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Using ChatGPT to Improve Learning in Applied Statics for Construction Engineering Students

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Abstract
A profound understanding of structural concepts is crucial in the education of construction engineers. It enables the analysis and prediction of structural behavior under various conditions. The Applied Statics course plays a pivotal role in laying the foundational principles for structural analysis; however, students often encounter significant challenges mastering these concepts, which impacts their academic and professional development. An exploratory mixed-methods approach was used, combining surveys and classroom activities. Data were collected from 32 Construction Engineering students enrolled in the Applied Statics course during the spring 2024 semester at a private university in Chile. Surveys were administered at three stages—beginning, after AI-mediated activities, and end of semester—capturing students' perceptions of ChatGPT's integration. The study demonstrates that ChatGPT was positively perceived as a complementary learning tool, helping students clarify doubts, reflect on errors, and strengthen critical thinking. Over the semester, students developed greater confidence in the tool, valuing its support for creative problem-solving. Furthermore, the study revealed an increased ethical awareness regarding the responsible use of AI, emphasizing the importance of proper citation and institutional ethical guidelines. Future research should explore the long-term impact of AI tools on key skills, learning outcomes, and critical thinking, supported by structured integration frameworks, ethical training, and comparative studies with traditional methods across diverse educational settings.
Keywords: Applied statics, ChatGPT, engineering education, critical thinking, artificial intelligence, ethics, construction

Introduction

The construction sector in Chile plays a central role in the economy and society, establishing itself as one of the fundamental pillars of national development. In 2023, its contribution to the Gross Domestic Product (GDP) reached a notable 6%, highlighting its significance as a driver of economic activity. Additionally, the sector accounted for an impressive 63% of total aggregate investment, solidifying its position as a key engine for sustainable economic growth and development in the country [1]. On a global scale, the potential impact of generative artificial intelligence on the construction sector is estimated to range between 0.8% and 1.3% of the industry's total revenues, with an annual economic contribution projected at $90 to $150 billion. These technologies promise to optimize key processes such as research and development, structural design, and logistics, which are critical to improving efficiency and sustainability in construction projects [2].
The Construction Engineering degree is essential for the sustainable and efficient development of urban and transportation infrastructure projects and building projects for diverse uses such as residential, commercial, industrial, educational, and healthcare purposes. These projects demand a robust technical and practical knowledge foundation that enables the design, planning, and execution of constructions that address societal needs while respecting the environment. Within this context, the Applied Statics course is included in most Construction Engineering programs due to its fundamental role in developing competencies related to the analysis and design of structures [3]. This course introduces students to the study of loads acting on structures and the supports that provide stability, enabling them to

understand how to ensure construction systems' equilibrium, strength, and stability. Mastery of these principles is crucial for addressing the technical challenges involved in the safe and efficient execution of building and infrastructure projects [4].

Understanding these concepts is critical for construction engineers, as they apply to multiple real-world scenarios inherent to the sector. A solid foundation in these principles is indispensable to ensure that projects meet standards of quality, safety, and efficiency, which are vital for the professional performance of engineers. However, Construction Engineering students often face significant challenges in grasping the concepts of Applied Statics [5]. These difficulties are reflected in their struggles to analyze and solve structural problems, a key competency in their training. The lack of understanding of these concepts not only impacts students' academic performance, leading to low grades and course repetition but also compromises their future professional capacity to evaluate the behavior and execution of structures effectively.

Several factors contribute to learning challenges in the academic setting. Traditional teaching methods often limit active student participation, hindering meaningful learning. Additionally, the lack of interactive and personalized educational resources poses another significant obstacle to students' comprehension and application of key concepts. To address these issues, the use of artificial intelligence (AI) tools in engineering classrooms has proven effective. These tools help students understand complex theories, simulate real-world scenarios, and solve practical problems [6].

From a cognitive perspective, the abstract and mathematical nature of concepts like those in Applied Statics presents significant barriers for students. Recent studies emphasize that tools such as ChatGPT can serve as allies in understanding complex ideas and developing problem-solving skills [7].
The integration of AI technologies, such as ChatGPT, into the educational process, has shown a positive impact on the dynamic and personalized interaction between students and content. These tools enable learners to resolve doubts and improve their understanding through clear examples and detailed explanations [8]. ChatGPT, developed by OpenAI, is an advanced generative model that processes large volumes of data to provide responses in a conversational format. Its ability to solve complex problems, generate code in various programming languages, and support educational tasks makes it an innovative technology in the academic field [9].

Nevertheless, the incorporation of tools like ChatGPT also raises ethical and pedagogical challenges. Among the main concerns are the potential for technological dependency, which could limit critical thinking and creativity, and the need for constant supervision to ensure the quality and accuracy of the generated information [10]. However, when implemented in a balanced manner, ChatGPT can become a valuable resource for fostering student autonomy and motivation, improving their academic performance and content comprehension [11].

Considering the above, this research aims to analyze students' perceptions of the incorporation of ChatGPT into their learning processes, specifically in the Applied Statics course. By doing so, it seeks to provide a stronger foundation for the integration of AI into the teaching of technical disciplines in engineering programs from the student's perspective.

Methodology

This study employs an exploratory approach and utilizes a mixed-methods methodology, combining quantitative and qualitative methods to gain a comprehensive understanding of students' perceptions regarding the use of ChatGPT as a complementary resource in their learning of Applied Statics.
The sample consists of students enrolled in the Applied Statics course during the spring semester of 2024, part of the Construction Engineering program at a private university in Chile. Surveys were administered at three key stages to collect data: at the beginning of the semester, after each activity involving ChatGPT, and at the end of the course [12-13]. These surveys aimed to capture students' opinions on integrating this tool into their learning process.

