





Do Engineering Students Know How to Use Generative Artificial Intelligence? A Case Study

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Abstract. In the context of engineering education, the utilization of generative artificial intelligence (AI) holds significant promise for enhancing learning experiences. This article presents a compelling case study designed to assess the proficiency of engineering students in employing generative AI, particularly focusing on ChatGPT. Students from diverse engineering disciplines and academic levels engage in a knowledge questionnaire, with one group utilizing ChatGPT and the other leveraging unrestricted internet resources. The study not only investigates the effectiveness of generative AI as a learning tool but also explores its impact on problem-solving skills. Towards the end of the questionnaire, students are surveyed using a validated instrument to gauge their perceptions and experiences regarding the use of ChatGPT and generative AI in the realm of engineering education. This research contributes valuable insights into the integration of generative AI as a pedagogical tool, shedding light on its potential to shape the future of engineering instruction.

Keywords: Artificial Intelligence · AI · Generative · Engineering Education

1 Introduction

In today's rapidly evolving society, the methods and tools utilized in teaching and learning must also progress accordingly. Information and Communication Technologies (ICTs) have played a pivotal role in various domains, with education being no exception. Internet and web-based platforms, such as Learning Management Systems (LMS), have notably shaped the educational landscape. However, one of the most disruptive technologies in recent times is Artificial Intelligence (AI). While AI is not a novel concept [1] and has been applied across diverse sectors such as agriculture [2], healthcare [3], law [4], transportation [5] or education [6, 7] for many years, its recent advancements have led to unprecedented opportunities and challenges.

The application of AI aims to support individuals in their tasks, saving time, energy, facilitating access to information, etc. [8]. In education specifically, AI has

been employed over the past three decades for personalized learning, skill development, collaborative learning, student engagement, learning support, and decision-making processes [1, 7] through intelligent tutoring systems, teaching robots, learning analytics dashboards, adaptive learning systems, and more [9]. Numerous systematic reviews have explored various facets of AI in education [8, 10–12].

However, the definitive disruption in the realm of AI stems from the emergence of Generative AI and its implications for education [13]. The pivotal moment came with the release of ChatGPT in November 2023, a freely accessible chatbot based on a Large Language Model (LLM) capable of responding to natural language queries. Its exponential impact was evident, with 5 million users in its first 5 days of life, 100 millions in about a month and 180 million users in January of 2024 [14]. This marked the beginning of a new era, with other Generative AI applications such as Bard and Copilot swiftly following suit, along with advancements in image, video, and sound generation [14].

The integration of Generative AI in education has sparked debates [15, 16], with proponents touting it as the future cornerstone of education, while skeptics perceive it as a potential threat [13, 17]. However, irrespective of these views [18], the reality is that students will inevitably encounter Generative AI beyond educational institutions. Therefore, it becomes imperative to equip them with the requisite knowledge and skills to effectively utilize such technologies, including the ability to ask pertinent questions [16].

While recent research has explored students' perceptions and usage of ChatGPT [19], there remains a gap in understanding how it is applied in specific engineering tasks or activities. This paper aims to address this gap by presenting a case study examining how students leverage Generative AI, specifically ChatGPT 3.5, to answer knowledge questions in engineering scenarios. The study seeks to ascertain whether students possess sufficient know-how to effectively utilize Generative AI in education or if specific training is required.

The rest of the paper is structured as follows first the theoretical context about AI and Generative AI in Education is presented. Third section describes the case study carried out in an engineering context. Forth section shows the produced results and a discussion about them is carried out in section fifth. Finally, some conclusions are posed.

2 Theoretical Context

This section briefly introduces some key concepts to aid in the understanding of the paper. Firstly, it outlines the concepts of AI and Generative AI, followed by an exploration of their applications in education.

