*Journal of Infrastructure, Policy and Development* 2024, 8(14), 9953.
https://doi.org/10.24294/jipd9953

Article

# Scientific research in engineering with the advent of ChatGPT

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**CITATION**

Milla Pino ME, Rodriguez Ordoñez FR, Shimabuku Ysa RA, et al. (2024). Scientific research in engineering with the advent of ChatGPT. Journal of Infrastructure, Policy and Development. 8(14): 9953. https://doi.org/10.24294/jipd9953

**ARTICLE INFO**

Received: 29 October 2024
Accepted: 20 November 2024
Available online: 22 November 2024



**Abstract:** The objective of this work was to analyze the effect of the use of ChatGPT in the teaching-learning process of scientific research in engineering. Artificial intelligence (AI) is a topic of great interest in higher education, as it combines hardware, software and programming languages to implement deep learning procedures. We focused on a specific course on scientific research in engineering, in which we measured the competencies, expressed in terms of the indicators, mastery, comprehension and synthesis capacity, in students who decided to use or not ChatGPT for the development and fulfillment of their activities. The data were processed through the statistical *T*-Student test and box-and-whisker plots were constructed. The results show that students' reliance on ChatGPT limits their engagement in acquiring knowledge related to scientific research. This research presents evidence indicating that engineering science research students rely on ChatGPT to replace their academic work and consequently, they do not act dynamically in the teaching-learning process, assuming a static role.

**Keywords:** artificial intelligence; ChatGPT; teaching-learning; deep learning; research competence; science didactics

## 1. Introduction

Artificial intelligence (AI) is a subject that is currently at the forefront of interest among the topics related to teaching in higher education institutions, since it combines hardware tools, software and programming languages in order to implement deep learning procedures to replace the tasks inherent to human beings.

In the field of AI we find that Shrivastava (2023) points out that globalization has radically altered human society in the last 150 years, hence, the internet of things, energy and cyber-physical systems governed by it, constitute factors that in the framework of conventional education face an immense challenge, since education in the future will be associated with these factors.

In this vein, Alblooshi et al. (2023) developed research with the purpose of identifying the moderating role of AI between leadership skills and business continuity. The findings revealed that AI and leadership skills have a significant impact on business continuity. Furthermore, the findings confirmed the moderating role of AI on the relationship between leadership skills and business continuity.

In this sense, the field of AI proposes alternatives, such as machine learning, pattern recognition, machine intelligence, cognitive computing, expert systems, neural networks, genetic algorithms, fuzzy logic, parallel programming, data mining and

decision trees, oriented to generate human-like capabilities with the purpose of providing elements for decision making.

ChatGPT is an interactive platform that allows searching and obtaining information in any field of knowledge in such a short time that it is not comparable to the time it would take a human being. Hence, although it is true that ChatGPT contains an interface mechanism that guarantees interaction with other search engines to provide a quick and refined response, it is also true that this action is intended to replace and impact learning from a social point of view.

In that line of thinking, Xingzhi et al. (2023) state that the manufacturing industry involves innumerable complex tasks that require significant knowledge and expertise to execute. With the rapid development of artificial intelligence, particularly with the emergence of powerful large language models such as ChatGPT, new opportunities to deliver knowledge through conversation have emerged. With its seemingly infinite knowledge base and highly organized response style, ChatGPT is expected to revolutionize all aspects of the industry.

Society has a permanent dynamic from which a set of needs and problems emerge, and the university is called upon to contribute to society, through the presentation of scientific and technological alternatives aimed at providing solutions to these problems. Under the premise that knowledge generates knowledge, all techniques that facilitate the acquisition of knowledge must be considered.

In this context, the objective of this research was to analyze the effect of the use of ChatGPT in the teaching-learning process of scientific research in engineering. This article is of interest to educators in engineering professions as it sheds light on how artificial intelligence, specifically, ChatGPT affects students' competence in engineering science research.