Throughout the semester, classroom interventions were implemented, specifically designed for students to use ChatGPT to solve certain types of questions and problems. These activities were planned to be carried out in groups, fostering discussion and reflection among the students. As part of the process, problems were initially solved using traditional methods, followed by addressing the same questions with the support of ChatGPT. The activities were designed to stimulate both collaborative learning and critical thinking, enabling students to compare the effectiveness of traditional approaches and the use of ChatGPT as an educational tool.

A. Participants. The participants were 32 students enrolled in the Applied Statics course within the Construction Engineering program at a private university in Chile. The characterization survey revealed that the sample consisted of students aged 19 to 26, with the majority (81.3%) between the ages of 19 and 22. Among the participants, 31 were male and only one was female. A total of 75% of the students were in their fourth semester, corresponding to the semester when the course was offered, while the remaining students were delayed from more advanced semesters.
Regarding their employment status, 37.5% were part-time workers, and the rest were full-time students. Regarding technology use, smartphones were the most used device (93.8%), followed by laptops/notebooks (78.1%). Tablets (34.4%) and desktop computers (31.3%) showed lower adoption rates.
Among the participants, 97% had used ChatGPT. Most of them utilized it for assignments or projects (84.4%), as well as for personal matters (46.9%) and out of curiosity (43.8%). A smaller percentage used it for exams (15.6%) or other purposes (9.4%). Additionally, 67.5% agreed that ChatGPT is easy to use, 28.1% had a neutral opinion, and 6.3% disagreed with its ease of use. Furthermore, 87.5% of the participants reported not receiving formal training in artificial intelligence. Among those who had, YouTube videos were the most common resource (18.8%), followed by expert talks on AI (6.3%). No participants reported attending formal courses, seminars, or university classes. Most students (87.5%) expressed interest in using AI tools as part of their coursework.

B. Context. The Applied Statics course is offered in the fourth semester of the Construction Engineering program, which currently has a total student population of 198, with women comprising 10% of the enrollment. The course requires prior approval of the Introduction to Mechanics course. It serves as a foundation for subsequent coursework, such as Structural Analysis, making it a critical curriculum component. The course's primary objective is to develop skills in the analysis and calculation of isostatic structures, with an emphasis on applying fundamental principles of material strength, mechanical equilibrium of rigid bodies,

and calculation of internal forces in structural members. Upon completion of the course, students are expected to:

1. Apply the fundamentals of material strength to structural elements.
2. Use equilibrium equations for solids subjected to external forces.
3. Calculate stresses, deformations, and internal forces in simple structures.

The course methodology includes lectures-based classes, practical exercises, and written evaluations, fostering quantitative scientific reasoning and analytical skills to address the problems specific to Construction Engineering.

D. Procedure. Table 1 provides details of the instruments and activities conducted during the study, indicating the specific weeks of the semester in which they were implemented.

Table 1. Timeline of activities and assessments incorporating ChatGPT in the applied statics course.

Time of the semester	Content	Week of the semester (out of 17)
Beginning	Characterization survey	Week 5
Activity 1	Topic: Analysis of distributed loads, idealization of supports, and calculation of beam reactions. Part 1: Traditional method Part 2: Using ChatGPT	Traditional method: Week 9 Using ChatGPT: Week 10
Activity 2	Topic: Analysis and representation of shear and moment diagrams in beams. Part 1: Traditional method Part 2: Using ChatGPT	Traditional method: Week 14 Using ChatGPT: Week 15
Final	Collection of student perceptions, reflections, and recommendations regarding using ChatGPT.	Week 17

C. Instruments and Activities

The instruments applied in this study are described below:

- *Initial survey:*
  This survey aims to gather information about students' perceptions regarding the use of Artificial Intelligence (AI) tools, particularly ChatGPT, in the learning process for the Applied Statics course. The survey is structured into three categories: Perception of AI Tools, Critical Thinking, and Ethics. It includes personal characterization questions (age, gender, occupation, etc.), Likert scale options to measure attitudes and perceptions, and open-ended questions to allow students to express their opinions.
- *Intermediate practical activities:*
  Two practical activities were conducted, described as follows:
  - Activity 1:
    This activity aims to combine theoretical and practical concepts in analyzing distributed loads, support idealization, and calculating reactions in beams, using ChatGPT as a complementary tool to reinforce learning.
    Structure:
    1. First Part: Students answer theoretical questions and solve practical exercises traditionally (manually) using a calculator.

2. Second Part: The same exercises and questions are input into ChatGPT to compare results, reflect on the generated responses, and validate the calculations obtained.

The activity includes Likert scale questions to evaluate students' perceptions of ChatGPT's usefulness in problem-solving and open-ended questions to identify differences between manual and AI-assisted calculations, advantages and disadvantages of using ChatGPT, and its potential to complement or replace traditional methods.

- Activity 2:
  This activity aims to combine theoretical and practical concepts in analyzing and representing shear and moment diagrams in beams, integrating ChatGPT as a complementary tool in the learning process. The structure in this activity was identical to those in Activity 1.

- *Final Survey:*
  Similar to the initial survey, this survey's objective is to collect information about students' perceptions of using AI tools, particularly ChatGPT, in the learning process for the Applied Statics course. The survey is structured into three categories: Perception of AI Tools, Critical Thinking, and Ethics. It includes Likert scale questions to measure perceptions and open-ended questions for students to express their reflections and provide recommendations based on their experiences.

*E. Results analysis and ethical considerations***.** The results were analyzed using statistical tools in MS Excel to synthesize and visualize the collected data effectively. Regarding the ethical considerations of the research, strict adherence to ethical guidelines applicable to the educational context was maintained. All participants were thoroughly informed about the study's purpose, objectives, and scope. Confidentiality was ensured by using anonymous identifiers and securely storing all information. Additionally, written informed consent was obtained, guaranteeing that participants understood their right to withdraw from the study at any time without any consequences.