2.1 Definitions of AI and Generative AI

Although AI is currently experiencing a disruptive moment, the term itself was coined approximately 70 years ago [1]. The initial inquiry into AI was sparked by Turing's contemplation of whether machines could exhibit human-like thought processes [20], with John McCarthy later defining it as "The science and engineering of making intelligent

machines” [21]. However, defining AI in a singular manner proves challenging due to its diverse approaches and development paths [22]. Various categories of AI have been described [23]:

- Artificial narrow intelligence (ANI). A kind of AI which possesses a limited range of abilities and represents the only achievement thus far.
- Artificial general intelligence (AGI). A kind of AI which aims to emulate human-like capabilities.
- Artificial superintelligence (ASI). A kind of AI which surpasses human intelligence.
- Also some authors consider different types of AI such as [24]:
- Artificial Intelligence. A type which enables machines to replicate human cognition.
- Machine Learning. A subset focused on learning from data examples primarily through statistical methods like linear regressions and decision trees, requiring less data and computation power but more human intervention.
- Deep Learning. A subset of Machine Learning relying on neural networks, complex algorithms that demand more data and computing power while involving less human intervention.

Once the concept of AI is defined, it becomes essential to comprehend the current landscape, particularly with the emergence of a phenomenon that has gained significant popularity, known as Generative AI. Generative AI can be defined as “... a technology that (i) leverages deep learning models to (ii) generate human-like content (e.g., images, words) in response to (iii) complex and varied prompts (e.g., languages, instructions, questions)” [17]. Other possible definition could be “production of previously unseen synthetic content, in any form and to support any task, through generative modeling” [25].

AI can be classified based on the type of generative algorithms, as outlined by Jovanovic and Campbell, who differentiate between Generative Adversarial Networks (GAN), Generative Pre-trained Transformers, Generative Diffusion Models (GDM), or Geometric Deep Learning (GDL) [26]. Alternatively, García-Peñalvo and Vázquez-Ingelmo categorize algorithms and techniques into GAN, Encoder-Decoder Networks, Neural Networks, Transformers, and others [25]. However, the most notable approach in the past year has been the development of Large Language Models (LLMs).

Large language models, crucial in Natural Language Processing (NLP), are “models are trained on massive amounts of text data and are able to generate human-like text, answer questions, and complete other language-related tasks with high accuracy” [27].

They can be understood as “a statistical language model that assigns a probability to a sequence of m tokens $P(w_1, \dots, w_m)$ using a probability distribution” [28], widely applied in various tasks such as speech recognition, machine translation, part-of-speech tagging, parsing, handwriting recognition, and information retrieval. These models serve as the foundation for current Generative AI chatbots and other AI applications. However, maintaining them is challenging, requiring substantial investment and months of training, while accessing training data poses additional difficulties [29].

2.2 AI and Generative AI in Education

In the realm of AI applications, numerous studies have explored its potential and associated successes [30]. Various categorizations of potential applications exist, such as those

outlined by Dahwan & Batra [1] or the one proposed by Holmes et al. [31]. However, for the purpose of this research, we will consider two categorizations: one defined by Hwang et al. [7] focusing on application roles, and another by Ouyang [10], focusing on paradigms.

Regarding the former categorization by Hwang et al. [7], the authors delineated distinct roles for AI applications in education:

- Intelligent tutor: Encompassing systems aimed at personalizing and adapting learning to students' needs, including intelligent tutoring systems, adaptive/personalized learning systems, and recommendation systems.
- Intelligent tutee: Although less common, this role involves learners engaging with others to provide assistance.
- Intelligent learning tool/partner: Providing intelligent data gathering and analysis to identify critical focal points for learning.
- Policy Making Advisor: Implementing AI techniques to aid decision-makers by considering evidence generated within educational institutions.

As for the latter categorization by Ouyang [10], three possible paradigms are defined:

- AI-directed, learner-as-recipient: AI directs learning processes and defines suitable learning pathways, with intelligent tutoring systems serving as an example.
- AI-supported, learner-as-collaborator: AI serves as a supportive tool for students in their learning journey, assisting them in focusing on relevant issues.
- AI-empowered, learner-as-leader: AI functions as a tool to enhance human intelligence, aiding both learners and teachers in improving teaching and learning performance.

The utilization of a chatbot like ChatGPT could fall under the intelligent learning tool category of the former classification, as it assists students in avoiding mechanical tasks and finding solutions to facilitate their learning progression. Regarding the latter classification, it could be considered as part of AI-supported, learner-as-collaborator and AI-empowered learner paradigms, as it aids students in their work following interaction with AI technology and provides them with knowledge they may not have initially possessed.

