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Enhancing challenge-based learning with ChatGPT and product design methodologies

Mejorando el aprendizaje basado en retos con ChatGPT y metodologías de diseño de productos

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ABSTRACT

This study assessed the effectiveness of incorporating product design tools and ChatGPT into a challenge-based learning task, specifically a robotics challenge within a Mechanisms course for mechatronics students. The objective was to design and build a mobile robot mechanism capable of removing a flag from another robot. Students were divided into a control group and an experimental group, with both utilizing tools such as the House of Quality, Function Block Diagram, and Failure Mode and Effects Analysis (FMEA), with ChatGPT providing additional support. The methodology included instruction on the tools and their integration with ChatGPT. Results indicated that the experimental group outperformed the control group in task fulfillment, repeatability, and originality criteria. These findings suggest that combining traditional product design tools with AI tools like ChatGPT can enhance the ideation process and improve project outcomes. The potential for future research to explore and incorporate additional design methodologies is promising and could further validate these results.

Resumen

Este estudio evaluó la efectividad de incorporar herramientas de diseño de productos y ChatGPT en una tarea de aprendizaje basada en retos, en este caso, la construcción de un robot como parte de un curso de Mecanismos para estudiantes de mecatrónica. El objetivo era diseñar y construir un mecanismo de robot móvil capaz de quitar una bandera de otro robot. Los estudiantes se dividieron en un grupo de control y un grupo experimental, utilizando herramientas como Casa de la Calidad, Diagrama de Bloques Funcionales y Análisis de Modos y Efectos de Falla (AMEF) en combinación con ChatGPT como herramienta de apoyo académico. La metodología implicó instrucción sobre las herramientas y su integración con ChatGPT. Los resultados indicaron que el grupo experimental superó al grupo de control en cumplimiento de tareas, repetibilidad y criterios de originalidad. Además, los resultados muestran que la combinación de herramientas de diseño de productos tradicionales con herramienta de IA, como ChatGPT, mejoran el proceso de ideación y perfeccionan los resultados del proyecto.

Keywords
Challenge-Based Learning; ChatGPT; educational innovation; technology integration in education

Palabras clave
Aprendizaje basado en retos; ChatGPT; innovación educativa; integración de tecnologías en la educación

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INTRODUCTION

Experiential Education proposes that learners must be engaged in contexts of adventure and challenge to push students out of their comfort zones and into the learning zone (Northern Illinois University Center for Innovative Teaching and Learning, 2012). In an ideal scenario, learning does not end after completing the task.

As Apple Inc. (2010) explains, Challenge-Based Learning (CBL) is a dynamic and collaborative learning approach in which students works alongside experts and teachers to develop solutions to real-world problems. The activities, tasks, or situations presented are not only stimulating and challenging but also promote teamwork and a sense of shared accomplishment.

Ulrich and Eppinger (2004) proposed a comprehensive framework of tools and methods for designing and developing new products and services. Their approach begins with opportunity identification, followed by client needs identification, product specifications, concept generation, concept selection, proof of concept, product architecture, and industrial design, among other stages. Notably, it can also be adapted to the development of academic projects.

Design thinking, another widely used methodology, focuses on generating innovative solutions through five stages: empathize, define, ideate, prototype, and validate, as outlined by Brown (2008). Both design thinking and CBL have been integrated into a Mobile App Development course to leverage the strengths of these methodologies (Gama *et al.*, 2018).

In the last years, Artificial Intelligence (AI) tools have been incorporated into education. Previous studies suggest that the use of AI tools in education enhances learning outcomes, improves motivation and self-regulation, facilitates teacher-student communication, and reduces administrative workload (Bilad *et al.*, 2023). IA tools enhance students' motivation and learning strategies by providing them with indicators that help monitor and reflect on their learning processes. Moreover, IA tools contribute to more effective and engaged learning, ultimately improving educational outcomes (Michailidis *et al.*, 2022).

ChatGPT is a free-to-use AI model developed by OpenAI that generates human-like responses in conversational contexts. It was launched on

November 30, 2022, marking a significant advancement in conversational AI. OpenAI has continued to refine and expand the ChatGPT model by incorporating ongoing advancements in natural language processing (NLP). Baidoo-Anu and Owusu (2023) propose several educational applications for ChatGPT in education, such as interactive learning and personalized tutoring. However, they also highlight its limitations, including the generation of incorrect information when questions are poorly formulated or when the training data is insufficient or inaccurate. Similarly, Fuchs and Aguilos (2023) examine ChatGPT's potential as a tool for university students, emphasizing its use as a digital tutor, essay writer, or idea generator. They also provide an ethical perspective, suggesting that university authorities should regulate its use.