Results

The results of this study are presented based on the skills targeted by the research. First, the students' characterization is described in detail. Next, the initial and final semester results related to critical thinking and ethics are outlined. Following this, the findings from the surveys conducted during activities mediated with and without ChatGPT are presented. Finally, the specific results from the final perception questions regarding the use of ChatGPT are discussed.

Student characterization

An initial characterization survey was conducted to gather data on participants' age, gender, academic level, occupation, use of technological devices, AI-related training, and experience with AI-based tools such as ChatGPT. This data provided a detailed profile of the participants, highlighting their main characteristics and level of exposure to innovative technologies and educational tools.

Nearly half of the participants (46.9%) reported feeling familiar with AI-based tools like ChatGPT. Conversely, 18.7% indicated being less familiar, while 34.4% adopted a neutral stance. Most participants (65.7%) found ChatGPT easy to use, with only 6.3% expressing difficulty and 28.1% maintaining a neutral opinion. This suggests a generally positive perception of ChatGPT's ease of use. Moreover, most participants (75%) believed that AI-based tools like ChatGPT could be integrated into the educational process to support both

instructors and students. The remaining 25% held a neutral position, and no participants expressed disagreement. These results reflect a predominantly positive perception of the educational potential of such tools.

During this characterization phase, an open-ended question was posed: *"What do you hope to learn or improve by using ChatGPT in the Applied Statics course?"* The students' responses were categorized into emerging themes derived from the analysis, accompanied by examples of their answers (Table 2).

Table 2: Emerging categories of student perceptions on ChatGPT use in applied statics.

Categories emerged (frequency)	**Description (an example of response)**
Tool to enhance learning and understanding (22)	Most students perceive ChatGPT as a tool to reinforce their learning, improve their understanding of theoretical concepts, and address specific doubts about the subject. They also highlight its usefulness for complementing independent study and facilitating the development of exercises. *"I hope it helps me resolve doubts and serves as a resource in case I can't understand a study exercise."*
Exploration of methods and procedures (6)	Some students express interest in using ChatGPT to learn new ways to solve problems, automate procedures, and improve accuracy in specific calculations. They see the tool as an opportunity to explore alternatives to traditional methods. *"Maybe learn simpler methods or automate operations that help me better understand and complete the exercises."*
Limitations and skepticism about its use (4)	A smaller group of students expressed doubts or rejection about using ChatGPT in this subject. They mentioned concerns such as the potential loss of traditional skills or questioned its suitability for this context. *"I'm not sure if it's a tool for Applied Statics since, in this subject, we need to handle professional-level calculations that require a more human responsibility."*

Critical Thinking

The survey results conducted at the beginning and end of the semester (Tabs. 3 and 4) are presented below. The following tables compare student perceptions of ChatGPT's impact on critical thinking at the beginning and end of the semester. These results provide insights into how students' views evolved after experiencing ChatGPT's integration into the Applied Statics course.

Table 3. Student perceptions on critical thinking related to ChatGPT at the beginning of the semester.

Critical thinking- Beginning of the semester			
Question	**Disagree**	**Neutral**	**Agree**
ChatGPT should be integrated as a learning resource for the course Applied Statics	15.6%	21.9%	62.5%
ChatGPT inhibits students' critical thinking	34.3%	43.8%	21.9%
Dependence on ChatGPT discourages problem-solving and creativity	34.4%	34.3%	31.3%
ChatGPT is an unreliable source of knowledge - I don't trust it	53.1%	40.6%	6.3%

Comparing the results from the beginning of the semester (Table 3) with those at the end (Table 4) reveals a shift in students' perceptions. Notably, there was an increase in agreement

that ChatGPT serves as a valuable learning resource and a decrease in concerns about its potential to inhibit critical thinking or problem-solving skills. The inclusion of questions related to creativity and reflective thinking at the end of the semester highlights additional dimensions of students' experiences with ChatGPT.

Table 4. Student perceptions on critical thinking related to ChatGPT at the end of the semester.

Critical thinking- End of the semester			
Question	**Disagree**	**Neutral**	**Agree**
ChatGPT should be integrated as a learning resource for the Applied Statics course	9.1%	18.2%	72.7%
ChatGPT inhibits students' critical thinking	15.2%	42.4%	42.4%
Dependence on ChatGPT discourages problem-solving and creativity	18.2%	33.3%	48.5%
ChatGPT is an unreliable source of knowledge - I don't trust it	42.4%	42.4%	15.2%
Using ChatGPT allowed me to reflect on the solutions rather than just accepting the generated answer	0.0%	21.2%	78.8%
ChatGPT stimulated my ability to generate creative ideas in academic tasks	9.1%	18.2%	72.7%

Additionally, the following open-ended question was posed: *"How do you think ChatGPT could influence or is influencing the way you approach problem-solving in your studies?"* Below are the students' responses, categorized into emerging themes derived from the analysis, along with examples of their answers (Table 5).

Table 5. Emerging categories of student perceptions of ChatGPT's influence on problem-solving.

