodology for the evaluation of digital sources' reliability and the avoidance of predatory journals. Regarding ChatGPT, the video provided the following suggestions, most of which have also been provided by OpenAI [15]:

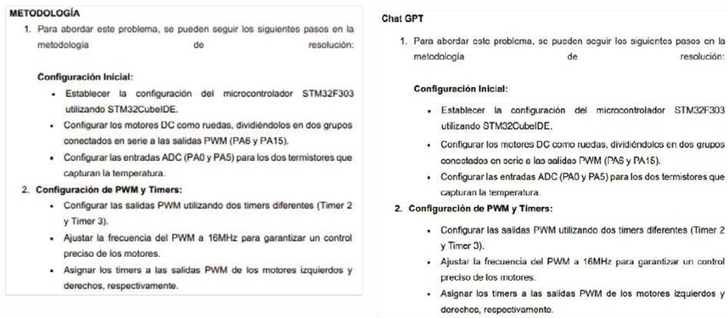
- being as clear and specific as possible when interacting with the GAI;
- asking context questions related to the topic before the question of interest;
- dividing a complex problem into sub-problems and making questions about these smaller, simpler problems;
- considering that besides written text, this GAI is capable of generating code and basic diagrams; and
- asking questions from topics in which they had previous knowledge in order to identify possible errors.

3.3 Experience

The four groups were informed of the tools they would be allowed to use the same day, a few hours before the experience. Then, they were given an hour to write a report proposing a methodology to make the robot follow a random route given by a thermal footprint through the shortest path and, at the same time, save the temperature values of the path in a lattice or vector. These values had to be sent to a second robot so it could follow the same route calculated by the first one. The students were requested to include a pseudocode algorithm to implement this behavior.

4 Results

The two groups that used ChatGPT along with digital resources performed poorly in high-order areas—content and structure—in their reports. In terms of content, as exemplified in Fig. 2, both groups chose to copy and paste ChatGPT answers directly without any attempt to integrate the information or even remove the use of the second person by the tool. The consequence of this approach was a document consisting of a sum of copied, isolated answers and lacking the level of depth expected for the activity.



METODOLOGÍA

1. Para abordar este problema, se pueden seguir los siguientes pasos en la metodología de resolución:

   Configuración Inicial:
   - Establecer la configuración del microcontrolador STM32F303 utilizando STM32CubeIDE.
   - Configurar los motores DC como ruedas, dividiéndolos en dos grupos conectados en serie a las salidas PWM (PA6 y PA15).
   - Configurar las entradas ADC (PA0 y PA5) para los dos termistores que capturan la temperatura.
2. **Configuración de PWM y Timers:**
   - Configurar las salidas PWM utilizando dos timers diferentes (Timer 2 y Timer 3).
   - Ajustar la frecuencia del PWM a 16MHz para garantizar un control preciso de los motores.
   - Asignar los timers a las salidas PWM de los motores izquierdos y derechos, respectivamente.

Chat GPT

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Fig. 2. Comparison of fragments of (a) a group's report and (b) a ChatGPT answer

Both groups allowed to use only digital resources created papers that were slightly more integrated and developed than those of their counterparts in terms of structure, even considering defects such excessive quotations as well as grammar and punctuation errors. A comparison of the pseudocodes proposed by the four groups also shows a significant difference in the depth of their algorithms. Table 1 shows the pseudocode proposed by one of the groups that was only allowed to use digital resources without any GAI. As seen in the image, a *while* loop and several *if* statements were included, as well as clear variables and mathematical relationships between them.

Table 1. A pseudocode created by a group that did not use ChatGPT

Students' proposed pseudocode
Begin
While (true)
If (timer variable, for example, 10s)
Calculate and convert data to temperature from thermistors
Calculate changes as current measurement minus previous measurement over a span of 50 milliseconds
Store current value in previous value variable
Store change calculations for each thermistor
Store change data in the array
If (changeT1 < 3.0 AND changeT2 < 3.0)
Set robot to static with PWM for both motors at 0.0
End If
If (changeT1 > 3.0 AND changeT2 < 3.0)
Turn counterclockwise with motor 1 at higher PWM than motor 2
End If
If (changeT1 < 3.0 AND changeT2 > 3.0)
Turn clockwise with motor 2 at higher PWM than motor 1
End If
If (changeT1 > 3.0 AND changeT2 > 3.0)
Move robot straight forward with motor 1 and motor 2 at the same PWM
End If
End If
Read array and send it via Bluetooth module to robot 2
Read array with a delay of 50 milliseconds for robot 2
End

In contrast, Table 2 shows the algorithm of one of the groups that did use ChatGPT. Their proposal was in fact a verbatim copy of the GAI's answer, which only schematizes the behavior of the robots in a series of functions but does not provide details about their execution.

