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EXPLORING THE APPLICATION OF CHATGPT IN MECHANICAL ENGINEERING EDUCATION

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ABSTRACT

The use of language models such as ChatGPT in the field of engineering has gained popularity in recent years due to their ability to assist engineers in their projects and tasks. In this study, we evaluated the effectiveness of ChatGPT in supporting students' learning in the Mechanism and Machine Theory (MMT) subject. The study involved participants who were asked to interact with ChatGPT to obtain concept clarification and factual information related to MMT.

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Our results show that the majority of participants were familiar with ChatGPT and had used it for academic or technical questions. They also found it easy to use and felt that it covered a wide range of topics. However, they noted that the answers provided by ChatGPT were not always clear or were ambiguous.

Our research also emphasizes the significance of critical thinking, analytical skills, and decision-making abilities while utilizing ChatGPT. While ChatGPT can serve as a valuable aid to students, enhancing their productivity and providing them with prompt information, it cannot replace their expertise and specialized skills. More studies are required to delve deeper into the complete potential of ChatGPT in bolstering engineering education and practice.

1 INTRODUCTION

In the past decade, the integration of artificial intelligence (AI) in education has emerged as a growing trend. ChatGPT is a chatbot system that appeared in November 2022 based on the GPT-3 language model of artificial intelligence. It is currently based on the GPT-4 version of this language model. ChatGPT is developed by OpenAI, and it represents a significant advancement in the field of generative AI. This technology has the ability to generate highly coherent written content, which closely resembles human-created texts.

OpenAI, established in 2015, is a research laboratory that focuses on the development of AI products for the common good. With significant support from individuals and companies (Meany 2023), the laboratory has made rapid progress in the development of its AI technologies. OpenAI has released a number of machine learning products for the general public, with ChatGPT being among the most well-known.

Generative AI, which generates novel outputs based on training data, has become the poster child of a broader development in AI. ChatGPT is a prime example of generative AI, as it uses Natural Language Processing (NLP) to enable computers to engage in natural language conversations. This technology has significant implications for various industries, it is an emerging area for research, and there are opportunities for future research to establish the potential impacts of ChatGPT empirically (Dwivedi et al. 2023).

As AI technologies become more prevalent in education, it is crucial to understand their potential and limitations. The integration of ChatGPT into the educational process requires adaptations in pedagogical methods (Schäfer 2022). Nowadays, we have an additional tool available for both educators and students that must be used with responsibility. Rather than merely preventing plagiarism, the primary concern for educators is to foster critical engagement with the system (Craig 2023). Educators need to ensure that students use ChatGPT as a tool to supplement their learning and not as a substitute for their intellectual efforts (Lund et al. 2023).

While this technology is not yet equipped to solve targeted mechanical engineering issues, it can offer valuable support in certain tasks (Tara 2023; GPTPromptsHubTeam 2023). ChatGPT is a versatile language model and due to its capacity for producing lines of code in various programming languages, it holds particular potential for use in mechanical engineering contexts.

In this study, we showcase the potential of ChatGPT to enhance the teaching and learning of mechanical engineering by proposing a framework of academic activities structured in a four-level pyramid format, each building on the previous one, with increasing complexity of the academic activity. The first level, Knowledge Retrieval and Comprehension, focuses on basic concepts and understanding of mechanical engineering. The second level, Synthesis and Evaluation, is focused with the fusion and summarization of sources of information. The third level, Application and Analysis, deals with applying this knowledge to practical situations and analyzing results. Finally, the fourth level, Creation and Innovation, requires the application of the knowledge in novel ways to solve complex problems.

2 METHODOLOGY

The study involved 65 participants from the second year of the Bachelor in Industrial Technology Engineering at the Barcelona School of Industrial Engineering (ETSEIB), from Universitat Politècnica de Catalunya (UPC). The age range of the participants was between 20 to 22 years old.