Categories emerged (frequency)	**Description (an example of response)**
Positive influence (17)	These responses highlight the benefits of using ChatGPT as a complementary tool. Students emphasize its usefulness in resolving doubts, broadening perspectives, and facilitating learning, which aids in understanding the subjects. *"From my experience, it has helped me study by giving me more options to approach problems and clarify doubts."*
Mixed influence (9)	These responses acknowledge the benefits of ChatGPT but warn about potential limitations, such as the risk of dependency or the possibility of incorrect responses, stressing the need to verify and supplement it with other reliable sources. *"I personally consider it as a second opinion in many cases. However, it depends on how the question is phrased and verifying the answers, as sometimes they may not be entirely correct."*
Limitations and challenges (6)	These responses express concerns about ChatGPT's negative impact, such as reduced creativity, excessive dependency on the tool, or a lack of development in cognitive skills like reasoning and independent problem-solving. *"I think negatively, as there are cases where it helps me, but I feel that if I use it too much, I will stop understanding and being able to do the exercises on my own."*

Ethics

Regarding ethical issues, the initial survey (Table 6) revealed that the majority of respondents recognize plagiarism as a form of academic dishonesty (81.3%) and agree that copying and pasting material without referencing its source is considered plagiarism (65.7%). Additionally, 68.8% agree that using ChatGPT to produce academic writing without properly citing its use constitutes plagiarism, demonstrating a clear understanding of the need to acknowledge its utilization. Furthermore, 71.9% believe that plagiarism involving ChatGPT can be detected by instructors through specialized software.

On the other hand, a significant percentage (87.5%) consider that ChatGPT should complement and enrich their research and writing but not replace the assigned work. However, 46.9% disagree that submitting assignments generated by ChatGPT without referencing them is not a problem. This reflects that most participants value academic ethics and the responsible use of this tool.

Table 6. Student perceptions on academic ethics and plagiarism related to ChatGPT at the beginning of the semester.

Ethics- Beginning of the semester			
Question	**Disagree**	**Neutral**	**Agree**
Plagiarism is a form of academic dishonesty because it involves presenting someone else's work as your own without giving credit to the original author or source.	3.1%	15.6%	81.3%
Copying and pasting material from various sources without referencing where it comes from is plagiarism.	9.3%	25.0%	65.7%
Using ChatGPT to produce academic writings without properly citing the source would be considered plagiarism.	12.4%	18.8%	68.8%
Plagiarism with ChatGPT can be detected by my instructor using special plagiarism detection software.	9%	18.8%	71.9%
ChatGPT should be used to complement and enrich my own research and writing, not to complete the assignments given to me.	0%	12.5%	87.5%
It's not a big deal if I submit assignments using text generated by ChatGPT without referencing it.	46.9%	43.7%	9.4%

Table 7. Student perceptions on academic ethics and ChatGPT at the end of the semester.

Ethics- End of the semester			
Question	**Disagree**	**Neutral**	**Agree**
Plagiarism is a form of academic dishonesty because it involves presenting someone else's work as your own without giving credit to the original author or source.	0.0%	6.1%	93.9%
Copying and pasting material from various sources without referencing where it comes from is plagiarism	0.0%	12.1%	87.9%
Using ChatGPT to produce academic writings without properly citing the source would be considered plagiarism	6.1%	15.2%	78.7%
Plagiarism with ChatGPT can be detected by my instructor using special plagiarism detection software	0.0%	15.2%	84.8%
ChatGPT should be used to complement and enrich my own research and writing, not to complete the assignments given to me	0.0%	6.1%	93.9%

It's not a big deal if I submit assignments using text generated by ChatGPT without referencing it	48.4%	27.3%	24.3%
The university should establish clear policies on the use of AI tools such as ChatGPT	12.1%	27.3%	60.6%
Students should receive formal training on the ethical use of artificial intelligence tools such as ChatGPT	3.0%	12.1%	84.8%

The final survey on ethics (Tab. 7) revealed a heightened awareness among students regarding the responsible use of ChatGPT and its ethical implications. A significant majority (93.9%) agreed that plagiarism is a form of academic dishonesty and recognized that copying material without proper citation is unethical (87.9%). Additionally, 84.8% believed that plagiarism involving ChatGPT could be detected using specialized software, indicating a general understanding of accountability in academic work.
Importantly, most students (93.9%) agreed that ChatGPT should be used to complement and enrich research and writing rather than replace assigned work. However, 48.4% disagreed with the notion that submitting assignments generated by ChatGPT without citation is acceptable, showcasing a strong commitment to academic integrity.
The survey also highlighted students' expectations for institutional guidance: 60.6% agreed that universities should establish clear policies on AI tool usage, and 84.8% emphasized the importance of receiving formal training on the ethical use of AI tools like ChatGPT. These results underscore the need to integrate AI ethics into educational frameworks to ensure responsible adoption of emerging technologies.

Open-ended questions

The following open-ended question was posed: *"What measures do you think should be taken to ensure the responsible use of ChatGPT by students?"* (Table 8) presents the students' responses, categorized into emerging themes derived from the analysis, along with examples of their answers.

Table 8. Emerging categories of suggested measures for ensuring responsible use of ChatGPT by students.

Categories emerged (frequency)	**Description (an example of response)**
Training and promotion of responsible use (22)	These responses suggest implementing training sessions that promote the proper and ethical use of ChatGPT, emphasizing the need to cite sources, use it as a support tool, and avoid overreliance. *"Provide courses that generate knowledge about the use of AI and its responsible application."*
Supervision and regulation (6)	These responses propose establishing control measures, such as direct supervision by instructors and implementing technological tools, like plagiarism detection software. The goal is to ensure proper use of ChatGPT, prevent misuse, and maintain academic integrity. *"Supervise students and use software to identify improper use of AI in tests or exams."*
Restriction on use (4)	These responses advocate for restricting or limiting the use of ChatGPT in specific situations, mainly to prevent plagiarism and ensure the authenticity of academic work and evaluations. *"A measure that could be taken might be limited use for students or for certain assignments."*

Results on student perceptions of classroom experiences conducted traditionally and mediated with ChatGPT

In Activities I and II, closed-ended questions were formulated to assess students' perceptions of the use of artificial intelligence tools like ChatGPT in solving Applied Statics problems. These questions aimed to identify levels of acceptance, trust, and perceived usefulness in learning, providing a quantitative perspective on the integration of this tool in an academic context.