Regarding the use of generative AI, it has gained significant popularity since its emergence in November 2023. Reactions to its potential applications have varied widely, with some authors describing its arrival as a “calculator moment” in digital writing classrooms—a transformative technology that necessitates a shift in educational goals [32].

However, as with any disruptive technology, there are also negative reactions, viewing the new technology as undermining scientific pursuits and moral principles by fostering a flawed understanding of language and knowledge [33].

Nevertheless, Generative AI is readily available, and understanding its potential applications is imperative. Authors such as Baidoo-Anu & Owusu have outlined several possible applications, including [16]:

- Personalized tutoring and feedback tailored to students' individual learning needs and progress.

- Automated Essay Grading to support teachers and streamline their workload.
- Language translation of texts into different languages following appropriate training.
- Interactive learning through virtual tutors that engage students in conversational interactions.
- Adaptive learning, which personalizes teaching methods based on student progress and performance.

This classification represents only a portion of the diverse range of tools provided by Generative AI. They can be categorized based on the outcomes they produce into various domains, including text generation (such as chatbots, content creation, exams generation, and language teaching), image generation (including graph and presentation generation), video generation, 3D objects generation, audio generation (including voice modulation and transcription), source code generation (including debugging and generation), and AI-generated text detection (including anti-plagiarism tools) [34].

The possibilities offered by the use of generative AI are vast. For instance, the work by Nerantzi et al. [35] gathers 101 potential ideas for using AI in education. However, it is crucial to acknowledge that generative AI comes with associated advantages, drawbacks, and challenges. Importantly, students across different educational levels are already using AI, highlighting the necessity for them to understand how to use it and develop critical thinking skills when interpreting the feedback they receive from AI-generated content [34].

3 The Case Study

3.1 Description of the Activity

The case study conducted entails an optional activity offered at the conclusion of the subject, which is completed online via an online form. The primary objective of this activity is to discern the disparity in answering knowledge questions, pertinent to the subjects covered, through the use of Generative AI versus other potential tools and sources. Therefore, the case study seeks to evaluate the following hypothesis:

- The utilization of Generative AI by students for answering knowledge questions is correlated with improved outcomes.

To examine this hypothesis, participating students will be divided into an experimental group and a control group. Students in the experimental group will utilize ChatGPT 3.5, whereas those in the control group will have the liberty to employ any other resources available on the internet. The responses provided will be evaluated and analyzed by the teachers.

This distribution enables us to explore the average means of the subgroups within the subjects, assess correlations with the manner in which ChatGPT was utilized, examine the most frequently utilized alternative tools, and ascertain students' use/perception of ChatGPT. Feedback will be gathered through a questionnaire concerning AI usage, adapted from [19].

3.2 Description of the Involved Subjects

In order to understand the background of the students involved in case study it is necessary to describe the courses in which they are enrolled. These are three:

- **Computer Systems Administration (CSA).** This is a fourth-year subject in the Bachelor's Degree in Computer Sciences. The subject is proposed in the final year of the degree as a journey through the public and private environment regarding their workflows, resources, data storage, data transmission, security, and optimization of these processes, among others. It is a subject that has both theoretical and practical aspects, so all concept explanations must be implemented in practice so that students further consolidate their knowledge and better acquire the necessary skills to pass this subject. The main interest of the subject is to show students the possibility that they themselves manage the information systems of an organization, as well as the ability to administer them. It is also intended for students to acquire the ability to carry out an analysis of the needs of any organization, public or private, in this area, and the subsequent implementation of these information systems, satisfying the anticipated needs optimally at the resource and economic levels. In this subject, the experiment is proposed as an optional activity with no impact on the student's final grade.
- **Service Oriented Architectures (SOA).** This is a fourth-year subject in the Bachelor's Degree in Computer Sciences. Currently, new computing models require Service-Oriented Architectures (SOA). These approaches make clients and providers pivotal actors in providing or consuming applications, which are generally accessible through services. The subject consists of three interconnected blocks aimed at enabling students to perform analysis, design, implementation, and deployment of service-oriented architectures. To achieve this, they must use the proposed standards in each case and follow a methodology based on Service-Oriented Engineering, thereby optimizing resources and the solution lifecycle. Additionally, various enterprise solutions based on Business Intelligence (BI) are proposed for analysis and subsequent deployment. As in the previous subject the activity carried out is not mandatory.
- **Informatics (INF).** A first-year subject shared by the Bachelor's Degree in Mechanical Engineering and the Bachelor's Degree in Agri-Food Engineering. The subject aims to provide students with the basic concepts of computer science, enabling them to expand their knowledge in this field in the future and allowing them to handle computers proficiently. This will facilitate their future academic and professional activities, enabling them to successfully meet the requirements of other subjects that involve the use of computer applications throughout their education. Specifically, fundamental concepts in computer science are taught, such as: basic computing, microprocessors, memory, peripherals, programming languages, operating systems, data structures, etc. When it comes to the case study, the proposed activity is optional but carries an additional weight of 10 points out of 100 in the final grade of the subject. These points will be added only if the subject is passed by successfully completing the mandatory activities.