To assess the participants' prior knowledge of ChatGPT, a questionnaire was developed consisting of 14 questions. The purpose of the questions was to gather information regarding the participants' level of acquaintance with ChatGPT, their prior use of the tool, and their opinions about its usefulness in college education. The questionnaire also included open-ended questions to gather more detailed information about the participants' experiences with ChatGPT.

Subsequently, a face-to-face session was designed to test the effectiveness of ChatGPT in supporting student learning using a four-level pyramid format. The session was held in a computer room and the students worked in pairs. The activities were structured in the following manner:

1) Knowledge Retrieval and Comprehension:

The participants were prompted to engage with ChatGPT to clarify concepts and obtain information related mechanisms and machine theory discussed in class. They were encouraged to ask questions related to the laws of physics, gear calculations and virtual power.

2) Synthesis and Evaluation:

Participants were tasked with using ChatGPT to summarize a specific section of the course textbook. Following this, they were instructed to generate five test questions related to Chapter 4 of the subject, each with four possible answer options (only one correct). After generating the questions, the students were required to seek the correct solution from ChatGPT. Finally, participants were asked to provide a critical evaluation of ChatGPT results.

3) Application and Analysis:

Participants were presented with a physical mechanical model to illustrate a curious behaviour of fundamental basis of mechanics. They were then asked to ask ChatGPT for help in understanding the fundamentals of the model.

4) Creation and Innovation:

The participants were instructed to use ChatGPT to generate novel ideas for mechanical engineering designs, products, and solutions based on the fundamental mechanisms discussed during the course. Specifically, they were prompted to consider ways to input their own models into ChatGPT. This activity aimed to test the participants' ability to apply their knowledge and creativity to practical engineering scenarios, as well as to evaluate the potential of ChatGPT as a tool for ideation and design in mechanical engineering.

In the face-to-face session, information was collected, also through a form, on the perception of usefulness of the ChatGPT that the students had for the different tasks proposed.

3 RESULTS

3.1 Usage and Perception of ChatGPT

All the students were familiar with ChatGPT. Among them, 70,8 % reported having used it, while 29,2 % knew about it but had not yet tried it. Out of the total surveyed students, those who had previously used the tool (46 out of 65) were the ones who continued with the questions about ChatGPT usage. Therefore, the following percentages were calculated based on this group. Among them, 39,1 % reported using it on a weekly basis, 34,8% used it between 5 and 15 times, and 26,1 % used it less than 5 times.

Students primarily used ChatGPT for academic questions (95,7 %) or technical questions (56,5 %). Fewer students used the tool for personal questions (10,9 %) or entertainment (37 %).

In terms of the usefulness of ChatGPT, 52,2 % of the students indicated that they consistently or frequently found the answers provided by the tool useful, while 34,8 % reported that they were only useful on certain occasions, and 13 % found them rarely useful. The majority of the students found ChatGPT to be user-friendly (82,6%) and indicated that it covers a wide variety of topics (78,3 %). However, they also highlighted that the answers provided were not always clear (76,1 %).

In general, most students agreed that ChatGPT was a valuable resource for university students, with 65,2 % indicating that it was useful for specific topics and 34,8 % finding it highly useful. Additionally, the survey indicated that a significant majority of students (84,8 %) believe that ChatGPT can serve as a viable alternative to traditional research sources such as libraries and academic databases. Moreover, the majority of students (81,3 %) do not believe that ChatGPT can replace MMT classes (see Fig. 1).

Do you think ChatGPT can replace traditional research sources such as libraries and academic databases?

Do you think that using ChatGPT to understand Machine and Mechanism Theory can replace the need to attend classes and read textbooks?

