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The Impact of Generative AI on Student Learning Outcomes: A Systematic Review of Empirical Studies (2020–2025)

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Abstract

Higher education is undergoing a revolution due to the fast-developing generative artificial intelligence (AI) solutions, including ChatGPT, Whisper, and DALL E. This review will capture a synthesis of evidence-based articles published in the period 2020 onwards aimed at establishing the impact of generating AI on the learning capabilities of students, learning engagement and motivation, cognitive development, and performance in academic learning among higher education institutions. The search was done logically utilizing databases including Scopus, Web of Science, and Google Scholar. Peer-reviewed empirical studies on generative AI use in classroom situations were the target of inclusion criteria. The selection and screening process followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement framework which led to 12 empirical studies being included. Emotional well-being, AI literacy, and discipline specialization were determined as key moderators of effectiveness. The study revealed more productivity and less anxiety amongst students. However, issues of academic integrity, over-dependency, and correctness of content were prevalent. Students and teachers both expressed the importance of policies and support for the use of ethical AI. In conclusion, generative AI has great potential to change the learning experiences by improving engagement, personalization, and accessibility.

Keywords: Artificial Intelligence (AI), Generative AI, students, learning outcome, education

1. Introduction

Generative artificial intelligence (GAI) has recently become an educational phenomenon. The introduction of ChatGPT by OpenAI in November 2022 was one of the stepping stones as it demonstrated the abilities of large language models (LLMs) to perceive, produce, and

communicate in natural language (Bahroun et al., 2023). ChatGPT received more than 100 million active users within a month, which means that it appeared among the most rapidly expanding online apps in the world, and some significant technological corporations have already launched their counterparts to the product, i.e., Google Bard and GitHub Copilot (Bahroun et al., 2023). Educational technologies are becoming centralized more and more: the process of learning, teaching, and evaluating works on academic performance.

Among the educational tasks that can now be assisted by the GAI tools, are automated essay-grading, adaptive tutoring systems, prediction (analytics) of student performance, content generation, etc. (Bahroun et al., 2023). In other areas like the medical and computer fields, these technologies provide instant feedback, medical case simulation exercises, and easy illustrations of complex issues. At the same time, in education, GAI can be applied by teachers who streamline administrative work, such as grading and planning lessons, as well as provide students with a personalized learning experience and immediate academic support (Întorsureanu et al., 2025).

Yet this ever-increasing integration is creating doubts as well. As it is mentioned by the authors under consideration, the very tool that aids can serve academic dishonesty, e.g. AI-generated essays or answers (Intorsureanu et al., 2025). Although much has been said about the potential of generative AI in education and the dangers associated with it, systematic assessments of the real effects of its application are rather scarce.

This gap is filled by this systematic review of the synthesis of empirical research between 2020 and 2025. Particularly, the following question would be used: What impact does generative AI have on the student learning outcomes of the empirical research published in the period 2020-2025? Critical to the review is the fact that the attention will be on real-world educational applications in clarifying how GAI is establishing academic performance, engagement, and skill development in different fields of discipline.

2. Methods

This systematic review is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. It identifies the empirical studies published in 2020-2025 focusing on generative artificial intelligence (GAI) on student learning outcomes. To achieve proper coverage of relevant literature and to obtain valid and reliable results, the methodology implementation was made in such a way that it provided rigorous selection criteria.

2.1 Search Strategy and Database Selection

To identify a wide range of applicable research, two major multidisciplinary databases were utilized: Scopus and Web of Science. The platforms have been chosen due to the broad scope of coverage of high-quality and peer-reviewed literature on topics related to educational technology, computer science, and pedagogy. To find the necessary information, the search strategy employed Boolean operators to unite the keywords associated with generative AI technologies and educational outcomes. The search string was created to achieve maximum sensitivity (generous coverage) and specificity (relevance to the research question).