The integration of ChatGPT into higher education has sparked significant interest and debate. Studies such as the one conducted by Baidoo-Anu and Owusu (2023) highlight the tool's potential to enhance learning through interactive and personalized tutoring. Students have acknowledged the usefulness of ChatGPT in providing immediate feedback, generating ideas, and assisting in various stages of the academic process. A survey conducted at the University of Hertfordshire, UK, involving 430 computer science students, found that while many students are familiar with ChatGPT, its application in academic contexts remains underutilized. These findings suggest that although students recognize its potential, skepticism exists about its positive impacts on learning (Singh *et al.*, 2023). This skepticism may stem from the lack of clear guidelines and the need for more education on effectively integrating ChatGPT into academic practices.

> The rapid generation of text by AI models like ChatGPT has raised concerns about academic cheating, leading some educators to call for developing new forms of assessment that can better safeguard against misuse

Moreover, the emergence of ChatGPT has also introduced new challenges, particularly concerning academic integrity. The rapid generation of text by AI models like ChatGPT has raised concerns about academic cheating, leading some educators to call for developing new forms of assessment that can better safeguard against misuse (Adeshola & Adepoju, 2023). The perception of ChatGPT's role in education is not uniform, as revealed by sentiment analysis studies on social media platforms, where opinions range from highly favorable to critical.

Despite these challenges, systematic literature reviews indicate that, when properly implemented, ChatGPT can positively impact the teaching-learning process. However, the success of its implementation heavily depends on the educators' ability to use the tool effectively and on developing comprehensive guidelines that address its benefits and limitations (Montenegro-Rueda *et al.*, 2023). Additionally, research into students' perceptions of ChatGPT reveals a generally favorable attitude towards its use, with reported benefits including time savings, personalized feedback, and assistance in idea generation (Romero-Rodríguez *et al.*, 2023). However, significant barriers remain, such as the difficulty in assessing the quality and reliability of AI-generated content and ensuring that ChatGPT is used ethically within an academic context (Michel-Villarreal *et al.*, 2023; Ngo, 2023).

Critical analyses of ChatGPT in educational contexts reveal its transformative potential and challenges. Studies have highlighted that ChatGPT can be a powerful tool for enhancing creativity, providing immediate feedback, and supporting students' academic endeavors. However, its benefits depend significantly on how educators introduce and guide it. For instance, systematic reviews emphasize the importance of aligning ChatGPT's use with pedagogical objectives to prevent over-reliance on the tool and to maintain academic integrity (Choque-Castañeda *et al*., 2023). This requires educators to establish clear guidelines and ensure students understand AI tools' strengths and limitations.

On the other hand, critical perspectives highlight the potential risks associated with ChatGPT, including the homogenization of thought, ethical concerns, and the perpetuation of biases inherent in its training data. Researchers have observed that while ChatGPT can democratize access to information and ideas, it may also inadvertently discourage deeper critical thinking and the development of original arguments if used without proper oversight (Guevara *et al*., 2024). Despite these challenges, frameworks that integrate ChatGPT as a complementary tool rather than a standalone solution can maximize its benefits while mitigating risks. By fostering reflective and responsible usage, educators can leverage ChatGPT to enhance learning outcomes while maintaining a focus on critical engagement and ethical practices (Pérez, 2024).

In the context of CBL courses, students can quickly generate a wide range of creative ideas and solutions, which is crucial in courses focused on solving real-world challenges. This AI-driven tool enables students to explore diverse perspectives and refine their ideas more efficiently. Additionally, AI tools like ChatGPT assist in the ideation process by offering suggestions that students might not have considered, thereby broadening the scope of potential solutions. This capability accelerates the problem-solving and deepens the learning experience by encouraging critical and iterative thinking. Thus, ChatGPT proves to be a valuable resource within the CBL framework, fostering innovation and enhancing overall educational outcomes (Thong *et al*., 2023).

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Implementing CBL in engineering education has shown significant promise in enhancing students' ability to integrate theoretical knowledge with practical problem-solving. Studies demonstrate that CBL fosters collaboration, creativity, and critical thinking by immersing students in real-world challenges that require interdisciplinary approaches (Terenzano *et al*., 2022). This methodology is particularly effective in courses such as mechatronics and robotics, where the complexity of tasks requires the application of diverse skills and tools. In this context, integrating AI-driven tools like ChatGPT aligns seamlessly with the objectives of CBL. These tools not only accelerate the ideation process but also broaden the range of potential solutions, empowering students to address challenges more effectively.

Moreover, ChatGPT has been shown to complement traditional engineering education methods by providing immediate feedback, refining design processes, and supporting technical understanding. For instance, its use in mechanical engineering education has enabled students to clarify complex concepts, explore alternative solutions, and validate their reasoning, making it an ideal companion to the iterative and exploratory

The present study seeks to explore the integration of ChatGPT and traditional product design tools as part of a comprehensive evaluation framework, aiming to enhance the ideation process and project outcomes in engineering education

nature of CBL (Ojeda *et al.*, 2023). By integrating ChatGPT into the CBL framework, educators can enhance the depth and breadth of student engagement, bridging the gap between theoretical learning and practical application. This synergy underscores the transformative potential of combining innovative pedagogical methodologies with cutting-edge AI technologies in engineering education.