## 2. Literature review

### 2.1. Digital transformation

In the AI scenario, Sabil et al. (2023) from a study conducted with the objective of identifying strategies for improving human resource management using AI in modern economic development, point out that there is an intersection between AI and human resource management, which suggests analyzing these factors together in order to formulate strategic alternatives for improving modern economic development.

Likewise, Abasaheb and Subashini (2023) express that digital transformation introduces companies to analyze the risks of changing strategic initiatives, adapting to technological advances and expecting AI to revolutionize the workforce of the future by empowering leadership.

In this regard, Albassam (2023) expounds that AI-based recruitment strategies, such as resume screening, candidate sourcing, video interviewing, chatbots, predictive analytics, gamification, virtual reality assessments, and social network screening, offer significant potential benefits for organizations, including increased efficiency, cost savings, and better quality hires. However, the use of AI in hiring also raises ethical and legal concerns, including the potential for algorithmic bias and dis-crimination.

Of note, Liu et al. (2023) note that generative search engines directly generate answers to user queries, along with online citations. A prerequisite feature of a reliable

generative search engine is verifiability, i.e., systems must cite comprehensively (high citation recall; all assertions are fully supported by citations) and accurately (high citation precision; each citation supports its associated assertion). Conducted a human assessment to audit four popular generative search engines: Bing Chat, NeevaAI, Perplexity.AI and YouChat, across a diverse set of queries from a variety of sources (e.g., historical queries from Google users, dynamically collected open-ended questions on Reddit, etc.). We found that existing generative search engine responses are smooth and appear informative, but often contain unsupported claims and inaccurate citations: on average, only 51.5% of the generated sentences are fully supported by citations and only 74.5% of the citations support the associated sentence. We believe these results are disturbingly low for systems that can serve as a primary tool for users seeking information, especially given their façade of reliability.

Similarly, Hu et al. (2023) express that recent advances in natural language processing have opened new possibilities for the development of large language models such as ChatGPT, which can facilitate knowledge management in the design process by providing designers with access to a wide range of relevant information. However, integrating ChatGPT into the design process also presents new challenges.

In this context, Raju et al. (2023) consider that the current version of ChatGPT may be useful in a limited way as a narrative AI chatbot for medical staff; however, researchers are advised to verify all the statements provided, keeping in mind their limitations.

Following this guidance, Siche and Siche (2023) say that ChatGPT adds to the list of AI-based systems designed to perform specific tasks and answer questions by interacting with users (Apple's Siri, Amazon's Alexa, Google's Assistant and Bard, Microsoft's Cortana, IBM's Watson, Samsung's Bixby, among others). ChatGPT works using OpenAI's GPT (Generative Pretrained Transformer) language model and is able to learn from users' preferences and behavior patterns to personalize their response.

## 2.2. Process automation

Regarding the dissemination of research results, it is necessary to note that authors of research articles should use ChatGPT with caution for scientific writing (Fang et al., 2024). In this regard, Suleiman et al. (2024), referring to the peer review process of scientific articles, recognize that ChatGPT is an artificial intelligence platform, whose use is growing rapidly, however, it has generated discussion regarding its possible biases and inaccuracies.

In assessing the ChatGPT's role as a scientific researcher, the capabilities of GPT-3.5 and GPT-4, on four dimensions, specifically, as a research librarian, research ethicist, data generator, and predictor of novel data, using psychological science as the testing ground and the results indicate that GPT is a flawed librarian, a decent ethicist, with the ability to generate data in domains with known characteristics, but poor at predicting novel patterns from empirical data to support future research (Lehr et al., 2024).

Motivated by the rise of ChatGPT, Lindebaum and Fleming (2024) state that many academics are promoting its use to write scientific articles and concern arises

about the type of knowledge it generates; hence it is convenient to reflect as teachers/researchers responsible for academic and professional training about how the absence of self-criticism and self-reflection undermines management capacity. The peer review process is a strategic ally to ensure the quality and integrity of scientific publications, even when editorial policies have included the use of Artificial Intelligence (AI) tools, specifically, the Chat Generative Pre-trained Transformer (ChatGPT), without guidelines for its application by reviewers (Mollaki, 2024).