Table 9 presents the results of students' responses to a series of statements regarding the use of ChatGPT as a learning tool in the context of the Applied Statics course. These statements were evaluated across two activities (Activity I and Activity II), with responses categorized into three groups: "Disagree," "Neutral," and "Agree." The percentages represent the distribution of responses in each activity, enabling a comparison of changes in students' perceptions between the two instances.

Table 9. Student perceptions of ChatGPT as a learning tool in applied statics (activity 1 and activity 2).

	Disagree		**Neutral**		**Agree**	
Question	**D A1**	**D A2**	**N A1**	**N A2**	**A A1**	**A A2**
ChatGPT was helpful in correcting errors in my manual calculations	5.7%	0%	17.1%	21.9%	77.2%	78.1%
ChatGPT improved my understanding of solving problems in Applied Statics	5.7%	3.1%	25.7%	25.0%	68.6%	71.9%
I am satisfied with using ChatGPT as a complementary tool for solving problems in Applied Statics	2.9%	0.0%	17.1%	15.6%	80.0%	84.4%
ChatGPT complements my learning compared to the traditional method (solving exercises manually using a calculator)	5.7%	9.3%	11.4%	18.8%	82.9%	71.9%
Using ChatGPT made me feel more confident in my ability to solve problems in Applied Statics	2.8%	6.2%	34.3%	31.3%	62.9%	62.5%
I would recommend using ChatGPT to other students for solving problems in Applied Sta tics	2.9%	3.1%	14.3%	18.8%	82.8%	78.1%
I am likely to use ChatGPT in future activities related to Applied Statics	2.8%	0.0%	22.9%	18.7%	74.3%	81.3%

Table 9 highlights a generally positive perception of ChatGPT as a learning tool in Applied Statics, with increasing satisfaction from 80.0% in Activity I to 84.4% in Activity II. Most students agreed that ChatGPT improved their understanding (68.6% to 71.9%) and helped correct errors in manual calculations (77.2% to 78.1%). Confidence in problem-solving remained steady at around 62.5%, and a growing number of students expressed a likelihood to use ChatGPT in the future (74.3% to 81.3%). These results indicate a stable and favorable acceptance of ChatGPT as a complementary resource in the course.

In addition to the closed-ended questions, open-ended questions were included in both activities. Tables 10-13 presents the students' responses, categorized into emerging themes from the analysis, along with an example response for each category.

Table 10. Emerging categories for the question: What differences did students identify between manual calculations and the results obtained from ChatGPT?

Categories emerged (frequency)	**Description (an example of response)**
More detailed and accurate results (20)	Students highlighted that ChatGPT provides more comprehensive results, often incorporating integrals or more technical steps than those used in their manual calculations. *"The differences were that the theoretical answers were more detailed, and the calculations were broken down into sections; in some cases, it used integrals to evaluate the exercises."*
Errors or inconsistencies in calculations (12)	Some students noted discrepancies in ChatGPT's calculations, such as incorrect values or approaches that did not align with the expected results. *"ChatGPT sometimes took forces in opposite directions."*

Table 11. Emerging categories for the question: What advantages and disadvantages do students find in using ChatGPT to solve problems in Applied Statics?

Categories emerged (frequency)	**Description (an example of response)**
Advantages	
Speed and efficiency (19)	ChatGPT is valued for its ability to solve problems quickly, providing clear and accessible solutions. *"The advantage is that it is much easier and faster to use, and it gives you clear results."*
Learning complement (13)	Students appreciated ChatGPT as an additional tool that facilitates understanding and reinforces what they learn in class. *"It's a good tool to check my results or use it if I'm in trouble."*
Disadvantages	
Technological dependency (17)	A recurring concern is that excessive use of ChatGPT could limit the development of students' analytical and practical skills. *"The disadvantage is that you get used to everything being easy and don't fully develop your abilities."*
Errors and discrepancies in responses (15)	Students mentioned that ChatGPT might provide incorrect or confusing answers, particularly for more complex problems. *"It's not always correct; you have to check what it solves and know the subject to see where it makes mistakes."*

Table 12. Emerging categories for the question: What is your perception of using ChatGPT as a learning tool in Applied Statics compared to traditional learning?

Categories emerged (frequency)	**Description (an example of response)**
Complementary tool (21)	The majority of students view ChatGPT as a useful complement, particularly for clarifying doubts and reinforcing acquired knowledge. *"It's a complementary tool; it doesn't replace traditional learning but rather enriches it."*
Preference for traditional method (11)	Several students prefer traditional learning due to its more human and personalized approach, which facilitates a deeper understanding of concepts. *"Traditional learning is much more comfortable, and you learn much more."*

Table 13. Emerging categories for the question: Do you think the use of ChatGPT could replace traditional problem-solving methods in Applied Statics?

Categories emerged (frequency)	Description (an example of response)
Would not replace the traditional method (20)	The majority stated that ChatGPT is not equipped to replace traditional learning, emphasizing the importance of human judgment in problem-solving. *"I don't think it can replace it, as it's not the same to have a robot explain something as having a person explain it."*
Potential replacement in the future (12)	Some students believe that with technological advancements, ChatGPT could eventually replace certain aspects of learning, particularly in more technical or mechanical tasks. *"Yes, because technology advances and it could be automated to become more efficient."*

This table reflects the prevailing opinion that ChatGPT cannot fully replace traditional methods while also acknowledging the potential for future technological advancements to change its role in learning.