The complete Boolean search string used was:

("generative AI" OR "ChatGPT" OR "GPT-3" OR "GPT-4" OR "large language model" OR "LLM" OR "Bard" OR "Copilot")

AND

("student learning" OR "academic performance" OR "skill development" OR "motivation" OR "engagement" OR "educational outcomes")

AND

("empirical study" OR "experiment" OR "quasi-experimental" OR "randomized controlled trial" OR "case study")

The search strategy was relied on preliminary testing to minimize it to an extent that all studies that are considered as related are included but nothing obviously irrelevant is included. The preliminary search was performed without applying any filters on the date so that it could be done manually during the process of selection (publication years).

2.2 Eligibility Criteria and Study Selection

Studies were included based on the following predetermined criteria:

1. **Publication Date**: The research was limited to studies published between January 2020 and June 2025 to focus on the most recent developments in GAI applications in education.
2. **Study Type**: Only empirical research employing quantitative, qualitative, or mixed research designs were included. Theoretical papers, editorials, and review articles were excluded.
3. **Intervention**: Studies must examine the use of generative AI tools (e.g., ChatGPT, GPT-3/4, Google Bard, GitHub Copilot) in educational contexts.
4. **Participants**: The research must involve students at any educational level (K-12, higher education, or professional training).
5. **Outcomes**: Included studies must report measurable learning outcomes such as academic performance, skill acquisition, motivation levels, or engagement metrics.

2.3 Exclusion Criteria

Studies were excluded if they:

- Were published before 2020 or after 2025, ensuring focus on contemporary GAI applications;
- Lacked empirical data (e.g., data collection, editorials, or literature reviews);
- Examined non-generative AI systems (e.g., traditional machine learning or predictive analytics without generative capabilities);

- Did not involve student participants or measure learning outcomes;
- Were not peer-reviewed or published in non-English languages;
- Focused solely on technical AI development without educational implementation; or
- Presented insufficient methodological details for quality assessment.

Additionally, duplicate publications and studies with critical design flaws (e.g., missing control groups in experimental designs) were excluded. These criteria ensured the review synthesized only high-quality, relevant evidence on GAI's educational impact.

2.4 Screening Process

The screening procedure was done in a three-step method as per PRISMA 2020. A total of 145 records attracted through initial database searches were found after the deduction of 15 duplicate entries. Records were not denied access by automation tools or on an accessibility basis during the identification process.