The benefits and risks of the use of Generative Artificial Intelligence (AI-Gen) in education make it a challenge for educational management and administration. In an evaluation of the scientific production of AI-Gen in the educational area, a bibliometric analysis of descriptive and quantitative documents from the Web of Science database was performed, applying the statistical program VOSviewer to identify keyword clusters and create the network map. The study concludes that more information is required on the use of AI-Gen during the teaching-learning process, in order to prevent plagiarism and obtain a comprehensive understanding of this technology as an educational resource (Dúo-Terrón, 2024).

In a reflection on recent advances in artificial intelligence (AI) technologies, Javanbakht (2024) argues that AI technologies are now capable of summarizing and analyzing large volumes of data, creating presentations and even writing parts of scientific papers with minimal human involvement, and in this sense it is timely to analyze the boundaries between humans and AI, which raises questions about the roles and responsibilities of academic researchers, in the interest of defining intellectual property.

In the context of the generation, evaluation, and implementation of ChatGPT 4, specifically, in the realm of scientific abstracts in a clinical study database, it is concluded that the implementation of AI-generated lay abstracts in ResearchMatch demonstrates the potential for a scalable and generalizable framework to broader platforms to improve research accessibility and transparency (Shyr et al., 2024).

The use of ChatGPT for writing scientific articles has generated pros and cons, with some studies revealing its great potential, while others highlight the negative impacts derived from its use. To minimize the risks while maximizing the positive potential of ChatGPT, a thorough understanding of the appropriate regulations for its use in scientific article writing is needed (Suntoro et al., 2024).

In the academic world there is an ongoing debate about the use and integration of artificial intelligence (AI) technology, specifically ChatGPT, in the context of higher education, hence the need to delve deeper into the advantages and disadvantages of adopting this technological tool (Widyaningrum et al., 2024). In this sense, Al Murshidi (2024) point out that Generative Artificial Intelligence (GAI) promises to improve the educational experience by providing personalized feedback and interactive simulations, but it is convenient to be clear about the challenges that its use represents.

## 2.3. Machine learning/large language models (LLMs)

Scientific workflow systems are becoming increasingly popular for the processing and analysis of complex data sets, as they offer the possibility of being

reproduced for scaling and automation purposes (Sänger et al., 2024). In this context, Fiorillo and Mehta (2024) state that the integrative action of artificial intelligence (AI) mechanisms at the enterprise level constitutes an alternative to improve productivity and efficiency, since it allows the automation of processes, including routine tasks, in order to accelerate responses and thus contribute to timely and accurate decision making.

Among the types of machine learning are Large Language Models (LLMs), which include a wide field of Natural Language Processing (NLP) scenarios. In this context, OpenAI's ChatGPT is a tool capable of automatically generating a single text, which conjugates several topics, synthesizing and restating them, which has originated some controversy in the academic world (Picazo-Sanchez and Ortiz-Martin, 2024). In the area of the integration of IA tools in research practices, Sampaio et al. (2024) discussed consequences and risks associated with authorship, research integrity, methodological limitations and changes in the dynamics of knowledge production, concluding on the need for an in-depth debate on public policies focused on regulating and developing technologies adapted to the different research needs.

In this order of ideas, the use of LLMs has progressively increased since the launch of ChatGPT, because many researchers are motivated to inquire about its scope in the area of scientific research. Likewise, there is evidence of a pronounced decrease in the frequency of queries and statistical coding records, which has an impact on social interactions and consequently on the opportunities for reciprocity (Millard et al., 2024).

Consistent with the above, Schulze Balhorn et al. (2024) note that ChatGPT can possibly comprehend and generate text, hence it is expected to be of great impact on society, through academic research, expressed in terms of its domain-specific response capabilities. In a systematic empirical evaluation of their abilities to answer questions in the domains of natural sciences and engineering, it was found that the ChatGPT response score decreases significantly as the educational level of the question increases and as skills, such as critical attitude, that go beyond the frontier of scientific knowledge are assessed.