Final Perceptions

Table 14 summarizes students' perceptions of the use of AI-based tools, such as ChatGPT, in the context of the Applied Statics course. These statements were evaluated at the end of the course to assess the perception of this tool in learning, its utility as an educational complement, and students' interest in integrating it into their training. The data is categorized into "Disagree," "Neutral," and "Agree."

Table 14. Final perceptions of students on the use of ChatGPT in the Applied Statics course.

Question	Disagree	Neutral	Agree
Using ChatGPT has significantly contributed to my learning in the Applied Statics course	6.0%	30.3%	63.7%
I would recommend using ChatGPT to other students in the Applied Statics course	0.0%	15.2%	84.9%
AI-based tools, such as ChatGPT, can be used as part of the educational process, supporting teachers and students by facilitating teaching and learning	0.0%	6.1%	93.9%
I am interested in learning how to use AI-based tools as part of my courses	3.0%	6.0%	91.0%
My initial expectations about using ChatGPT were met	0.0%	9.1%	90.9%

Table 14 highlights that the majority of students (63.7%) agreed that using ChatGPT significantly contributed to their learning in the Applied Statics course. Additionally, a remarkable 84.9% of students would recommend using ChatGPT to others, and 93.9% believed that AI-based tools, like ChatGPT, can effectively support the educational process by facilitating teaching and learning. Furthermore, 91.0% of students expressed interest in learning how to use AI-based tools as part of their courses, and 90.9% felt their initial expectations about ChatGPT were met, reflecting strong acceptance and perceived value of the tool in their academic experience.

Finally, as part of the study's closing phase, an open-ended question was posed to students: *"What did you like most about using ChatGPT in the Applied Statics course?"* Table 15

presents the students' responses, categorized into emerging themes derived from the analysis, along with example responses for each category.

Table 15. Positive aspects highlighted by students on the use of ChatGPT in the applied statics course.

Categories emerged (frequency)	Description (an example of response)
Support for learning and understanding (26)	Most students highlighted ChatGPT as a valuable tool for reinforcing learning, resolving specific doubts, and better understanding exercises and course concepts. They also appreciated its ability to provide detailed and personalized explanations, facilitate independent study, and offer unlimited resources. *"It helped me resolve doubts outside of class hours, and thanks to it, many questions were answered correctly."*
Efficiency and speed in problem-solving (6)	Several students valued ChatGPT's speed and efficiency in solving problems, saving time, and providing clear results. This helped them optimize their learning process. *"The speed with which exercises are solved; it's a tool that helps with learning."*

Categories in Table 15 highlight the most appreciated aspects of ChatGPT, focusing on its ability to enhance learning and its efficiency in problem-solving.

Discussion

The findings of this study reflect a predominantly positive perception of ChatGPT as a complementary tool in the Applied Statics course. Both survey responses and open-ended questions highlight the significant value students attribute to its potential to facilitate learning, enhance understanding of complex concepts, and optimize time spent on problem-solving. However, certain limitations were also identified, emphasizing the importance of using the tool critically and under proper guidance to ensure effective integration into learning without compromising the development of essential skills.

Characterization

Most students considered ChatGPT a valuable aid in reinforcing their learning and resolving specific doubts in the course, praising its ability to provide detailed and personalized explanations. This aligns with previous studies emphasizing the role of AI tools in improving accessibility and personalization in learning.

Additionally, open-ended responses suggest that students view ChatGPT as a valuable resource for reinforcing learning and exploring new problem-solving methods, though some expressed concerns about its impact on traditional skills and academic ethics. This finding echoes previous research indicating that excessive reliance on tools like ChatGPT could lead to a decline in essential skills such as independent problem-solving and critical thinking, presenting significant challenges in educational settings [14]. These results underscore the need for guided and balanced integration of such tools to ensure they complement traditional methods and promote critical and responsible use.

Critical Thinking

Survey results at the beginning and end of the semester indicate a generally positive perception of ChatGPT as a learning resource, with 62.5% agreeing at the start (Table 3),

increasing to 72.7% by the end of the semester (Table 4). However, concerns persist, such as ChatGPT inhibiting critical thinking, with agreement rising from 21.9% (Table 3) at the beginning to 42.4% (Table 4) at the end.
By the end of the course, a significant proportion of students (78.8%) (Table 4) indicated that ChatGPT allowed them to reflect on generated solutions rather than passively accepting them. This shift highlights the value of guided use, where the tool acts as a complement rather than a substitute for traditional learning. Its ability to foster reflective analysis and provide detailed explanations has also been recognized in other educational contexts, such as programming, where it is used to guide advanced cognitive processes and stimulate critical skills [15].

Qualitative findings suggest that ChatGPT has the potential to enrich reflective learning, particularly when students use it to explore new perspectives and address doubts independently. This indicates that ChatGPT can act as a catalyst for meaningful learning if used in a structured and guided environment. This potential has been identified in engineering education, where AI tools are valued for enhancing the understanding of complex concepts and supporting problem-solving while promoting personalized learning experiences [16].

However, concerns about excessive dependency and diminished creativity highlight the need to design strategies that encourage students to critically evaluate and verify generated information. This approach fosters analytical and critical reflection skills, as suggested by Jack and Yan [17], who argue that tools like ChatGPT push students to take an active role in evaluating solutions, developing metacognition and critical thinking skills by identifying and correcting errors in generated responses.

Ethics

The results of the initial and final semester surveys show a significant increase in students' ethical awareness and responsible use of ChatGPT. At the start of the semester, 68.8% (Table 6) acknowledged that using ChatGPT to produce academic writing without proper citation constituted plagiarism, increasing to 78.7% (Table 7) by the end. Similarly, confidence in detecting plagiarism with ChatGPT through specialized software rose from 71.9% (Table 6) to 84.8% (Table 7). These findings demonstrate a growing awareness of the importance of proper citation and avoiding academic dishonesty.