3.3 Materials and Methods

This research adopts a mixed-methods approach [36], integrating quantitative and qualitative analysis. The quantitative analysis involves comparing the scores assigned to

students' knowledge questions when utilizing ChatGPT versus other resources. On the other hand, qualitative analysis centers on students' perceptions regarding the use of ChatGPT and is currently in progress, with potential conclusions to be outlined in future research.

Initially, we provide an overview of the student sample, followed by an examination of the questionnaires.

The Sample. The sample is summarized by the Table 1. On it is possible to see the sample size, divided by gender and by subject and how many of the students are in the experimental and in the control group. This division was done following a systematic sampling, however some of the students did not understand properly the instructions and used the GenerativeAI option when they should not and vice versa, so it was necessary to change their groups to maintain coherence in average study. The activity involved 88 students. It is necessary to point out that there is an unbalance from the experimental and control group (specially in SOA subject) motivated by the fact the activity was elective, and the subject classes have ended when the activity was carried out. In addition, it is necessary to mention the clear lower number of female students in engineering (about a 26% in the case study) something common and already pointed out by several authors [37]. For the case study it is more relevant in Computer Science Degrees than in other engineering (between a 1,5%–1,7% in computer science subjects vs a 33% in the others engineering degrees involved in the case study).

Participation in the study was voluntary, and participating students had to explicitly accept and sign a consent form, by which they allowed instructors and the research team to access and analyze their data. For research purposes, data is anonymized. Students could cancel this agreement at any given moment. Participants were also informed that there were not risks associated with the study, nor any payment due for participation.

Table 1. Sample distribution.

	CSA	SOA	INF	Totals
N	20	17	51	88
Female	3	3	17	23
Male	17	14	34	65
Exp. Group	8	10	28	46
Female	1	2	12	14
Male	7	8	16	28
Cont. Group	12	7	23	42
Female	2	1	5	8
Male	10	6	18	34

The Knowledge Questionnaire. The knowledge questionnaire comprised two knowledge questions for each subject, along with common procedure questions for both experimental and control groups across all subjects.

For the CSA subject, the knowledge questions were:

- K1. Describe the differences between SCRUM and Extreme Programming.
- K2. Describe the differences between and ERP and a CRM.

For the SOA subject:

- K1. What is the protocol XMPP and what is its purpose?
- K2. What is the Enterprise Service Bus?

For the INF subject:

- K1. What are the functions of the arithmetic logical unit of a computer?
- K2. What does it mean that the Operating Systems acts as a Extended Virtual Machine?

The procedure questions for the experimental group, which utilized ChatGPT, were as follows:

- Experimental Group (same questions for knowledge questions 1 and 2):
 - EP1. Have you used the ChatGPT to answer question X? (Yes/No/I have edited it)
 - EP2. How many prompts did you use for question X?
- Control Group
 - CP1. List the tools you used to answer the questions.
 - CP2. Among all of them, which do you consider the best for answering?