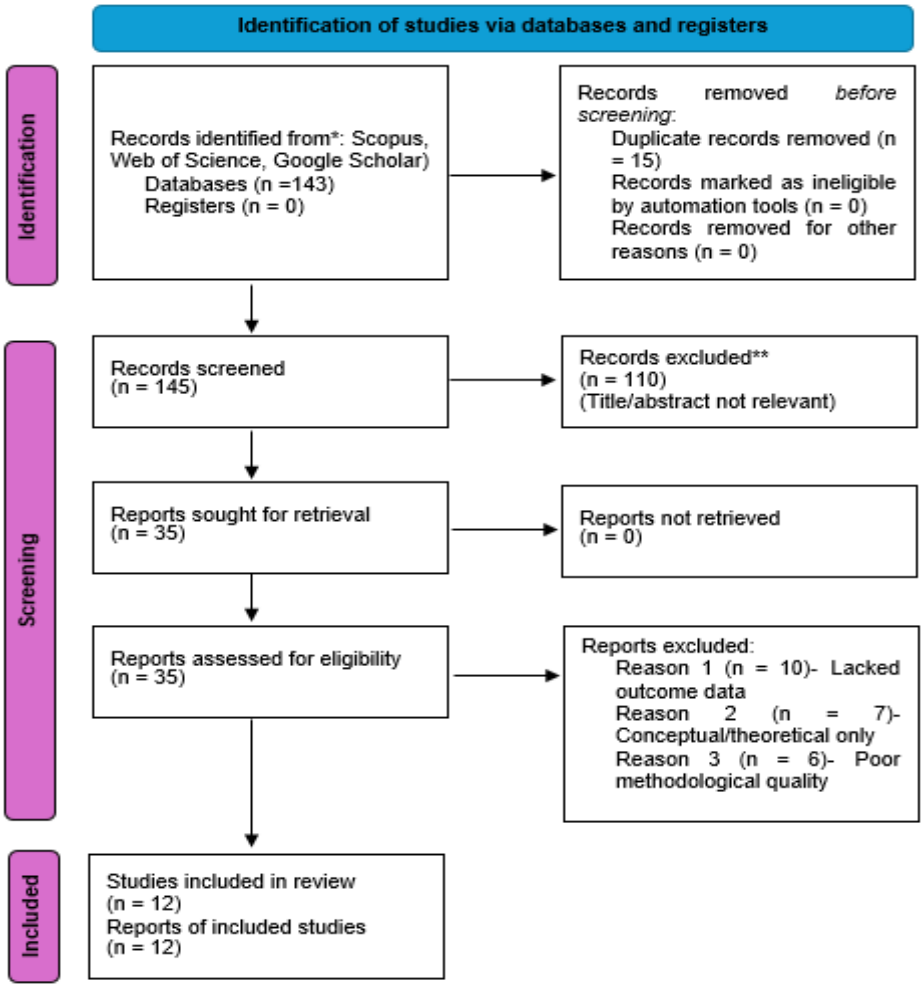

Figure 1. PRISMA Flow Diagram

(Source: Self-Created)

In the title/abstract screening, 145 studies were considered and 110 of them were discarded because they did not fulfil the inclusion criteria. The full-text articles of the remaining 35 studies were downloaded to undertake a detailed appraisal. Among these articles, 23 were excluded due to the following reasons: 10 studies did not provide any relevant data outcomes, 7 were conceptual/theoretical articles, and 6 did not show a proper methodological quality by using predefined evaluation criteria.

The synthesis contained 12 studies that fulfilled all the eligibility criteria. During the screening process, it was ensured that every selected study met the following criteria: (1) used generative AI tools within education, (2) had the participation of students, and (3) described the results and outcomes measurable in terms of learning. The screening method was relatively rigid to reduce the selection bias but was likely to incorporate all the related published empirical evidence within the specific period of 2020-2025.

The whole process of screening is reported in the PRISMA flow diagram (Figure 1) which clearly illustrates how many records were identified, screened, excluded, and finally included in the systematic review. This was an organized process that selected the studies that were to be analysed thoroughly and free of bias.

3. Findings

This review compiled the results of 12 recent empirical studies (2020-2025) examining the question of the impact of integration of generative AI in education. The research covers diverse regions such as China, Taiwan, India, Saudi Arabia, the UK, Australia, Uruguay and the USA. The types of research designs included cross-sectional surveys of different quasi-experiments, as well as mixed-method research, with the participation of primary school students, learners, and educators, at the university level. The sample size varied- some studies had 78 respondents whereas some studies involved more than 23,000 respondents. The considered AI tools mostly contained ChatGPT (version 3.5 and 4), DALLE-3, Grammarly, BARD, and Bing AI. Research was done on their effect on students' academic performance, motivation, engagement, precision thinking, and the effectiveness of teaching. The data are indicative of the fact that AI technologies can be helpful tools in the educational area, including personalized learning, content creation, and scholarly assistance. There were also pointed out challenges associated with academic integrity, AI accuracy, over-reliance, and unequal access.

Although the evidence is given in favour of increasing adoption and the sense of usefulness, there still exist limitations like small sample size, contextual bias, and self-reporting.

The Table 1 below summarizes these findings in detail.