However, a minority still underestimates the ethical implications, with 24.3% (Table 7) continuing to believe that submitting assignments generated by ChatGPT without referencing is not problematic. This aligns with research by Uhlig and Jawad [18], which emphasizes the need to educate students on the ethical and responsible use of tools like ChatGPT to prevent inappropriate dependency that could limit academic and professional development.

The qualitative analysis of open-ended responses provides valuable insights into addressing these ethical challenges. A significant proportion of students (22 responses see Table 8) highlighted the need for training programs promoting responsible use of ChatGPT, emphasizing proper citation and its use as a complementary tool. This aligns with Wyne and Farahani [19], which underscores the importance of establishing clear institutional policies and training programs that promote academic ethics, discourage dishonest behaviors, and encourage critical and responsible use of tools like ChatGPT.

Additionally, other responses suggested measures such as supervision and regulation, including the use of plagiarism detection software (6 responses see Table 8) or specific restrictions on its use (4 responses see Table 8) to ensure the authenticity of assignments and evaluations. These proposals reflect concerns about maintaining academic integrity, aligning with the need to establish clear institutional policies on the ethical use of AI tools.

In this context, it is essential for educational institutions to promote formal training programs on the ethical use of tools like ChatGPT, providing students with clear guidelines on how to integrate them responsibly into their learning. Furthermore, instructors should play an active role in supervising the use of these technologies, ensuring they complement but do not replace the development of fundamental skills such as critical thinking and academic writing. This approach aligns with the need to develop a culture of ethical reflection in engineering, fostering students' ability to identify and address complex ethical dilemmas associated with the adoption of emerging technologies [20].

Activities conducted

The activities provided a framework for evaluating students' perceptions of ChatGPT's use in the Applied Statics course. The results revealed that this tool is valued as a complement to learning, though concerns were identified regarding its impact on the development of analytical skills.
Based on the data presented in Table 9, key trends were identified that reflect students' perceptions and experiences with ChatGPT in Applied Statics activities:

- Activity I: 77.2% of students agreed that ChatGPT was helpful in correcting errors in their manual calculations, increasing slightly to 78.1% in Activity II. This increase suggests a consistently positive perception of the tool's support.
- The percentage of students who agreed that ChatGPT improved their understanding rose from 68.6% in Activity I to 71.9% in Activity II, indicating improved perceptions of its capacity to facilitate learning.
- Satisfaction grew from 80.0% in Activity I to 84.4% in Activity II, showing greater acceptance with continued use of the tool.
- Although 82.9% of students in Activity I agreed that ChatGPT complements their learning compared to traditional methods, this percentage decreased to 71.9% in Activity II. This may reflect more critical reflection after prolonged use of the tool.
- A high percentage of students recommended the use of ChatGPT, though there was a slight decrease from 82.8% in Activity I to 78.1% in Activity II.
- The intention to continue using ChatGPT increased from 74.3% to 81.3%, highlighting the perceived value of the tool as an educational resource.

The analysis of open-ended responses (Tables 10-13) reinforces these findings. Students identified advantages such as ChatGPT's speed, efficiency, and ability to provide detailed results. However, they also expressed concerns about errors in calculations and the risk of technological dependence. For example, one student stated: *"It's not always correct; you have to check what it solves and know the subject to see where it makes mistakes."* Most students also believed that ChatGPT could not replace traditional learning due to the importance of human judgment in problem-solving. This reflects a recognition of the tool as a useful complement rather than a substitute for traditional methods. This perspective aligns with comparisons between ChatGPT and calculators in education, where both are emphasized as supportive tools that should not replace traditional teaching and interactions with instructors, which are essential for developing fundamental skills [21].

*Final Perception*s

The final perceptions (Table 14) reveal a general consensus on the value of ChatGPT in education. The high proportion of students who would recommend its use and expressed interest in learning more about AI-based tools reflects a positive attitude toward integrating innovative technologies into learning. However, the responses also suggest that some students may prefer traditional methods due to concerns about the accuracy of results or the lack of human interaction.

- 63.7% of students agreed that ChatGPT significantly contributed to their learning, while 30.3% remained neutral, and only 6.0% expressed disagreement. These results suggest that the tool was widely perceived as an effective resource for complementing learning in the course. The neutrality of some students may indicate a lack of deep exploration of ChatGPT's capabilities or a preference for traditional learning methods. However, the low level of disagreement highlights that most students view ChatGPT as a valuable support for technical learning.
- An overwhelming 84.9% of students indicated that they would recommend using ChatGPT to other students, with none expressing disagreement. This high level of acceptance reinforces the positive perception of the tool, not only in terms of its personal utility but also as a resource considered valuable for the academic community. This finding highlights ChatGPT's potential to be integrated as a common practice in similar courses.
- 93.9% of students agreed that tools like ChatGPT can be used as part of the educational process, with only 6.1% remaining neutral. This response reflects a high level of acceptance of artificial intelligence as a pedagogical complement. The absence of disagreement underscores students' confidence in the transformative role that these technologies can play in education, benefiting both instructors and students.
- 91.0% of students expressed interest in learning how to use AI-based tools as part of their courses, with only 3.0% in disagreement. This result highlights significant openness to adopting innovative technologies in learning. Leveraging this openness by implementing training strategies on the responsible and effective use of these tools would be beneficial.
- 90.9% of students indicated that their initial expectations regarding ChatGPT's use were met, while 9.1% remained neutral. This finding suggests that students' experiences with ChatGPT aligned with their expectations. The absence of disagreement reinforces the perception that ChatGPT fulfilled its promise as a useful and accessible resource for problem-solving and learning.