The ChatGPT Questionnaire. Another interesting aspect is understanding the students' knowledge about using ChatGPT. To assess this, we utilized part of the questionnaire proposed by Amo-Filvà et al. [19]. Specifically, the following questions were included:

- CQ1. I know what Generative AI is and how to use it (measured on a 5-point Likert scale).
- CQ2. I am familiar with the tool ChatGPT (measured on a 5-point Likert scale).
- CQ3. I have a ChatGPT account (Yes/No).
- CQ4. I use ChatGPT (participants select one or more options from “No”, “for learning”, “in my personal life”, “at work”, “other”).

Additionally, there are other questions answered by the students that are not included in this study as they are still under analysis.

4 Results

To present the results, it is crucial to analyze the students' responses. The initial analysis focuses on the average grades obtained by students when completing the activity. To achieve this, a descriptive analysis of the samples is necessary, followed by a comparison of the means. Table 2 presents the descriptive statistics of each group and subject, including the ratio of students who completed the activity compared to those enrolled in the subject.

Table 2. Descriptive statistics and ratio of completion

Subject	N	Avg. Mean (Std. Dev)	Var
CSA	20	6,65 (2,53)	6,42
Exp	12	7,92 (0,51)	3,08
Control	8	4,75 (0,84)	5,71
SOA	17	7,35 (2,88)	8,30
Exp	10	8,25 (0,66)	4,40
Control	7	6,07 (1,32)	12,29
INF	51	8,21 (1,99)	3,97
Exp	28	9,82 (0,10)	0,30
Control	23	6,26 (0,24)	1,38

Ratio of completion vs Enrolment			
		Enrolled	Percentage
CSA	20	25	80%
SOA	17	24	71%
INF	51	85	60%

After conducting the descriptive analysis, it is essential to compare whether there are significant differences between the experimental and control groups, i.e., between students who used ChatGPT and those who used other tools. The null hypothesis assumes that there is no difference between the groups. Table 3 presents the values for the difference tests.

CSA satisfies the normality and homoscedasticity test criteria, allowing for the application of a Student's t-test. However, for the other two subjects, the sample distribution is not normal, necessitating the application of non-parametric tests such as the Mann-Whitney U test.

Table 3. Mean Differences Tests

Student T Test					
Subject	Avg. Exp	Avg. Cont	t	df	p-value
CSA	7,92	4,75	3,42	18,00	0,0030

MannWhitney U Test					
Subject	U	W	Std Error	p-value	
SOA	18,50	46,50	10,06	0,1090	
INF	17,50	293,50	48,79	0,0000	

On the other hand, another potential issue to explore is the correlation between the grades in the experimental group and the number of prompts used in ChatGPT, as well as between the grades and whether students used the answer directly or edited it. Table 4 presents these correlations. If the sample is normally distributed, the Pearson correlation test is employed; otherwise, Kendall's Tau is used. Additionally, the table includes the number of prompts per student and the percentage of students who edited their answers.

Table 4. Correlations between average mean, prompts and edits

Pearson Correlation Test						
Subject	Pearson Corr. Prompts	Sign. Prompts	Pearson Correlation Edits	Sign. Edits	Prompts Per Student	Percentage Edits
CSA	-0,714	0,009	0,075	0,817	1,29	50%
Kendall's Tau Test						
Subject	Corr. Prompts	Sign. Prompts	Corr. Edits	Sign. Edits	Prompts Per Student	Percentage Edits
SOA	-0,111	0,716	-0,162	0,588	1,15	20%
INF	0,202	0,259	-0,087	0,641	1,14	21%

Regarding the questions related to ChatGPT knowledge and use, Table 5 presents some of the results categorized by subjects. The responses for CQ1 and CQ2 are described as the average mean of the answers, while for CQ3, the table provides the percentage of users with a ChatGPT account. In this case, the table does not differentiate between the results of the experimental and control groups, as all students completed these questions.

Table 5. ChatGPT Knowledge and Use Results by Subject

	CSA	SOA	INF
CQ1	3,90 (1,12)	4,00 (0,93)	3,90 (0,70)
CQ2	4,25 (1,21)	4,41 (1,00)	4,41(0,66)
CQ3	90,00%	88,23%	70%

Regarding CQ4, which assesses the students' use of ChatGPT, Fig. 1 illustrates graphs for each of the subjects.