Incorporating robust evaluation methodologies is essential to strengthen the validity and reliability of outcomes in educational research. Meta-analyses and systematic reviews have highlighted the importance of using validated instruments and critical evaluation frameworks to assess the effectiveness of pedagogical approaches in diverse learning contexts. For instance, the application of meta-analysis in educational settings provides a replicable and objective methodology to synthesize data from multiple studies, offering a comprehensive understanding of underlying patterns and trends (Botella & Zamora, 2017). Such approaches emphasize the need for rigorous instrument design and validation, particularly when evaluating innovative interventions like AI tools in CBL.

Furthermore, studies analyzing evaluation methodologies in competency-based education have underscored the significance of aligning evaluation criteria with learning objectives to ensure meaningful assessments. By integrating validated tools and reflective practices, researchers can more effectively capture the nuances of student learning experiences and outcomes (Salazar & Donoso, 2013). These insights are particularly relevant for the context of CBL, where the dynamic and iterative nature of the learning process requires a multi-faceted approach to evaluation. Building on this foundation, the present study seeks to explore the integration of ChatGPT and traditional product design tools as part of a comprehensive evaluation framework, aiming to enhance the ideation process and project outcomes in engineering education.

This study evaluated the effectiveness of incorporating product design tools and ChatGPT into a CBL course, specifically within a robotics challenge in a Mechanisms course for fifth-semester mechatronics students. The primary objective for the students was to design and build a mobile robot mechanism capable of removing a flag from another robot. This investigation aims to examine the impact of using ChatGPT on enhancing the students' ideation process and improving project outcomes.

METHODOLOGY

Participants

The experiment to execute the challenge was conducted with two groups of 30 fifth-semester undergraduate students enrolled in a Mechanisms course. Students were organized into teams of three or four members. The first group (control group) only used product design tools to solve the challenge. The second group (experimental group) used product design tools in combination with ChatGPT to solve the challenge. In both groups, the students did not have prior knowledge of the product design tools or their usefulness before the experiment. To ensure a fair comparison between the two groups, the teacher used an evaluation rubric focused on the effectiveness of problem-solving through the application of product design tools, independent of the use of AI tools.

Implementation

Initially, the professor explained the theoretical concepts and examples of the product design tools in both groups:

- The House of Quality emphasizes the importance of prioritizing the elements of the project and establishing comparisons against competitors.
- The Function Block Diagram analyzes the functions required to complete the task appropriately.
- The FMEA aims to identify potential project failures, learn how to prioritize them, define actions, and assign responsibility.

The selection of product design tools for this study was guided by their proven effectiveness in engineering education and professional design processes. The House of Quality was chosen for its ability to translate customer or project requirements into prioritized design elements, fostering a structured approach to addressing user needs while benchmarking against competitors. The Function Block Diagram was included due to its utility in systematically mapping the functional requirements of a design, providing students with a clear understanding of the relationships between subsystems and their roles in achieving the overall objective. Finally, the Failure Mode and Effects Analysis (FMEA) was employed to help students identify potential risks, evaluate their impact, and prioritize mitigation actions and critical skills to ensure robust and reliable designs. Together, these tools were selected for their complementary strengths in guiding the ideation, analysis, and refinement stages of the design process, making them particularly suitable for the context of the robotics challenge.

In addition to the class, a series of videos explaining the product design tools was prepared and provided to the students to reinforce their learning and understanding. An evaluation was conducted to ensure that the students had reviewed the material.

In the case of the experimental group, the professor introduced and explained the use of ChatGPT. Students participated in a session where the application of ChatGPT was demonstrated alongside the product design tools to help them understand how this AI tool could be utilized to solve different problems. For instance, the professor asked ChatGPT about potential design failures that might arise in a project (e.g., flat knitting machine automation) with characteristics similar to their challenge, as illustrated in Figure 1. Following this explanation and demonstration, the professor assigned exercises for students to practice using ChatGPT. These exercises ensured that students could effectively formulate prompts for the AI tool and critically analyze the responses to confirm their accuracy and feasibility in addressing the problem.