Many aspects of everyday life have been revolutionized with the rise of artificial intelligence (AI) and natural language processing (NLP), such is the case of medical research article writing, as AI tools gain space in society, how it may affect the future of medical literature is not measured. Therefore, it is critical to address the barriers related to IL and to address ethical and regulatory issues to improve research quality and scientific output (Hind et al., 2024).

In investigating researchers' knowledge, perceptions, and attitudes toward the use of ChatGPT and other chatbots in academic research, we found that the increasing use of chatbots in academic research requires careful regulation that balances potential benefits with inherent limitations and potential risks (Abdelhafiz et al., 2024).

A large language model is a type of artificial intelligence (AI) model that provides alternatives for practical development, research, and education in healthcare, even as scholars assert that there is an urgent need to address with a proactive approach the complex problem of the consequences of unvalidated and inaccurate information (Gwon et al., 2024).

## 3. Materials and methods

### 3.1. Course selection

A scientific engineering research course was selected, the objective of which was to elaborate a research project, for which knowledge was imparted on the phases, stages and elements of the research process, with emphasis on the conception phase, specifying the stages of choosing the topic and design of the research. The construction of the project required a search for international, national, regional and local information that would allow the contextualization of the situation under study and the definition of the state of the art in order to adequately structure the research design.

This course develops the contents, title, problem statement and hypothesis, formulation of the general and specific objectives, conceptual framework and methodology, including type and design of research, population, sample and sampling, methods, techniques and instruments for data collection and data analysis.

The reasons why this course was chosen are the following: the search for scientific information in databases such as Scopus, Web of Science, SciELO and Latindex, among others, is required; in addition to the technical and scientific writing of documents containing title, problem, hypothesis, objectives, methodology, schedule and budget. Therefore, this course is an appropriate scenario to explore the use of technological tools, such as ChatGPT, to facilitate the performance of the assigned tasks, both at the level of consultation of scientific production, as well as report writing.

### 3.2. Study and control group

In a course related to scientific engineering research, students were free to use or not to use the ChatGPT tool, the condition was that they had to inform their decision at the beginning of the course, thus defining the study group (ChatGPT user) and the control group (non ChatGPT user). Each group was made up of ten students.

The students enrolled in the scientific research course, which is taught in the eighth semester of the engineering profession, are aged between 20 and 23 years, 60% male and 40% female, with an average of 4.5 years in higher education, have passed specialty courses where solutions to engineering problems are designed and developed, as well as, they use information search tools, such as, Google and ChatGPT.

It should be noted that the students who decided to use ChatGPT received an induction on the scope of this tool, as well as on the advantages and disadvantages of its use in the field of scientific research. In addition, they were taught to define the canonical search equation and the filters required to obtain information related to the problem under study.

In order to mitigate the risk of information exchange between groups, each student addressed a different problem, inter- and intra-group, and was advised by a specialist in the corresponding scientific area.

### 3.3. Pre-test and post-test

At the beginning of the course (pre-test) and at the end of the course (post-test), competencies in the presentation of the subject matter were measured, including indicators such as mastery, comprehension and synthesis capacity.

Mastery measures the knowledge and handling of the topic addressed in the research, which guarantees fluency in the transmission of information in a clear, concise and precise manner.

Comprehension measures the contextualization of the topic under study, identifying and/or delimiting the scientific areas that are directly and indirectly connected to the research objective. In this sense, it specifies the multi-, inter-, trans- and multi-disciplinary approaches of the science.

The synthesis capacity measures the elaboration of a concrete idea from the knowledge and/or knowledge generated, which can be obtained through the analysis and interpretation of common and uncommon elements, organized in a sequential and systematic way.

## 3.4. Variables measured

The indicators of mastery, comprehension and synthesis capacity were measured on a vigesimal scale and each represented one third of the competence variable.

The response variable measured in the research was the competence in the elaboration of a research project, acquired during the scientific research course. This methodological competence covers the structure of the research, since in it coexist knowledge, attitudes, abilities and skills required as fundamental elements for the conception of a research project.