Table 1. Summary of 12 Empirical Studies

No.	Author(s) & Year	Country	Study Design	Sample/Participants	Educational Context	AI Tool/Technology Used	Key Findings	Limitations
1 1.	Fan et al. (2025).	China	Cross-sectional survey using structured anonymized questionnaires	148	Engineering education	Chat gpt	Over half of the participants reported that generative AI improved their learning efficiency, initiative, and creativity, while nearly half noted enhanced independent thinking.	Performance unchanged, concerns raised about generative AI's accuracy, reliability.
2 2.	Jia & Tu (2024).	Taiwan	Cross-sectional	637	College students	AI tools	AI may boost critical thinking by improving self-efficacy and motivation.	Genetic factors not considered – Focus limited to motivational variables. Marginal model fit – Some relationships were weak or non-significant. Incomplete use of RBT – Reinforcement theory applied partially, needing deeper exploration.
3 3.	Zhu et al. (2023).	Asia	Quasi-experimental study	130	Undergraduate Students	Chat Gpt	High potential in education Risks to critical thinking and creativity Needs thoughtful, research-based use	Needs multiple prompts – ChatGPT often requires refined input to give complete answers. Struggles with complex tasks – Limited in handling subjective or nuanced concepts.
4 4.	Banjade et al.. (2024		Design-based empirical study with prototype evaluation.		General higher education context	DALLE-3, Chat gpt Whisper, and DALLE-3. Specifically, the setup for the GPT-3.5-turbo model	AI helps tutors quickly create and customize course content. Students get flexible learning via text, audio, and chatbots. Saves educators time by automating lesson planning.	AI may misread complex content. Data privacy and bias risks exist. Personalization is still limited
5 5.	Mahapatra(2024)	India	Mixed Method intervention design	78+56: 134	Undergraduate ESL students in an elite private-run university in India	Chat Gpt	Positive impact of GPT as a feedback tool.	Could lead to a lack of motivation to think and more machine dependence.
6 6.	Jingwei He, et al. (2025)	Asia	Cross-Sectional	680 Students	Hong Kong University of Science and Technology	Chat Gpt	82.36% AI literate students Supports AI curriculum integration High ChatGPT popularity Peak usage at Guangzhou campus	Risk of academic dishonesty Concerns over ChatGPT accuracy and reliability
7.	Almufarreh (2024).	Saudi Arabia	Quantitative cross-sectional study		College students	Chat GPT 3	Emotional wellbeing is the top driver of AI satisfaction. Content quality and perceived utility also influence satisfaction.	Possible response bias due to self-reported data. Limited generalizability from Saudi student sample.

8.	Johnston et al. (2024).	University of Liverpool , England	Cross-Sectional	2555	Students of university of Liverpool	Chat GPT	High awareness (93%) and academic use of GAI tools reported. Support for grammar tools like Grammarly, but resistance to full essay writing via ChatGPT. Students want clear university policies; banning GAI may disadvantage less confident writers.	ChatGPT aids article selection but may misrepresent content. Prone to referencing errors and bias from training data.
9.	Lee et al. (2024).	Australia	Mixed	Surveyed 30+ Interviewed 8	Higher Education (HE)	Chat Gpt, Google's chatbot BARD, and Dall-E, Bing AI	48.3% of staff used AI in teaching, with fewer using it in administration (33.3%) and research (28.6%). Concerns about academic integrity and AI accuracy exist, but views are mixed and often ambiguous.	Small, localized sample (n=30) may limit generalizability of findings.
`10.	Ravšelj et al. 2025		convenience sampling method,	23,218 students from 109 countries and territories,	higher education students	Chat GPT	a). Interest & Use: 70% students found ChatGPT interesting but rarely used it for creative tasks. b). Learning Impact: Helpful for general knowledge and simplifying info,	Less prominent in enhancing soft skills. Findings are based on early impressions, which may evolve. Self-reported data may include bias or inaccuracies.
11.	Jauhiainen& Garagorry Guerra (2024)	Uruguayan schools	Cross-Sectional	110 student	Primary school education	ChatGPT-3.5 and 4	Generative AI enabled real-time personalization of lessons, enhancing student motivation and performance. AI-supported content adaptation aligned well with curriculum goals and individual learning needs.	Limited to two schools in Uruguay, restricting generalizability across broader educational contexts.
12	Bhandari et al. (2024).	United States	Quasi-experimental	207 test respondents	undergraduate students	Chat GPT	Comparable Quality – ChatGPT-generated questions matched textbook items in difficulty and discrimination (no significant difference). High Alignment – ChatGPT questions showed strong learning objective alignment (similarity score: 0.9666).	Limited Scope – The study focused on a single lesson and subject (algebra), which may limit the generalizability of the findings to other topics or disciplines.