Together, these tools were selected for their complementary strengths in guiding the ideation, analysis, and refinement stages of the design process, making them particularly suitable for the context of the robotics challenge

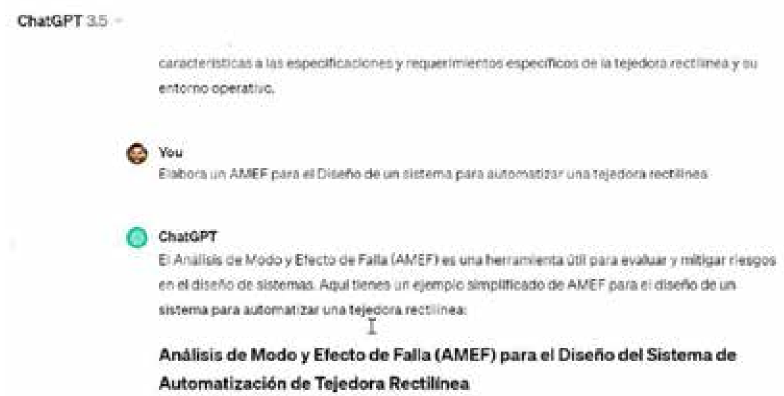

Figure 1. Example of an FMEA request to ChatGPT (in Spanish).

The challenge's objective was to design and build a mechanism mounted on a mobile robot capable of removing a flag from another mobile robot. In the next class sessions, the professor explained the robot's characteristics and guided the initial ideation process. The type of mobile robot selected for the mechanism was a Sumo Robot, as shown in Figure 2.

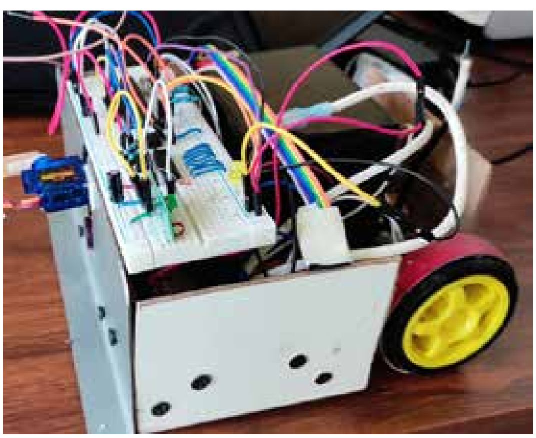

Figure 2. Sumo Robot.

Both groups had the same amount of time to complete the challenge and evaluate the results. The experimental group was told that they could use ChatGPT at any stage of the robot design and implementation process. When the students needed help, they asked the teacher to check the elaboration of the prompts. Although a deadline was set for the delivery of the project, the professor in both groups reviewed the progress made and answered any doubts that the students might have.

CBL provides a framework for engaging students in real-world problem-solving by encouraging interdisciplinary collaboration and iterative thinking. In the context of mechatronics, CBL aligns well with the need to integrate theoretical knowledge with practical applications, offering a dynamic platform for students to develop technical and non-technical skills simultaneously. The first task assigned to students was to prepare a report detailing some of the results of their design. Figure 3 presents some sketches from the groups. Although the initial sketches do not demonstrate a significant difference between the two groups, it is essential to note that the students in the experimental group were the first to deliver the requested progress.

As previously mentioned, the students in the experimental group also used ChatGPT, and Figure 4 shows a prompt they used; the responses obtained formed the basis for the idea-generation process. ChatGPT was integrated as a supportive tool throughout the CBL framework. During the ideation phase, it facilitated brainstorming by

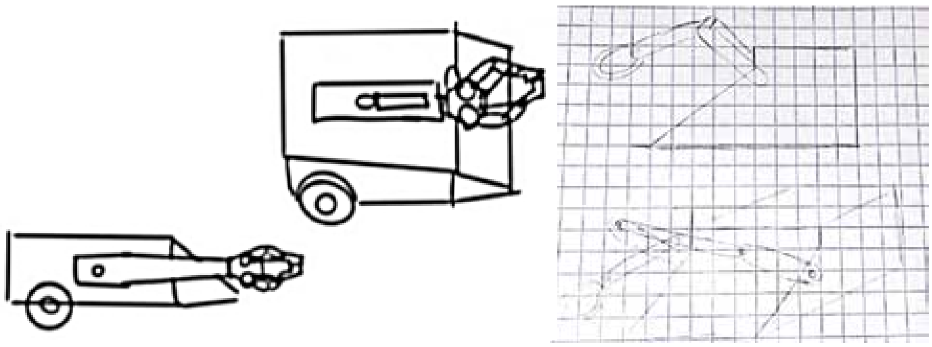

Figure 3. First sketches of one team of the experimental group (Left) and first sketches of one team of the control group (Right).

generating diverse perspectives and potential solutions. In the design phase, ChatGPT provided feedback on technical specifications and helped refine project ideas. The tool helped students troubleshoot and optimize their designs during implementation by explaining complex concepts and suggesting improvements. Finally, in the evaluation phase, ChatGPT supported students in articulating their findings and reflecting on their learning processes.

Figure 4. Part of a ChatGPT prompt of the experimental group (in Spanish).