The professor who teaches the course on scientific research in engineering was responsible for the evaluation. For this purpose, he applied a rubric that included for the mastery indicator, level and scope of knowledge, truthfulness of the information, ease of expression and precision in the exposition. For the comprehension indicator, contextualization of the topic and identification and/or delimitation of scientific areas directly and indirectly related to the objective. Regarding the synthesis capacity indicator, analysis and interpretation and organization in a sequential and systematic manner were considered.

The rubric was subjected to a validation process through expert judgment, which allowed making the respective adjustments and then a pilot test was conducted, which generated the necessary information for the application of Cronbach's Alpha Reliability Coefficient, given the ordinal measurement scale of the competence variable, obtaining a value equal to 0.94, which reflects a high reliability.

## 3.5. Statistical analysis

The data were subjected to a test for related samples in the intragroup case and a test for in-dependent samples in the intergroup case. The test statistic was t-student and Statistix V.8 soft-ware was used.

The information obtained from the application of the pre-test and post-test to the two groups was organized through a matrix structure for processing, analysis and interpretation. In addition, to facilitate the understanding of the results, box and whisker plots were prepared, which harmoniously combine the measures of central tendency, dispersion and position, which allow describing the behavior of the situation under study.

### 3.6. Conceptual framework

The research begins with the selection of a course that will serve as a pilot, in this case the scientific research course. Then, among the students enrolled in the course, two groups are defined, those who will use ChatGPT as a tool to develop the assigned activities (study group) and those who will not use ChatGPT (control group), i.e., they will apply traditional techniques. The decision to use or not to use ChatGPT is the student's responsibility. At the beginning of the course an exam (pre-test) is applied to both groups, the contents established in the syllabus are taught during the academic cycle and at the end an exam (post-test) is applied. The instruments applied are intended to measure the variable response competence, which is expressed by the indicator's mastery of the subject, comprehension of the subject and synthesis capacity. The information recorded for each of the groups is subjected to a hypothesis test to decide which group obtained greater competence in scientific research.

The scheme shown in **Figure 1** represents the logical sequence of stages developed, which constitutes the conceptual framework that supports the research design.

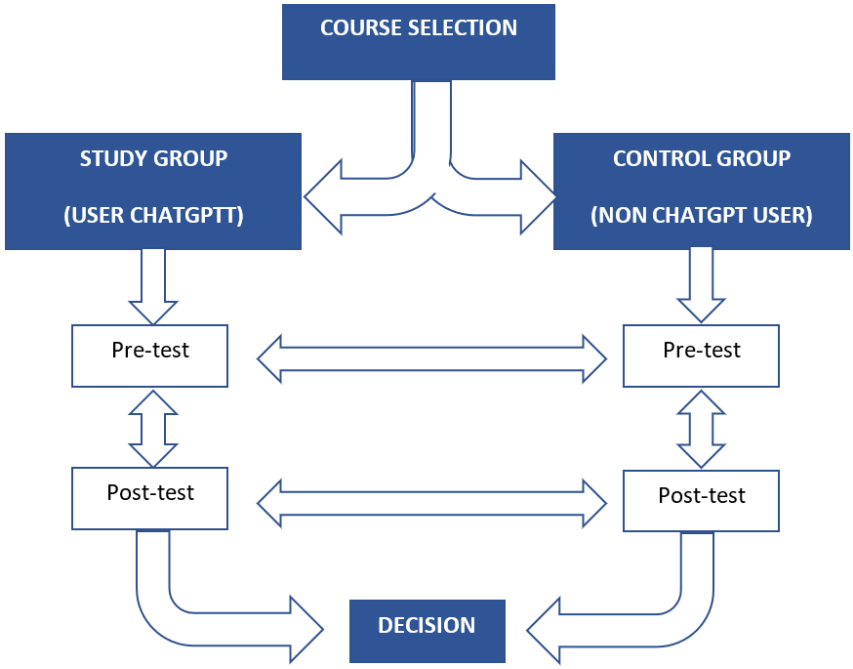


**Figure 1.** Conceptual framework.

### 3.7. Limitations

The scientific research in engineering course selected for this work had a total of 20 students enrolled, which allowed the formation of 2 groups of 10 students each.