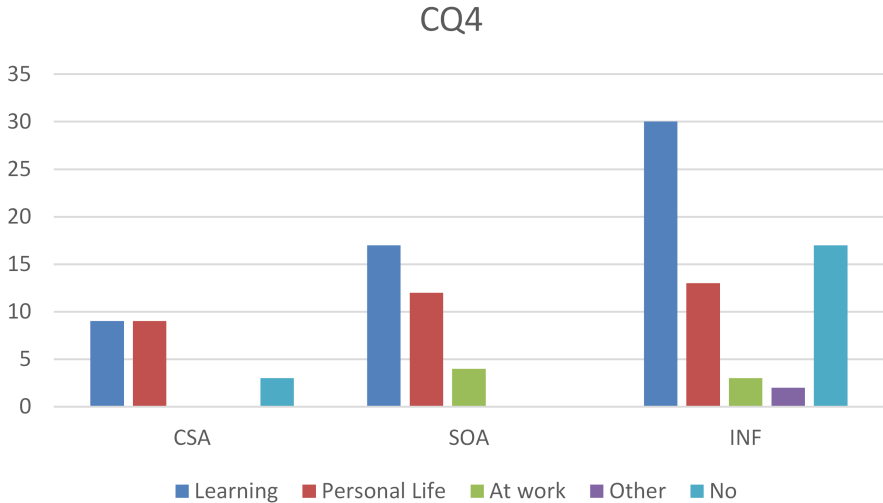


Fig. 1. Distribution of CQ4 answers per subject, considering how students use ChatGPT in chase they use it.

5 Discussion

Regarding the obtained results, several issues need to be explored:

- Table 2 reveals a significant difference in average grades across all subjects. However, techniques for average mean comparison have been applied. It is important to note that the samples for CSA and SOA may present limitations for this research.
- The participation percentage, measured as the number of students who completed the activity compared to the number of students enrolled in the subject, is quite high in all subjects, exceeding 60%. Notably, for INF, where students were awarded for completing the task, the participation percentage is the lowest. This may be attributed to the topic of the activity, as INF students come from engineering disciplines other than Computer Science.
- Average comparison indicates a significant difference in tests for both CSA and INF, leading to the rejection of the null hypothesis that stated there were no differences between experimental and control groups. Differences in grades mean that the application of ChatGPT yields different outcomes compared to other resources, with higher average grades in these cases.
- Table 4 displays correlations between the number of prompts and edits of students and their grades, along with statistics about these interactions. For CSA, there is a correlation between prompts and grades, possibly due to the higher number of prompts per student or the perceived difficulty of the questions. However, for other subjects, the correlation is not significant. Regarding edits or direct use of provided answers, no clear correlation is evident. Notably, in CSA, where more prompts are used, there are also more edits, potentially indicating question difficulty.

- CQ1 and CQ2 responses indicate that students have a high perception of their knowledge about Generative AI and ChatGPT before the activity, with answers close to “I agree” across most subjects.
- CQ3 responses show relatively high percentages of students who have or have not had an account in ChatGPT. Notably, students from INF have a lower percentage, possibly due to their enrollment in engineering disciplines unrelated to computer science.
- CQ4 reveals how students use ChatGPT, with most using it for learning. However, in INF, there is a significant number of students who do not use it. The percentage of students using ChatGPT in their personal life is higher for Computer Science students than for those in other engineering disciplines involved in the study.

6 Conclusions

The integration of artificial intelligence (AI) has already permeated various disciplines, yet the advent of generative AI marks a significant shift, necessitating a universal understanding of its principles. This pivotal moment underscores the importance of comprehending AI's nuances for individuals across all fields. For students, acquiring comprehensive education on AI, encompassing both theoretical foundations and practical applications, is essential. Moreover, cultivating an educational environment that embraces AI-driven methodologies is crucial for preparing students for the evolving technological landscape.

This study has aimed to illuminate the usage patterns of AI among engineering students, highlighting the need for deeper insights into their AI-related practices to inform educational strategies effectively. The findings indicate a robust understanding of AI among participants, affirming its suitability for educational integration. Furthermore, the analysis of the case study data suggests that the utilization of generative AI, exemplified by ChatGPT, may enhance academic performance in specific tasks. However, further research involving diverse subject areas and larger sample sizes is required to validate these findings conclusively. Additionally, targeted training initiatives focusing on generative AI, especially in non-computer science disciplines, are imperative to leverage its potential effectively for educational enhancement.