3.1 Thematic Synthesis of Key Findings

3.1.1 Student Learning Outcomes and Cognitive Engagement

The findings reveal that Generative AI has a significant impact on the learning process of students, particularly in the creation of the engagement and efficiency. According to Fan et al. (2025), more than 50% of the engineering Chinese students surveyed indicated greater productivity, creativity, and initiative because of the AI tools, especially when it comes to faster feedback and production of material. Mahapatra (2024) noticed that the quality of writing and confidence, as well as lowered anxiety among ESL learners using ChatGPT as a feedback device, improved significantly. Zhu et al. (2023) also have proved the fact that ChatGPT improved interdisciplinary digital literacy and collaborative learning, especially interdisciplinary digital literacy in STEM students. They also reported that non-STEM students had a difficulty with timely optimization, and there were complaints among participants that they might become mentally passive since they began to rely on AI. Jia & Tu (2024) put some nuance into such understanding because they demonstrated that AI does not specifically facilitate critical thinking yet, it can do so indirectly, improving self-efficiency and motivation. Together, these findings can be interpreted as the idea that although AI can lead to better engagement and cognitive stimulus, its overall impact on learning in terms of assessment achievement and higher-order thinking is situationally dependent.

3.1.2 Personalization, Inclusivity, and Emotional Impact

The possibility of the use of AI to personalize learning was also among the major themes in several studies. Jauhiainen & Garagorry Guerra (2024) demonstrated that ChatGPT was an effective tool for the adaptation of lesson content in primary school, which improved motivation and individual performance. One of the main predictors of student satisfaction with generative AI tools identified by Almufarreh (2024) was emotional well-being, the quality of the received content, and perceived utility. Mahapatra (2024) observed that, in ESL classrooms with limited resources, ChatGPT was used to reduce anxiety and support the development of peer-to-peer collaboration owing to the ease of obtaining feedback. As Jingwei et al. (2025) pointed out, many differences were seen in the use and effect of AI depending on the age of students, academic discipline and area of origin, where AI literacy proved as a decisive element. These studies reflect the significance of developing emotionally appealing and user-friendly AI that could assist various learners. Individualized and accessible AI may serve as a key to filling accessibility and participation gaps, among non-technical and disadvantaged student populations. Thus, emotional and contextual sensitivity is essential to effective and fair AI installation in education.

3.1.3 Pedagogical and Institutional Transformation

Generative AI is creating a shift in the ways of education and policies. The authors managed to reflect the views of the Australian university staff and identified the transformations in the pedagogy, specifically, in assessment design (Lee et al., 2024). Such efforts and hope were supported by only a minority who advocated for the need for faculty development programs and defined ethical practices. This was echoed by Johnston et al. (2024) who indicated that

students are insisting on consistent policies on AI at the university-wide level, especially with the increase in concerns related to plagiarism, fairness, and academic integrity. The largest-ever study around the world, by Ravsljev et al., in 2025, concluded that students were mostly using ChatGPT in brainstorming and generalizations and praised its functionality, but cautioned its excessive usage in avenues such as critical thinking and numeracy. According to Banjade et al. (2023), even though AI aids in the field of education by saving time, increasing access to learning, and some new realms of learning capabilities, it has a bitter element of data privacy, lack of personalization, and bias. In all these studies, what is undoubted, is that the academe has an important role to play in supporting the dual potential of AI, both transformative and disruptive, by preconditioning training, ethics, and support into the academic framework.

3.1.4 Assessment Quality and Fairness

The issue of AI-generated assessment validity is increasingly a topic of discussion. Bhandari et al. (2024) evaluated the psychometric difference between ChatGPT-generated and conventional textbook questions and found a strong and close comparison. They made no notable finding on the difficulty and discrimination levels with a slight advantage enjoyed by AI-generated items over traditional items in spelling out the difference in student ability. In addition, AI-generated items were closely linked to the learning goals of specific lessons, and they revealed that generative AI can produce sound and formative assessments aligned to constructs. Participants in other research reports, including Zhu et al. (2023) and Johnston et al. (2024), posed questions regarding whether AI will work as a professional in evaluating comprehension of nuanced responses and controlling academic integrity. Such issues also enhance the importance of teacher control and policy clarification in the use of AI assistive technology in assessment.