The analysis of open-ended responses (Table 15) further supports these quantitative findings. Most students (26 responses) positively valued ChatGPT as a learning support tool, highlighting its ability to resolve specific doubts and provide detailed explanations that facilitate understanding of course concepts. Other students (6 responses) emphasized ChatGPT's efficiency and speed in solving problems and delivering clear results.

Conclusions

This study analyzed students' perceptions of incorporating ChatGPT into the Applied Statics course to explore its potential as a complementary tool in engineering education. Using a mixed-methods approach, data were collected from students in the Construction Engineering program at a private university in Chile through surveys conducted at the beginning, during,

and end of the spring 2024 semester. The findings provide insights into students' experiences and opinions, forming the basis for the following conclusions.

This study demonstrates that integrating ChatGPT into the Applied Statics course is a promising pedagogical strategy, positively perceived by students as a complement for addressing doubts, providing detailed explanations, and fostering reflective learning. Over the semester, students developed greater confidence in the tool, recognizing its usefulness in generating creative ideas and reflecting on solutions.

In the ethical domain, the results show increased awareness of the responsible use of AI tools, with greater recognition of the importance of properly citing sources and avoiding plagiarism. However, the need for clear policies and ethical training programs to guide the conscious and responsible use of these technologies is emphasized.

While ChatGPT offers clear benefits such as efficiency and accessibility, concerns were also identified regarding technological dependence and inconsistencies in its results. This highlights the importance of combining its use with traditional methods to develop critical, creative, and autonomous skills.

This study calls for future research on the long-term impact of emerging tools like ChatGPT on key skills, as well as their effectiveness in interdisciplinary contexts. It also underscores the importance of designing clear ethical guidelines and training programs to maximize their potential as complementary resources in higher education.

The study presents several limitations that should be considered. It was conducted with a specific group of students from a single university program, limiting the generalizability of the findings to other disciplines or institutions. The analysis is short-term, focusing on one semester, leaving the long-term effects of ChatGPT integration unexplored. Data collection relied on self-reported surveys, which may be subject to biases, and the study primarily reflects student perceptions, without incorporating instructor insights.

Works could focus on exploring the long-term impact of ChatGPT on learning outcomes, critical thinking, and skill retention across diverse educational settings and disciplines. Comparative studies with other tools and traditional methods would provide insights into its relative effectiveness. Additionally, incorporating instructor perspectives, standardized skill assessments, and ethical training programs would help design structured frameworks for its integration. Addressing accessibility and equity issues, as well as studying its potential in interdisciplinary and collaborative learning contexts, could further enhance its role as a valuable educational resource.

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Appendix 1. Activities conducted during the semester

A sample of the two implemented activities is attached (each consisting of one theoretical question and one practical exercise). The activities involving ChatGPT correspond to the same tasks mentioned above, with the only difference being that they are developed using the ChatGPT tool.

Activity No. 1
Analysis of distributed loads and idealization of supports

Objective: To facilitate the understanding and application of the concepts of distributed loads on beams and the idealization of supports through theoretical comprehension questions and practical exercises.

General Description: This activity consists of answering theoretical comprehension questions and solving practical exercises related to distributed loads on beams with various types of supports.
For this initial stage of the activity, students may only use their class notes and a standard calculator (not a cell phone calculator).

Theoretical comprehension questions

1. Explain the purpose of the following types of supports. In addition, provide an example of a structure in which each of them can be used.

Explain the function and application of the fixed support.	Provide an example of a structure in which a fixed support can be used.

Practical exercise

Part 1: Traditional resolution

(*Perform calculations manually. You may use a calculator, but not a cell phone calculator. Discussion with classmates is allowed.*)

Students will perform an analysis of a simply supported beam subjected to both distributed and point loads, applying the principles of statics. They must use the equilibrium equations to determine the support reactions.

Exercise 1: Beam with uniformly distributed load

Problem description: A beam of 6 meters in length is fixed at the left end (Point A). A uniformly distributed load of 2 kN/m is applied along the entire length of the beam.

Questions:

1. Draw the proposed structural diagram, calculate the magnitude of the resultant force of the distributed load, and indicate its location along the beam with respect to point A.
2. Calculate the reaction forces at the fixed support.

Activity No. 2
Shear force and bending moment diagram analysis

Objective: To facilitate the understanding and application of shear force and bending moment diagram concepts in beams through theoretical comprehension questions and practical exercises involving the calculation and representation of these diagrams.

General Description: This activity consists of answering theoretical comprehension questions and solving practical exercises related to shear force and bending moment diagrams in beams subjected to different types of loads and supports.

For this initial stage of the activity, students may only use their class notes and a standard calculator (not a cell phone calculator).

Theoretical comprehension questions

1. Explain the importance of the shear force diagram in structural analysis.

Practical exercise

Part 1: Traditional resolution
(*Perform calculations manually. You may use a calculator, but not a cell phone calculator. Discussion with classmates is allowed.*)

Students will analyze simply supported beams subjected to various loads and will apply the principles of statics to develop shear force and bending moment diagrams, also determining the reactions at the supports.

Exercise 1: Beam with uniformly distributed load
Problem description: A beam 6 meters in length is fixed at the left end (Point A). A uniformly distributed load of 2 kN/m is applied along the entire length of the beam.

Questions:

1. Draw the proposed structural diagram and calculate the reaction forces at the fixed support (Point A).
2. Calculate the shear force equations and draw the corresponding shear force diagram.
3. Calculate the bending moment equations and draw the corresponding bending moment diagram.