In summary, to ensure replicability, a detailed implementation protocol was followed. The experiment consisted of the following steps:

1) Training on Product Design Tools: Students in both groups attended an introductory session where the House of Quality, Function Block Diagram, and FMEA were explained with practical examples. Supplementary video materials were provided, and a follow-up quiz was conducted to ensure understanding.
2) Training on ChatGPT: The experimental group participated in an additional session focused on ChatGPT's functionalities, including crafting effective prompts and evaluating AI-generated suggestions.
3) Challenge Execution: Students were tasked with designing and building a mobile robot mechanism capable of removing a flag from another robot. Both groups received identical specifications and timeframes.
4) Supervision and Feedback: Throughout the project, the instructor monitored progress, provided guidance, and clarified doubts.

The following resources were required for the implementation:

- Technological Resources: Laptops with internet access for running ChatGPT, and software for design tools.
- Physical Materials: Motors, sensors, microcontrollers, batteries, and other components for building the robots.
- Human Resources: A facilitator with expertise in product design tools and AI applications.
- Infrastructure: A laboratory equipped for assembling and testing robotic mechanisms.

RESULTS AND DISCUSSION

Opinion of the students

Three questionnaires were administered to the students in the group that utilized the product design tools and ChatGPT to address the challenge. The first questionnaire evaluated their prior use of ChatGPT in projects for other courses. As in shown in Figure 5, nearly half of the students had already used ChatGPT for academic projects before this experiment.

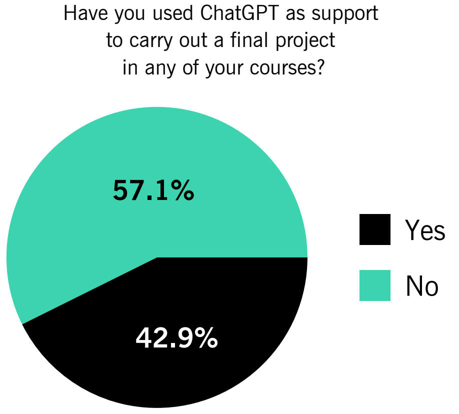

Figure 5. Use of ChatGPT in previous projects.

In that questionnaire, students who had used ChatGPT in their projects made comments such as "(I use it) when I feel out of ideas" or "It helped me to generate new ideas."

The second questionnaire was distributed after the videos were provided to the students. It included the following questions for each tool:

a) How useful do you consider the House of Quality for your mechatronic projects?
b) How functional is the Function Block Diagram for your mechatronic projects?
c) How useful do you consider FMEA (Failure Modes and Effects Analysis) for your mechatronic projects?

A Likert scale ranging from 1 to 5 was used, with 1 representing the minimum value and 5 the maximum. The results in Figure 6 show that after introducing the tools, students were optimistic about using the product design tools in their projects. Although the results are presented for the House of Quality, a similar opinion was expressed regarding the Function Block Diagram and the FMEA.

Finally, another questionnaire was administered to the students in the experimental groups after the challenge was completed, with the following questions:

1) What was the easiest part of this project/challenge for you?
2) What was the most difficult part of this project/challenge for you?
3) How helpful were the provided tools (House of Quality, Function Block Diagram, and FMEA) in combination with ChatGPT to carry out this challenge?
4) Would you use ChatGPT again when undertaking a new project/challenge in your courses?

A Likert scale ranging from 1 to 5 was used, with 1 representing the minimum value (very little) and 5 the maximum value (very much). The results for the first two questions are presented

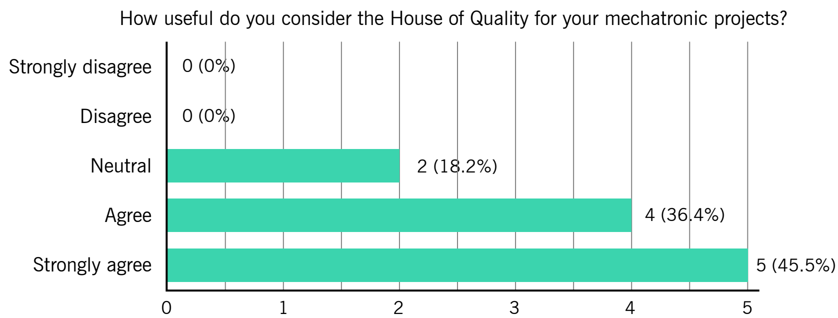

Figure 6. Expected usefulness of the House of Quality.