4. Discussion

The recap of the empirical literature shows the current fast-changing environment where generative AI units, especially ChatGPT, are transforming the education procedure in a variety of settings, studies, and types of learners. These studies show the potential and the challenges of the implementation of AI into higher education. One of the findings that remain consistent with various studies (Fan et al., 2025; Zhu et al., 2023; Mahapatra, 2024) is an increase in learning efficiency, motivation, and cognitive involvement with proper integration of AI tools into the curriculum. Across numerous students, such outcomes are reported as gains in productivity, self-confidence, and cooperative learning, especially in the context of a lot of feedback, e.g. on writing-related assignments or interdisciplinary problem-solving. This beneficial effect usually depends on variables such as AI illiteracy, discipline, and the idea of fitting the tasks. An example would be that students with STEM expertise gained more AI-based learning than their non-STEM counterparts who had difficulties with prompt optimization or the amalgamation of AI navigation (Zhu et al., 2023).

The subtle connection between AI and cognitive development is the other recurrent theme. Although AI can assist in surface-level academic assignments like summaries, writing, and brainstorming (Ravšelj et al., 2025; Johnston et al., 2024), its impact on the more profound levels

of skills, including critical thinking, seems to be reduced to minimal values (Jia & Tu, 2024). These results demonstrate that AI should not be seen as a substitute for cognitive work instead it should be considered as a support to higher-order thinking, which needs to be designed carefully pedagogically. Moreover, such psychological and emotional aspects as AI usage have also become important factors in defining how well it works. According to the research given by Almufarreh (2024) and Mahapatra (2024), emotional well-being, peering cooperation, and low anxiety are crucial to maintaining student engagement. It demands a more emotion-sensitive and all-embracing AI design, particularly for marginalized or less competent learners.

Strengths of AI applied in the educational field are personalization and accessibility as shown by Jauhiainen and Garagorry Guerra (2024) and Jingwei et al. (2025). However, personalization also has its boundaries: in many cases, the AI is unable to understand subtle or context-based materials and raises concerns over over-reliance and loss of student agency. The problem of academic integrity, fairness, and ethical use of AI is another ongoing challenge especially when used by students to complete activities other than grammar assistance (Johnston et al., 2024). Moreover, the teacher experience, according to Lee et al. (2024), records the mismatch between technological potential and institutional readiness and requires more specific policies and professional development as possible guidelines for applying AI. In sum, although AI seems to have tremendous possibilities to become a useful learning tool, its successful and fair implementation demands not one, but many facets to be considered when choosing between pedagogical, ethical, emotional, and technical.

5. Limitation

This review of empirical research on the use of generative AI is prone to various limitations, which should be considered. To begin with, most of the reviewed studies depend on self-reported data and use surveys and interviews, this factor may lead to response bias and restrict the objectivity of the results. Furthermore, there is uneven representation in the disciplines. The research on the application of AI in humanities arts or vocational areas is scarce compared to the works on STEM or language-based fields. This restricts the applicability of results throughout the whole higher learning.

Moreover, the majority of the studies are located at a particular geographical or institutional level, so comparisons across cultures are hard. These studies under account the degree to which cultural differences, differences in educational policy, and institutional preparedness can be a great factor in how AI can be identified and embraced. In addition, ethical issues like algorithmic bias, data privacy, or the contribution of AI to academic inequalities were under-explored. Thus, there is a demand for additional interdisciplinary research to deal with these systemic and socio-technical challenges holistically.

6. Conclusion

The synthesis of the empirical research form shows that generative AI is quickly changing the nature of higher education as well as improving student engagement, learning efficiency, and personalization. Experience in various scenarios demonstrates that with the help of such tools as ChatGPT, it is possible to foster content creation, formative assessment, provision of

feedback, and transdisciplinary learning. Nevertheless, there are also issues that are accompanied by high dependence levels and decreased cognitive loads, issues related to academic integrity, data privacy, and the inability of AI to think critically.

Overall, the introduction of AI into the learning process must be regarded not only as a technological shift but also as a pedagogical transformation that requires considerate design as well as inclusivity and transparency. The research on the future should not be limited to short-range assessments but rather the long-term effects of varied fields, geographical worlds, and different types of learners. The current use of generative AI (and AI in general) should be reciprocally balanced, maximizing the positive changes and, simultaneously, reducing the risks, as it will be crucial to make certain that such tools indeed improve the quality, equity, and innovation of education sustainably.

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Data sharing statement

No additional data are available.

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