## 4. Results

The analytical and graphical results of the application of the statistical tests for related samples (within-group) and independent samples (between-group) are presented below. The statistical test used was the t-student test due to the unknown population variance and samples smaller than 30.

## 4.1. Statistical test

The analytical results of the application of the t-student test for related samples (**Table 1**) and for independent samples (**Table 2**) are presented below.

**Table 1.** Comparison within each group (intragroup).

| **Group** | ***T*-Student Test** | | **Remarks** |
|---|---|---|---|
| | ***T*** | ***P*-value** | |
| Study | 0.25 ns | 0.8114 | No significant differences |
| Control | 10.16 ** | 0.0000 | There are highly significant differences |

ns: not significant ($P > 0.0500$).
*: significant ($P < 0.0500$).
**: highly significant ($P < 0.0100$).

**Table 2.** Comparison between groups (intergroup).

| **Moment** | ***T*-Student test** | | **Remarks** |
|---|---|---|---|
| | ***T*** | ***P*-value** | |
| Pre-test | −0.17 ns | 0.8685 | No significant differences |
| Post-test | −6.08 ** | 0.0001 | There are highly significant differences |

ns: not significant (P > 0.0500).
*: significant (P < 0.0500).
**: highly significant (P < 0.0100).

## 4.2. Graphical representation

Box-and-whisker plots generated from the study group (CE) pre-test and post-test (**Figure 2**), control group (CC) pre-test and post-test (**Figure 3**), study group vs. control (CA) pre-test (**Figure 4**) and study group vs. control (CD) post-test (**Figure 5**) are presented below.