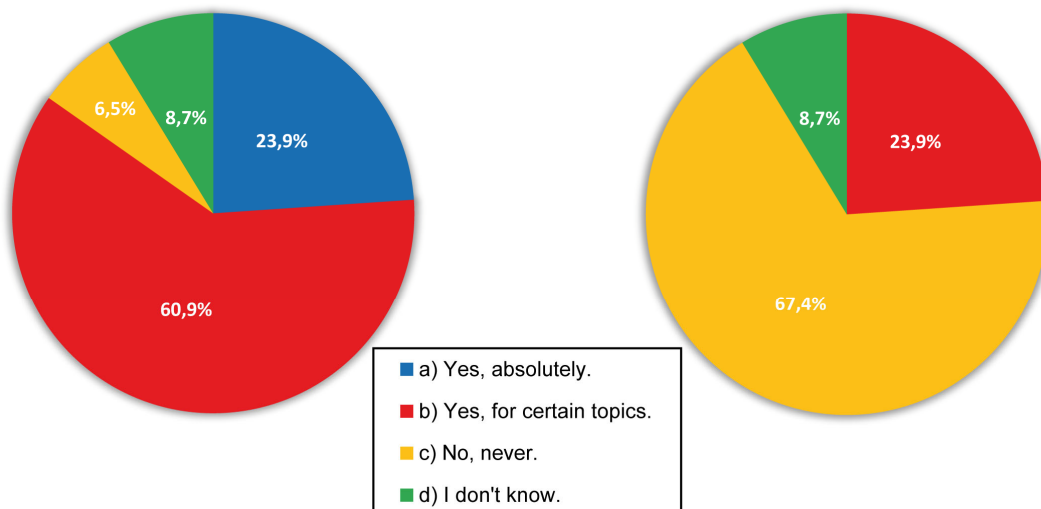
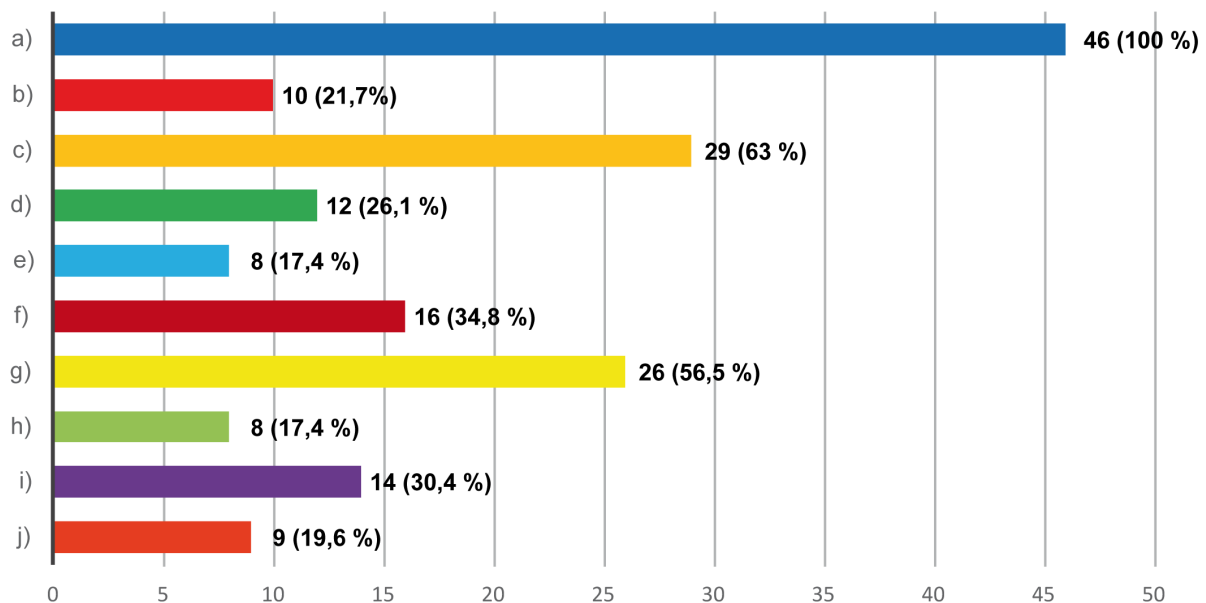


Fig. 1. Two questions about using ChatGPT at the university

Continuing with the questions about mechanism and machine theory, when specifically asked about the application of ChatGPT to the MMT subject, on one hand all students unanimously agreed that it could be useful for theoretical concepts, but on the other hand, less than 25 % of the students believed that it could be useful for solving exam problems, especially those involving geometric equations (see Fig. 2).