7 Disclosure of Interests.

The authors have no competing interests.

Acknowledgments. A third level heading in 9-point font size at the end of the paper is used for general acknowledgments, for example: This study was funded by X (grant number Y).

References

1. Dhawan, S., Batra, G.: Artificial intelligence in higher education: promises, perils, and perspective. *Expanding Knowl. Horizon. OJAS* **11**, 11–22 (2020)

2. Bannerjee, G., Sarkar, U., Das, S., Ghosh, I.: Artificial intelligence in agriculture: a literature survey. *Int. J. Sci. Res. Comput. Sci. Appl. Manage. Stud.* **7**, 1–6 (2018)
3. Yu, K.-H., Beam, A.L., Kohane, I.S.: Artificial intelligence in healthcare. *Nat. Biomed. Eng.* **2**, 719–731 (2018)
4. Surden, H.: Artificial intelligence and law: an overview. *Georgia State Univ. Law Rev.* **35**, 19–22 (2019)
5. Abduljabbar, R., Dia, H., Liyanage, S., Bagloee, S.A.: Applications of artificial intelligence in transport: an overview. *Sustainability* **11**, 189 (2019)
6. Qu, J., Zhao, Y., Xie, Y.: Artificial intelligence leads the reform of education models. *Syst. Res. Behav. Sci.* **39**, 581–588 (2022)
7. Hwang, G.-J., Xie, H., Wah, B.W., Gašević, D.: Vision, challenges, roles and research issues of Artificial Intelligence in Education. *Comput. Educ. Artif. Intell.* **1**, 100001 (2020)
8. Zafari, M., Bazargani, J.S., Sadeghi-Niaraki, A., Choi, S.-M.: Artificial intelligence applications in K-12 education: a systematic literature review. *IEEE Access* **10**, 61905–61921 (2022)
9. Chen, X., Xie, H., Zou, D., Hwang, G.-J.: Application and theory gaps during the rise of Artificial Intelligence in Education. *Comput. Educ. Artif. Intell.* **1**, 100002 (2020)
10. Ouyang, F., Jiao, P.: Artificial intelligence in education: the three paradigms. *Comput. Educ. Artif. Intell.* **2**, 100020 (2021)
11. Tahiru, F.: AI in education: a systematic literature review. *J. Cases Inf. Technol. (JCIT)* **23**, 1–20 (2021)
12. Tang, K.-Y., Chang, C.-Y., Hwang, G.-J.: Trends in artificial intelligence-supported e-learning: a systematic review and co-citation network analysis (1998–2019). *Interact. Learn. Environ.* **31**, 2134–2152 (2023)
13. García-Peñalvo, F.J.: La percepción de la Inteligencia Artificial en contextos educativos tras el lanzamiento de ChatGPT: disrupción o pánico. *Educ. Knowl. Soc. (EKS)* **24**, e31279 (2023)
14. García-Peñalvo, F.J.: Generative Artificial Intelligence in Higher Education: A 360° Perspective. *IFE Conference 2024*, Monterrey, Mexico (2024). <https://doi.org/10.5281/zenodo.10499828>
15. Qadir, J.: Engineering education in the era of ChatGPT: promise and pitfalls of generative AI for education. In: *Conference Engineering Education in the Era of ChatGPT: Promise and Pitfalls of Generative AI for Education*, pp. 1–9 (Year)
16. Baidoo-Anu, D., Ansah, L.O.: Education in the era of generative artificial intelligence (AI): understanding the potential benefits of ChatGPT in promoting teaching and learning. *J. AI* **7**, 52–62 (2023)
17. Lim, W.M., Gunasekara, A., Pallant, J.L., Pallant, J.I., Pechenkina, E.: Generative AI and the future of education: Ragnarök or reformation? A paradoxical perspective from management educators. *Int. J. Manag. Educ.* **21**, 100790 (2023)
18. Arboleda, A.M.: Producción y análisis de textos con ChatGPT. presentado en Evento ReCrea, México (2023)
19. Amo Filvã, D., et al.: Usos y desusos del modelo GPT-3 entre estudiantes de grados de ingeniería. In: *Conference Usos y desusos del modelo GPT-3 entre estudiantes de grados de ingeniería*, pp. 415–418. Universidad de Granada, (Year)
20. Turing, A.M.: Can a machine think. *World Math.* **4**, 2099–2123 (1956)
21. McCarthy, J., Minsky, M., Rochester, N., Shannon, C.: *Dartmouth Summer Research Conference on Artificial Intelligence*. Dartmouth College (1956)
22. Nilsson, N.J.: *Principles of Artificial Intelligence*. Springer, Heidelberg (1982). <https://doi.org/10.1007/978-3-662-09438-9>
23. What are the 3 types of AI? A guide to narrow, general, and super artificial intelligence, Codebots, <https://codebots.com/artificial-intelligence/the-3-types-of-ai-is-the-third-even-possible>. Accessed 02 Feb 2024