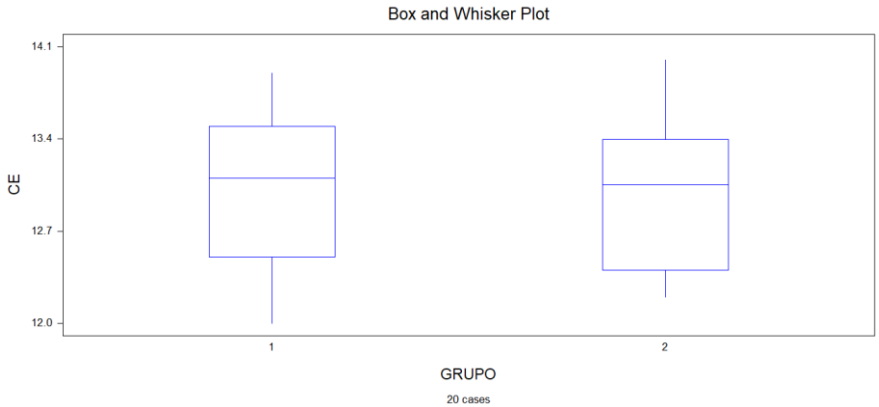


**Figure 2.** Box-and-whisker plot of study group (CE) competencies at baseline (1) and endline (2).

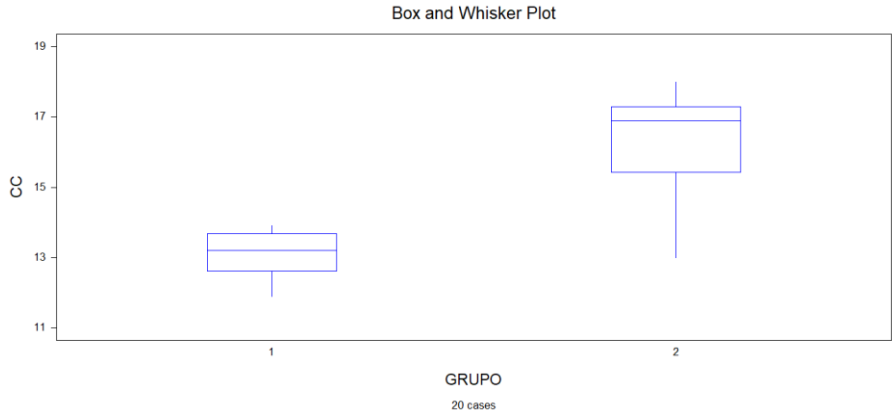


**Figure 3.** Box-and-whisker plot of the competencies of the control group (CC) at baseline (1) and at the end (2).

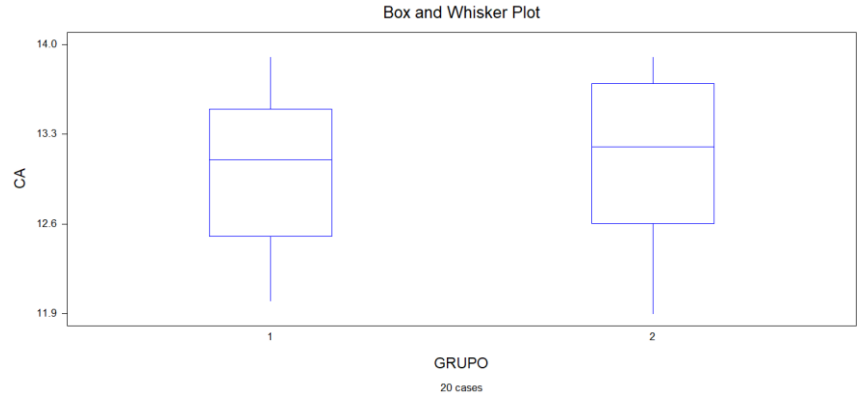


**Figure 4.** Box-and-whisker plot of the competencies of the study (1) and control (2) groups at the beginning of the course (CA).

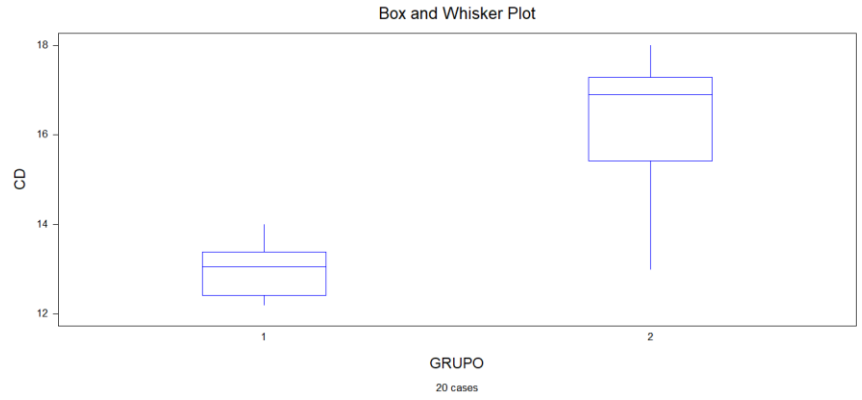


**Figure 5.** Box-and-whisker plot of the competencies of the study (1) and control (2) groups at the end of the course (CD).

## 5. Discussion

With respect to the comparison between the measurements taken at the beginning and at the end in each group (**Table 1**), the study group did not present significant statistical differences, while in the control group there were highly significant statistical differences. This can be observed, since for the study group a value of $t$ = 0.25 was obtained with a probability $P$ = 0.8114, which indicates that it is not

significant, while for the control group a value of $t$ = 10.16 was found with a probability $p$ = 0.0000, which translates as highly significant.

In this sense, we can point out that using ChatGPT had no effect on the competencies, and the traditional learning strategy allowed improving the competencies, which was reflected in a greater mastery, comprehension and synthesis capacity, aspect that reinforce the findings of Fang et al. (2024) and Lindebaum and Fleming (2024) who point out that caution should be exercised when using ChatGPT for scientific writing, although many academics are promoting its use for writing scientific papers.

Regarding the comparison between the measurements made in each group at the beginning (**Table 2**), no significant statistical differences were observed, but in the final measurement highly significant statistical differences were evidenced. This is evidenced by the fact that for the pre-test a value of $t = -0.17$ with a probability $P$ = 0.8685 was obtained, which indicates that it is not significant, but not so for the post-test, which showed a value of $t = -6.08$ with a probability $P$ = 0.0001, which is highly significant.