What kind of questions related to Machine and Mechanism Theory do you think ChatGPT could answer? (You can select more than one)



- a) Theoretical concepts.
- b) Practical and exam problems.
- c) Real-world application examples.
- d) Find geometric equations if the mechanism is explained.
- e) Find geometric equations if the link to the mechanism diagram is provided.
- f) Can't find geometric equations, but can find how to solve them in a programming language.
- g) Provide formulas for gear calculations.
- h) Identify simple planetary gear trains in a compound planetary gear train.
- i) Find and solve dynamics equations if the mechanism is explained.
- j) Find and solve dynamics equations if the link to the mechanism diagram is provided.

Fig. 2: Perception of the usefulness of ChatGPT in the MMT subject

In the open-ended questions, students mentioned that ChatGPT could help them with theoretical questions such as friction cone, holonomy, redundancies, or degrees of freedom concepts. Some students also suggested that ChatGPT could be useful for solving exercises, but others noted that its contribution is currently limited since it cannot interpret diagrams or schematics.

3.2 Feasibility of ChatGPT in Mechanism and Machine Theory

ChatGPT was evaluated based on its performance in the defined levels of tasks related to mechanical engineering, specifically in mechanism and machine theory. In the first level (Knowledge Retrieval and Comprehension), ChatGPT was found to be a reliable tool for obtaining definitions, particularly for concepts such as gears, degrees of freedom, kinematic pairs, Grashof's law, holonomy, inversions, etc.

Both, authors and students noted that ChatGPT's responses often contain inaccuracies, and that the accuracy of its responses varies depending on the language used, with less accurate results observed in Catalan and Spanish compared to English. Therefore, critical thinking skills are crucial when using ChatGPT to ensure that the information provided is reliable and appropriate. Analytical skills and decision-making abilities are also essential to evaluate the responses generated by ChatGPT and use them effectively.

For text summarization tasks (second level), ChatGPT performed reasonably well although it struggled with texts containing equations or a high number of variables. Other AI tools like Humata.ai may be more suitable for summarizing such texts.

ChatGPT's performance in the third and fourth levels of the pyramid tasks was found to be limited. In terms of application (level 3), it was capable of correctly solving some reasoning tasks that involved the application of simple formulas, but it made mistakes when dealing with more complex equations and variables. Therefore, students must not rely solely on ChatGPT's responses and use their critical thinking skills to verify the accuracy of the tool's output. Furthermore, it is worth noting that different users may receive varying and inconsistent responses to the same prompt from ChatGPT, as depicted in Fig. 3. It is important to highlight that in some cases, ChatGPT was unable to correctly solve the equation involving combined operations.