24. Therón, R.: *Inteligencia Artificial en la Enseñanza de Idiomas. Herramientas y aplicaciones*. presentado en *Inteligencia artificial en la enseñanza de idiomas: Herramientas y aplicaciones*, Salamanca, España (2023)
25. García-Peñalvo, F., Vázquez-Ingelmo, A.: What do we mean by GenAI? A systematic mapping of the evolution, trends, and techniques involved in Generative AI (2023)
26. Jovanovic, M., Campbell, M.: Generative artificial intelligence: trends and prospects. *IEEE Comput. Soc.* **55**, 107–112 (2022). <https://doi.ieeecomputersociety.org/10.1109/MC.2022.3192720>
27. Kasneci, E., et al.: ChatGPT for good? On opportunities and challenges of large language models for education. *Learn. Individ. Differ.* **103**, 102274 (2023)
28. García-Peñalvo, F.J.: La integración de la inteligencia artificial generativa en la práctica docente. V Seminário Escola Digital: A Educação na Era da Inteligência Artificial, Centro de Competência TIC da Escola Superior de Educação do Instituto Politécnico de Bragança (CCTIC), Portugal (2023). <https://bit.ly/3AhcCKI>
29. García-Peñalvo, F.J.: Cómo se percibe la Inteligencia Artificial en la educación tras el lanzamiento de ChatGPT. Foro Internacional “La Inteligencia Artificial y la Docencia Científica”. , Centro de Investigaciones Económicas, Administrativas y Sociales del Instituto Politécnico Nacional, Mexico (2023). <https://bit.ly/45rtrB3>
30. Chen, L., Chen, P., Lin, Z.: Artificial intelligence in education: a review. *IEEE Access* **8**, 75264–75278 (2020)
31. Holmes, W., Bidarra, J., Køhler Simonsen, H.: *Artificial Intelligence in Higher Education: A Roadmap and Future Perspectives*. SmartLearning og forfatterne (2021)
32. Jihinke, R., Cummings, R., Di Lauro, F.: Reclaiming the technology of higher education for teaching digital writing in a post—pandemic world. *J. University Teach. Learn. Pract.* **20** (2023)
33. Chomsky, N., Roberts, I., Watumull, J.: The False Promise of ChatGPT. The New York Times, New York, USA (2023). <http://bit.ly/3GycXfx>
34. García-Peñalvo, F.J., Llorens Largo, F., Vidal, J.: The new reality of education in the face of advances in generative artificial intelligence. *Revista Iberoamericana de Educación a Distancia* **27**, 9–39 (2024)
35. Nerantzi, C., Abegglen, S., Karatsiori, M., Martínez-Arboleda, A.: 101 creative ideas to use AI in education, a crowdsourced collection. *Comput. Software*. Zenodo (2023). <https://doi.org/10.5281/zenodo.8355454>
36. Green, J.L., Camilli, G., Elmore, P.B.: *Handbook of Complementary Methods in Education Research*. American Educational Research Association by Lawrence Erlbaum Associates, Inc. (2006)
37. Charlesworth, T.E., Banaji, M.R.: Gender in science, technology, engineering, and mathematics: Issues, causes, solutions. *J. Neurosci.* **39**, 7228–7243 (2019)