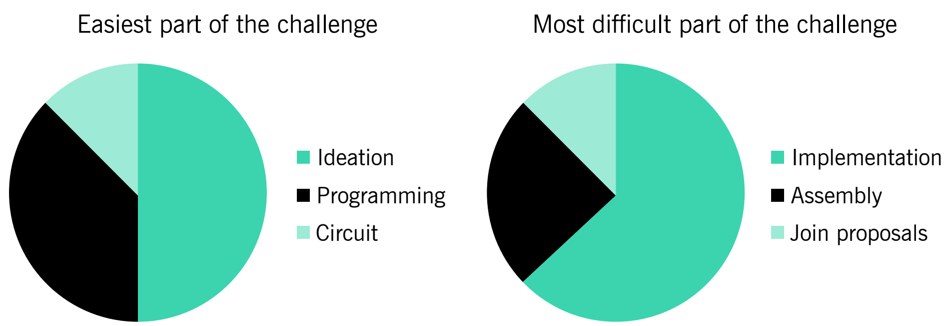

Figure 7. The easiest and most difficult part of the challenge.

in Figure 7. Notably, half of the students reported that the ideation was the easiest part, likely because the provided tools facilitated the quick generation of design ideas. In contrast, the most challenging aspect was the implementation, as is often the case in projects involving the construction of physical devices.

Figure 8 presents the results for questions 3 and 4. On average, students acknowledged the usefulness of the provided tools and expressed a greater likelihood of using ChatGPT for future projects.

Finally, for those who indicated they would use ChatGPT for future projects, Figure 9 shows their preferences regarding the tools they would likely use in conjunction with ChatGPT.

The integration of ChatGPT within the CBL framework enhances the students' problem-solving process rather than a replacement for the

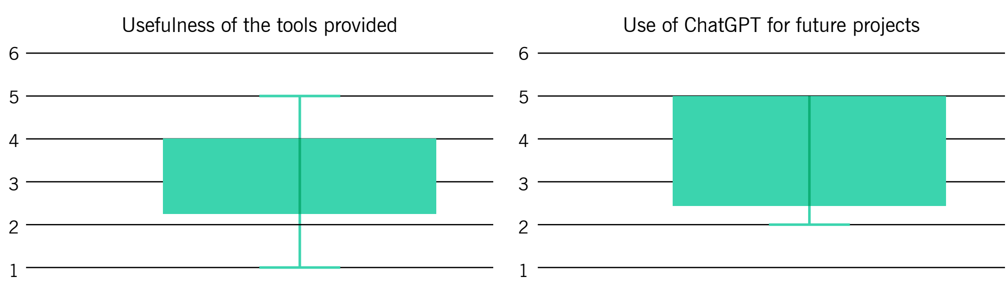

Figure 8. Usefulness of the tools provided (Left), and Use of ChatGPT for future projects (Right).

foundational principles of CBL. By acting as a collaborative assistant, ChatGPT reinforces critical thinking and creativity, which are core objectives of CBL, particularly in tackling real-world challenges in mechatronics education.

Evaluation of the final mechanisms

The final evaluation focused on two mechanisms: one developed by the control group and the other by the experimental group, as illustrated in Figure 10. These mechanisms were assessed based on five criteria:

a) Performs the function adequately: This criterion evaluated the mechanism's ability to effectively remove a flag from another robot, with an emphasis on precision and reliability during repeated trials.
b) Good repeatability: This assessed the consistency of the mechanism's performance across multiple attempts. A highly repeatable mechanism would perform the task similarly each time, indicating stability and reliability in its design.
c) Ease of assembly: This criterion examined how straightforward the mechanism was to assemble, considering factors such as the number of components, the complexity of the assembly process, and the clarity of assembly instructions.

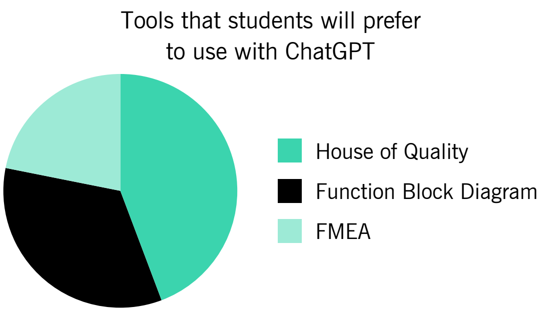

Figure 9. Students' preference regarding the tools

d) Ease of operation: This focused on the ease of operating the mechanism once assembled. It involved evaluating the simplicity of the control interface, the intuitiveness of its operation, and the level of user intervention required during its functioning.
e) Originality of the mechanism: Finally, this criterion evaluated the uniqueness and creativity of the mechanism's design, including innovative approaches to solving the problem and the use of novel features or materials.