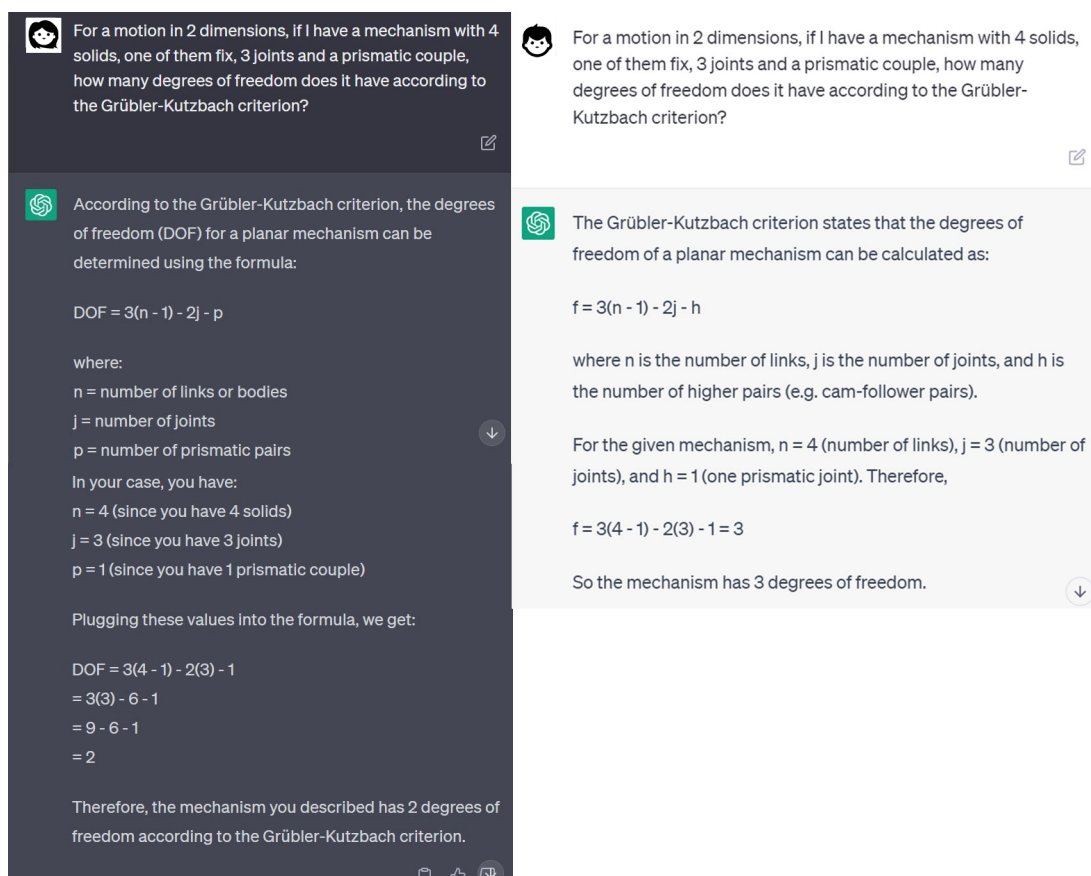



Fig. 3: Same prompt and two different answers


It is worth noting that ChatGPT has the ability to generate computer code for tasks such as solving geometric equations, regardless of the programming language used

(including Python, Matlab, R, C++, Fortran, etc.). When prompted appropriately (with occasional need for interaction when error messages arise), ChatGPT can produce the proper code (see Fig. 4). This functionality, since coding is not a required competency in MMT subject, has the potential to greatly aid students and can be seen as a valuable tool for them.

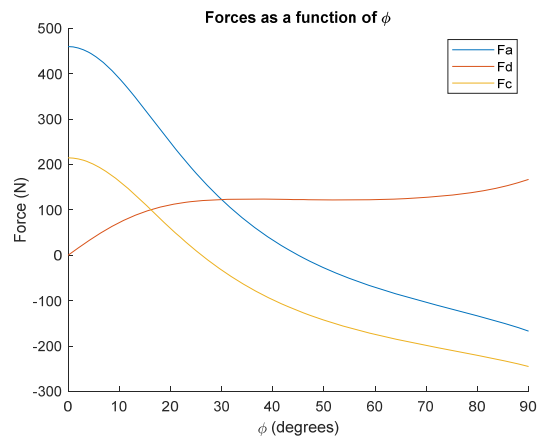
 For Assuming that F_a , F_d , and F_c are unknowns, write Matlab code to solve the following system of equations and find symbolic expressions for the unknowns as a function of the variable ϕ and the parameters l , s , m , and g .

$$\begin{aligned} F_a \cos(\phi) + F_d \sin(2\phi) - F_c - m \cdot g &= 0 \\ -F_a \sin(\phi) + F_d \cos(2\phi) &= 0 \\ -F_a \cdot 2 \cdot s + F_c \cdot 2 \cdot l + m \cdot g \cdot l &= 0 \end{aligned}$$

Assuming that F_a , F_d , and F_c are unknown, and assigning the values $l=0.75$ m, $s=0.55$ m, $m=25$ kg, and $g=9.807$ m/s², write the Matlab code to draw the graphs of F_a , F_d and F_c as a function of ϕ for values of ϕ between 0 and 90 degrees.