Table 2. A pseudocode created by a group that did use ChatGPT (translation)

Students' proposed pseudocode
// Step 1: Capturing temperatura trajectory from the first robot
Matrix temperature_robot_1
captureTemperature(temperature_robot_1) // Function that captures temperature along the route
// Step 2: Obtaining optimal route
Route optimal_route
optimal_route = findOptimalRoute(temperature_robot_1) // Function that finds the optimal route based on temperature
// Step 3: Displacement of the second robot
Matrix temperature_robot_2
transmitData(temperature_robot_1, temperature_robot_2) // Function that transmits data to the second robot
// Step 4: Implementing route following by the second robot
route route_second_robot
route_second_robot = followOptimalRoute(temperaturE_robot_2)
// Function that guides the second robot following the optimal route
// Specific functions
function captureTemperature(temperature_robot):
while robot is moving:
read temperature from termistors
store temperatura in the matrix temperature_robot
function findOptimalRoute(temperature_robot):
create graph based on temperature change:
apply optimal route search algorithm (such as Dijkstra o A)*
return optimal route
function transmitData(temperature_robot_1, temperature_robot_2):
transmit temperature_robot_1 to second robot
temperature_robot_2 = receiveData()
function followOptimalRoute(temperature_robot):
follow the route defined by received temperature changes
return route followed by the second robot

The reports submitted by each group of students were assessed through the rubric presented in Table 3 according to three criteria: the level of integration of diverse academic disciplines in the proposed solution, the capacity to analyze the problem and then synthesize these solutions into one major solution, and the consideration of low-order concerns (grammar, punctuation, spelling, and word choice).

Table 3. Rubric created to assess the students' work

Criteria	1	2	3
1. Integration of technical and scientific disciplines	The problem is approached from one or none of the technical and/or scientific disciplines involved in its resolution.	The problem is approached from two to three technical and/or scientific disciplines involved in its resolution.	The problem is approached from more than three technical and/or scientific disciplines involved in its resolution.
2. Analysis and synthesis	Basic cognitive skills are applied in the resolution of the problem. In most cases, the written content is just a summary of information from different sources, but this information is not properly processed so that it can be useful to solve the problem.	There is a partial analysis of the problem as a division of sub-problems, but their solutions are not properly joined to create a major solution.	The problem is properly divided into sub-problems, after which these are synthesized to create a final solution to the greater problem.
3. Grammar, punctuation, spelling, and word choice	There are several concerns in terms of grammar, punctuation, spelling, and word choice in the document that difficult its understanding.	Although understandable, concerns in grammar, punctuation, spelling and/or word choice lower the quality of the paper in an academic or professional context.	The document is free or mostly free of errors in grammar, punctuation, mechanics, and word choice.

Students from the experimental group had poor performance in Criterion 1 and 2, as their work was basically copy-pasted ChatGPT answers. Students from the control group had a slightly better performance in these criteria. Both the control and the experimental groups had a mid-level performance in terms of low-order concerns (Criterion 3). In the case of the former, the main reason behind this score is the presence of grammar, punctuation, and spelling mistakes. On the other hand, although the experimental group had a better performance in these areas, there are word-choice concerns caused by the use of the second person by ChatGPT, which was not removed from the submitted work.

5 Discussion

The results obtained from the experimental group show the failure of these students in using this tool in the intended form. Moreover, their approach was not only detrimental to the quality of the proposed methodology but also made explicit the students' own weaknesses in technical writing skills. These results highlight the necessity of providing clearer guidelines on the optimum use of ChatGPT and any GAI when integrating them into higher education. Besides resources such as the videos, students will probably comprehend this methodology better if they receive extensive preparation in prompt engineering, including exercising and seeing examples of its application in similar situations to clearly understand all the steps involved.

6 Conclusion

This experience was an initial practical attempt to integrate a GAI into a classroom activity in an engineering course. Although the obtained results were not satisfactory, the inevitability of the use of ChatGPT and similar tools by students compels researchers to keep proposing and testing new strategies to work with this technology until desired results in terms of students' performance and learning are reached. For this reason, future areas of investigation should include the addition of prompt engineering as part of the academic curricula in engineering courses and the proposal of project-based activities that balance the necessity of higher-level cognitive skills and the application of previous knowledge from the students.

7 Limitations

This study has some limitations that must be mentioned. The main one is the reduced number of students selected for the experiment, who were separated into groups that created a total of four reports. These four pieces of work are not statistically significant to generalize the insights gathered from their analysis. However, there are at least two measures that can avoid this limitation in the future. Firstly, a larger set of students would yield a more statistically significant sample representative of the totality of the population from this particular higher education institution. Secondly, having the students from each group divide their tasks into identifiable parts would increase the comparable samples, allowing a more accurate generalization.

There is a second limitation in the biased selection of students, who come from a particular course and career and particular generations, allowing a potential generalization for a very small group of students. This limitation can be mitigated by selecting subjects from courses with a larger group of students, such as basic sciences courses common to any engineering career.

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