Each criterion was rated on a Likert scale ranging from 1 to 10, where 1 corresponded to

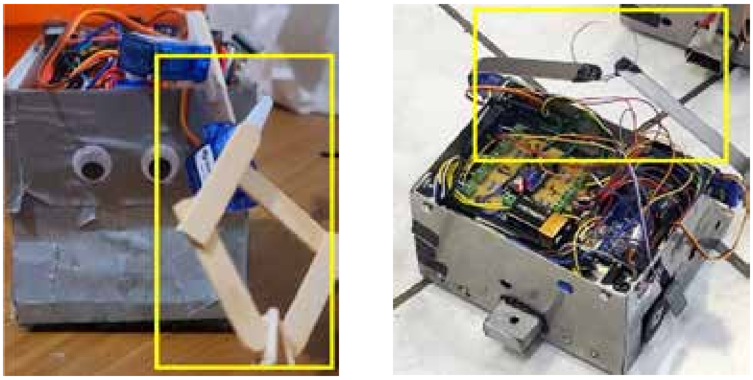

Figure 10. Final mechanisms attached to a Sumo Robot of Control (Left) and Experimental groups (Right).
Note: The requested mechanisms are inside the area of the yellow rectangles.

a marginal fulfillment of the criterion, and 10 indicated complete fulfillment. The evaluation process was designed to ensure objectivity and comprehensively highlight each mechanism's strengths and weaknesses.

As shown in Figure 11, the mechanisms produced by the experimental group outperformed those from the control group across all criteria. The experimental group's mechanism demonstrated superior functionality, repeatability, and ease of use. One likely reason for this difference is that the experimental group benefited from integrating ChatGPT during the design process. ChatGPT provided valuable insights and suggestions during the ideation phase, which may have contributed to a more refined and effective final design.

Moreover, the originality of the mechanism developed by the experimental group was particularly noteworthy, suggesting that the use of AI tools like ChatGPT can enhance creativity in the design process. The experimental group's clear advantage in these evaluations highlights the potential benefits of integrating AI-driven idea generation with traditional product design methodologies in educational settings.

The results of the Mann-Whitney U Test revealed no statistically significant differences between the control group and the experimental group across all evaluated metrics. While these findings suggest that the integration of ChatGPT did not result in measurable distinctions in the specific scores analyzed, the instructor observed notable differences in the students' creative processes and the quality of the solutions presented. These qualitative observations highlight the impact of ChatGPT as a tool for enhancing student engagement and innovation during the project.

The integration of ChatGPT within the CBL framework complements and enhances the students' problem-solving abilities without replacing the foundational principles of CBL. Acting as a collaborative assistant, ChatGPT fosters critical thinking and creativity, aligning closely with the core objectives of CBL, particularly in addressing real-world challenges in mechatronics education. By supporting brainstorming, refining design ideas, and offering iterative feedback, ChatGPT contributes to a richer and more dynamic learning experience for students.

In general, it is important to highlight that the authors designed the questionnaires used in this study for the context of the robotics challenge. Their primary objective was to collect exploratory and direct information regarding students' perceptions of the product design tools and ChatGPT integration within the challenge. Although the questionnaires were not formally validated, they

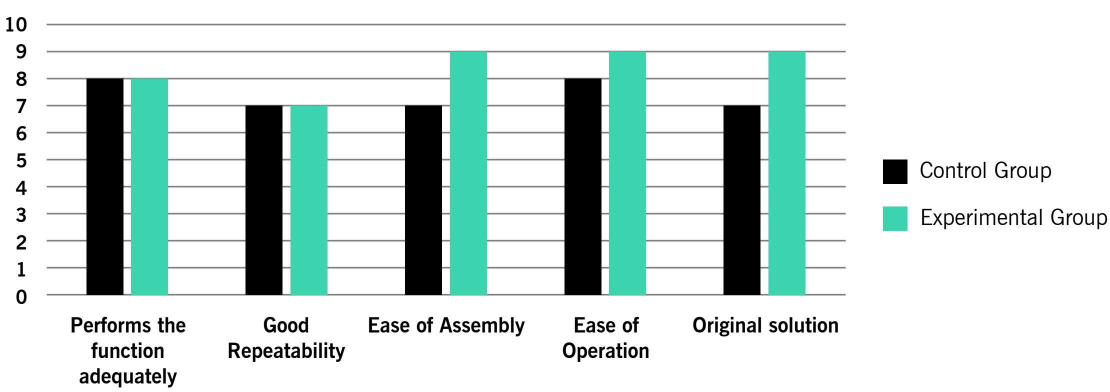

Figure 11. Comparison between mechanisms.

consisted of straightforward, clear, and specific questions, ensuring consistent understanding among participants. This approach enabled an objective assessment of key aspects, such as the perceived usefulness of the tools and the challenges faced during the project.

The exploratory nature of these questionnaires aimed to provide preliminary insights that could serve as a foundation for hypothesis generation and guide future research. However, we acknowledge that formal validation of the instruments would enhance the reliability and generalizability of the findings. Therefore, in future studies, we plan to adopt more rigorous processes for designing and validating instruments, ensuring greater precision and validity in the collected data.