In this context, it is appropriate to state that the groups started with a similar level of competence; however, at the end, the members of the control group obtained higher scores, which means that using traditional tools improved the mastery, comprehension and synthesis capacity, which positively impacts the competence. This may occur due to what was expressed by Suleiman et al. (2024) when referring to the possible biases and inaccuracies generated by ChatGPT.

In **Figure 2**, it can be observed that the study group (CE) evidenced similar behavior in the pre-test and post-test results, since both the measures of central tendency and dispersion present uniform values, which leads to affirm the non-existence of significant statistical differences, indicating that using ChatGPT did not improve the evaluated competencies. This may be due to the fact that since artificial intelligence technologies have the capability to write scientific papers with minimal human involvement, students transfer that task to ChatGPT and are not involved in the cognitive process, as expressed by Javanbakht (2024).

In **Figure 3**, it can be seen that the control group (CC) generated a different behavior in the pre-test and post-test results, since both the measures of central tendency and dispersion present non-uniform values, which leads to think that there are significant statistical differences, indicating that using traditional techniques improved the evaluated competencies.

In **Figure 4**, shows that the study group (CE) and the control group (CC) behave in the same way with respect to the results obtained in the pre-test, since the measures of central tendency and dispersion present uniform values, which allows us to express that there are no significant statistical differences, indicating that both groups started the course and therefore the research with the same level of competencies.

In **Figure 5**, it can be observed that the study group (CE) and the control group (CC) behave differently with respect to the results obtained in the post-test, since the measures of central tendency and dispersion present non-uniform values, which indicates that there are significant statistical differences, indicating that the control group obtained higher scores than the study group, indicating that using ChatGPT had no favorable effect on the competence evaluated in the present investigation.

The results obtained in this research reflect the need for a deep reflection on the incorporation and use of technological tools from artificial intelligence (AI) in the field of scientific research, specifically ChatGPT, since the debate should focus on the strengths and weaknesses, but also on the regulatory aspects that would regulate its use. In this context, the reality indicates that students think that ChatGPT came to replace their work and consequently destroy the myth that scientific research involves very complex processes. This analysis reflects that indicated by Schulze Balhorn et al. (2024) that in the natural sciences and engineering ChatGPT responses decrease significantly as the educational level of the inquiry increases.

In this order of ideas, it is necessary to regulate the use of ChatGPT, which implies specifying which aspects within the scientific research process can be carried out with the help of this tool, without jeopardizing the originality and intellectual authorship of the documents. Therefore, it is appropriate to point out that higher education institutions should define the regulatory framework for the use of ChatGPT as part of the institutional academic management strategic policy. Hence, it is necessary to understand that there is an urgent need to regulate the use of ChatGPT in the context of scientific research (Suntoro et al., 2024).

The above leads us to think that ChatGPT should be assumed as a strategic ally to achieve mastery of the subject, understanding of the subject and the ability to synthesize, which are elements that are an integral part of competence in scientific research, but we should not delegate our responsibility as generators of scientific knowledge.

## 6. Conclusion

Evidence indicates that engineering science research students rely on ChatGPT to replace their academic work and consequently, do not act dynamically in the teaching-learning process, assuming a static role.

**Author contributions:** Conceptualization, MEMP and FRRO; methodology, MEMP and RASY; software, DMJL and BACC; validation, MEMP, MMTC and ABFJ; formal analysis, RASY and FRRO; investigation, MEMP, FRRO, RASY, DMJL, MMTC, BACC and ABFJ; resources, MEMP and DMJL; data curation, BACC and MMTC; writing—original draft preparation, MEMP and FRRO; writing—review and editing, RASY and ABFJ; visualization, DMJL and BACC; supervision, MEMP; project administration, FRRO; funding acquisition, MEMP. All authors have read and agreed to the published version of the manuscript.

**Conflict of interest:** The authors declare no conflict of interest.

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