 To solve the system of equations and find symbolic expressions for the unknowns, we can use the symbolic math capabilities of MATLAB. Here's the code:

```
matlab Copy code
syms Fa Fd Fc phi l s m g
eq1 = Fa*cos(phi) + Fd*sin(2*phi) - Fc - m*g;
eq2 = -Fa*sin(phi) + Fd*cos(2*phi);
eq3 = -Fa*2*s + Fc*2*l + m*g*l;
```



(a)

(b)

Fig. 4: (a) ChatGPT prompt requesting a Matlab code to solve a system of equations (b) Correct result obtained in Matlab with the provided code

As a language model, ChatGPT has limitations when it comes to creating mechanical designs from scratch. However, it can provide some useful ideas and suggestions to assist mechanical engineers in their design process. When prompted with specific design requirements, ChatGPT can generate potential solutions that students may not have considered before.

While ChatGPT may not be able to create complete designs on its own, its potential in this field is continually increasing. The authors of the study noted that ChatGPT was previously unable to provide any schema for mechanical designs just a few months ago. At the time of conducting this study, ChatGPT demonstrated the ability to generate drawings of mechanisms using textual characters (see Fig. 5). However, the quality of the drawings was poor and often difficult to comprehend. As the tool continues to improve, it has the potential to become an even more valuable asset for mechanical engineers looking to streamline their design process and explore new avenues for innovation

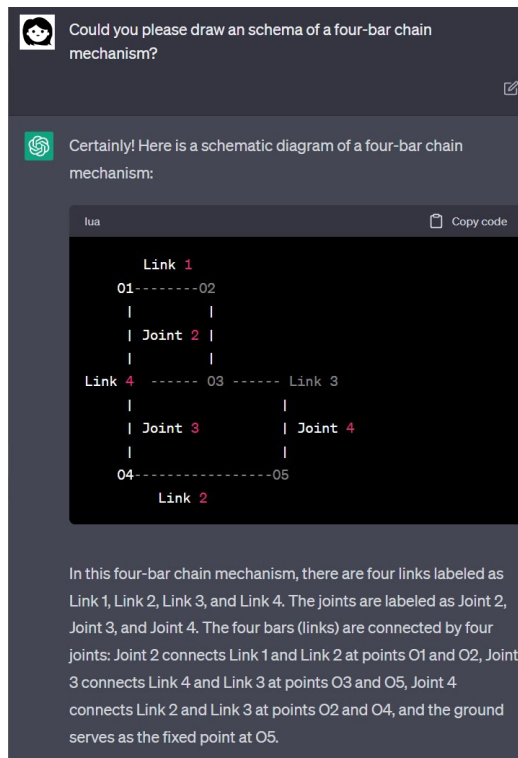


Fig. 5: Prompt and chatGPT answer for a schema of a four bar mechanism

4 SUMMARY AND ACKNOWLEDGMENTS

To summarize, this paper discusses the reliability and limitations of ChatGPT as a tool for mechanical engineering students. Our findings reveal that university students primarily use ChatGPT for academic and technical questions, and they find the tool easy to use and capable of covering a wide range of topics.

Applying this tool to mechanism and machine theory field, we want to highlight its accuracy in obtaining definitions and reasonable performance in text summarization, but limitations in handling complex equations and creating designs.

Although ChatGPT holds potential to support engineering student tasks, it is vital to approach its responses with critical thinking and acknowledge its limitations. Further research is required to develop advanced Natural Language Processing models for engineering tasks. As teaching, learning, and academic research undergo transformative impacts, it is important to remain open-minded about the potential applications of these technologies.

We think that ChatGPT should be seen as an assistant that can increase students' efficiency in completing tasks and projects. As such, it is recommended that engineering curricula incorporate the use of language models like ChatGPT to prepare students for the future of engineering and to enhance their problem-solving abilities.

The authors would like to thank the students who participated in the study. Additionally, we thank the developers of ChatGPT for providing us access to their technology. This paper has been developed with the assistance of ChatGPT,

highlighting the collaborative role of AI technologies and human skills in scientific research.

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