Pedagogical and ethical considerations

The findings of this study carry significant pedagogical implications, particularly in the context of integrating AI tools like ChatGPT into educational frameworks such as CBL. The ability of ChatGPT to enhance ideation and creativity underscores its potential as a supportive tool for fostering higher-order thinking skills among students. By streamlining the generation of ideas and providing diverse perspectives, ChatGPT can help learners move beyond rote memorization toward more critical and creative problem-solving approaches. However, its implementation must be guided by well-defined pedagogical strategies. Educators should design activities that leverage the tool's capabilities and encourage students to critically evaluate its outputs, ensuring that AI-generated content complements rather than replaces student effort. This aligns with constructivist principles, where learning occurs through active engagement and reflection, emphasizing the role of the educator as a facilitator in guiding the meaningful integration of technology.

From an ethical perspective, the widespread adoption of ChatGPT in education raises important concerns. These include potential over-reliance on AI, the perpetuation of biases embedded in training data, and challenges in ensuring academic integrity. Institutions must establish clear policies and guidelines to address these issues, promoting responsible use of AI tools. For instance, incorporating discussions on ethical AI practices into the curriculum can empower students to recognize the limitations and potential biases of ChatGPT while fostering a critical mindset. Additionally, educators must ensure that using ChatGPT does not create inequities, such as favoring students with better access to technology. By addressing these ethical considerations, educational institutions can create an environment where ChatGPT is used responsibly to enhance learning outcomes without compromising the values of fairness, originality, and integrity.

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CONCLUSIONS

The main objective of this study was to assess the effectiveness of using ChatGPT as a source of ideas, in combination with product design tools to solve a robotics challenge in a CBL course. Initially, students primarily used ChatGPT for homework tasks. However, after participating in the challenge, they expressed a greater likelihood of using ChatGPT alongside product design tools in future projects.

The results suggest that integrating ChatGPT with structured design methodologies can enhance student outcomes, particularly in the ideation phase of engineering projects. The experimental group, which used ChatGPT in conjunction with product design tools, achieved better results across various evaluation criteria than the control group. This indicates that when effectively integrated into the learning process, ChatGPT can be a powerful tool for facilitating creative problem-solving and improving the overall quality of student work.

Our results demonstrate that the key lies in the structured use of ChatGPT within a well-defined pedagogical framework. It positively impacts the enhancement of the student ideation process and project outcomes. By providing clear instructions and combining ChatGPT with established design tools, educators can maximize its educational benefits while minimizing potential drawbacks, such as misuse or over-reliance on AI-generated content.

The statistical analysis conducted in this study, particularly using the Mann-Whitney U Test, revealed no statistically significant differences between the control and experimental groups across the evaluated metrics. However, qualitative observations highlighted notable differences in the creative processes and the quality of solutions developed by the experimental group. These findings underscore the positive impact of integrating ChatGPT as a complementary tool in CBL, facilitating ideation and fostering the development of more innovative and effective solutions. Despite the lack of statistical significance in this study, the observed benefits highlight the potential of ChatGPT to transform how students approach and solve complex engineering problems, paving the way for more innovative and effective educational practices.

By providing clear instructions and combining ChatGPT with established design tools, educators can maximize its educational benefits while minimizing potential drawbacks, such as misuse or over-reliance on AI-generated content

Future research should focus on refining this integration, exploring its applicability in other educational contexts, and addressing the ethical implications of AI use in academic settings. This includes developing comprehensive guidelines and training for students and educators to ensure that ChatGPT is used responsibly and effectively in higher education. Additional product design tools, such as the 6:3:5 method, the morphological matrix, and decision matrices, could be incorporated into the proposed scheme to achieve better results. It is also important to consider increasing the duration of the experiment and altering the timing within the semester when these challenges are conducted, as students are typically overwhelmed with final projects and exams at the end of the semester.

In future iterations, closer interaction with the students will be essential. For instance, a workshop that includes a case study requiring product design tools, where students can use ChatGPT to gather valuable information and identify biases, would be beneficial. Additionally, further research is needed to substantiate these findings based on the results and statistical analysis. Future studies should involve a larger sample size, including more students and groups, to enable more robust data collection for formal statistical analysis. Such studies could explore long-term impacts on learning outcomes and the sustainability of integrating AI tools like ChatGPT into engineering education. Combining quantitative data with qualitative insights from both educators and students would offer a more comprehensive understanding of ChatGPT's role and effectiveness within the CBL methodology.

In general, the main limitations of this study include the small sample size and the relatively short duration of the experiment, which may have restricted the ability to detect statistically significant differences between groups. Additionally, while the evaluation tools were designed specifically for the context of this challenge, they were not formally validated, potentially limiting the generalizability of the findings. Future research should aim to expand the sample size and extend the experiment's duration to capture more robust and sustainable effects. Furthermore, incorporating validated instruments to assess the impact of ChatGPT on learning outcomes rigorously would enhance the reliability of future studies. Another promising avenue for future work involves exploring how different training approaches in using AI tools might influence their effectiveness and perception and evaluating their integration into diverse educational contexts and disciplines.

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