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Generative artificial intelligence in education: an umbrella review of applications and challenges

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Systematic Review

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Generative artificial intelligence in education: an umbrella review of applications and challenges

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Abstract

Multimodal generative artificial intelligence is revolutionizing critical domains, including education, healthcare, business, and entertainment. This article presents a comprehensive umbrella review of prominent surveys, reviews, and SLRs on advances in generative AI in teaching and learning, synthesizing its applications, benefits, challenges, and implications. We applied the systematic literature review (SLR) protocol and PRISMA framework to guide our search methodology and screen the relevant studies to ensure accuracy and replicability and reduce bias. We searched three popular academic databases, namely Scopus, Web of Science, and Google Scholar, screening 451 candidate articles published between 2020 and 2024. From these, we identified 46 relevant GenAI reviews in education. Our investigation of the reviews answered five research questions covering the academic disciplines adopting generative AI, applications of large multimodal models in education, their impact on student performance, their impact on teaching and assessment, and overarching challenges. Recent trends showed China and the USA as leading publishers of GenAI reviews, ChatGPT as the most popular GenAI tool used in education, and text as the primary modality of interaction among students and teachers. Several reviews explored the application of generative AI in multiple academic disciplines instead of a single domain. Students use GenAI tools to understand complex notions, learn foreign languages, improve writing skills, prepare for assessments, and enhance engagement. However, teachers apply GenAI tools to develop course materials, improve pedagogical methods, design various assessments, evaluate learning outcomes, and provide personalized feedback. We conclude our umbrella review by presenting a taxonomy of challenges impeding the adoption of multimodal generative AI in teaching and learning. Key issues of GenAI include academic dishonesty, negative impacts on critical thinking skills, integration with traditional teaching philosophies, and lack of emotional intelligence in generative AI platforms.

Keywords: Generative artificial intelligence, Large multimodal models, LMMs, Large language models, LLMs, Education, Teaching, Learning, Student, ChatGPT

1 Introduction

Artificial intelligence (AI) is defined as the interdisciplinary domain that aims to design machines that can accomplish tasks requiring human intelligence [1], [2]. AI has numerous subdomains, including expert systems, machine learning, machine vision, deep learning, and natural language processing. Many of these subdomains have already been applied to education [3]. Recent AI-driven tools, such as QuillBot, Aitists, Autogradr, speech recognition chatbots, Carnegie Learning, Knewton, Duolingo, and squirrel AI, are used across educational disciplines to perform a range of learning tasks. Such AI tools enhance learning, collaboration, and problem-solving by improving student comprehension and engagement. Moreover, these tools offer complex features for learners, such as organizing and collaborating on projects, text paraphrasing, AI agent building, automated grading, collaborative software building, personalized content and recommendations, gamified lessons and quizzes in different languages, query answering via voice commands, and personalized learning paths [4].

The recent hype on generative artificial intelligence (i.e., generative AI or Gen AI) is inspired by its ability to generate novel and original content in a variety of modes, like text, audio, images, computer code, video, and music, based on diverse inputs, comprising text, images, sounds, animation, 3D models, or other data types. The use of multiple modalities of input and output is referred to as multimodal generative AI (.e.g., LMMs). A myriad of generative AI tools are available nowadays, exploiting the benefits of deep learning models, like generative adversarial networks (i.e., GANs) or variational autoencoders (i.e., VAEs). Such models are pre-trained on huge multimodal datasets to identify patterns and structures and interpret complicated information in texts. These models then apply their knowledge to provide useful responses when users ask questions [5]. Various multimodal generative AI tools, such as ChatGPT, DALL-e, Bard, Midjourney, Microsoft Copilot, Google Gemini, and Call Annie are utilized to generate a more personalized and precise learning experience, novel image generation, music generation or composition, story generation based on user textual input, intelligent search and findings, and as a virtual assistant for English language learners. Generative AI in education across various disciplines helps students with advanced and personalized resources by making the educational process more effective and engaging [6].

Multimodal generative AI is rapidly integrated into various academic disciplines, such as computer science, engineering, finance, marketing, math, physics, communication, healthcare, and general education. In higher education, generative AI creates personalized learning material and environments based on student textual input, requirements, comprehension, and learning pace [7]. Generative AI-based learning environments can assess different learning behaviors to identify areas for improvement and provide personalized instruction [8]. Moreover, generative AI can automate various teaching tasks, like curriculum and instructional activities design, lesson plans, practice exercises, quizzes, assignments, scenario questions, projects, and grading. This helps teachers to concentrate on other teaching areas and research activities [9]. In healthcare education, generative AI enables practitioners and medical students to design medical education curricula, case scenarios, simulation scenarios, and quizzes, facilitating self-directed learning [10]. In marketing education, generative AI can achieve operational efficiency, cost-effectiveness, and valuable insights for better campaigns by monitoring ad performance and generating creative ad content. [11]. Indeed, generative AI has transformed traditional practices in many academic disciplines, including computer science [12], English [13], science [14], math [15], physics [16], and tourism [17] by creating personalized learning content and feedback based on unique student needs.

There has been a considerable surge in research exploring the utilization of generative AI in educational settings, specifically in teaching and learning. However, according to the best of our knowledge, none of the previous works provided an umbrella review that synthesizes findings from recent surveys or reviews on multimodal generative AI in teaching and learning. Table 1 succinctly summarizes the limitations extracted from selected GenAI surveys.

Our systematic literature review of surveys and reviews aims to thoroughly synthesize the applications of generative AI across academic fields. The review explores the perspectives of generative AI on improving student learning and performance and highlights the benefits of generative AI in advancing teaching methodologies and assessment strategies. Moreover, this review highlights the theoretical, technical, ethical, financial, and political issues of GenAI in education, concluding with important implications in education. We start by identifying the gaps in existing reviews within the area of generative AI in education.

1.1 A Summary of Existing GenAI Surveys and Reviews Limitations

- According to our knowledge, no umbrella review explores the use of generative AI in education (teaching and learning).
- Most existing reviews primarily focus on the applications of generative AI in medical or healthcare education. Fewer reviews compared to those in healthcare explore the applicability of generative AI in teaching and learning across other academic disciplines. Examples of such studies include [1, 5, 6, 7, 13, 17, and 18], which discuss the broader applicability of generative AI in educational settings.
- Several studies [e.g., 1,2,4,5,6,8,9,13,14,15,17 and 18] lack thorough details about their research methodologies, including paper selection procedures and criteria. This methodical gap raises concerns about the transparency and rigor of the research process and the validity of the findings.
- A notable limitation in existing research is the absence of detailed discussions on the impact of generative AI on student learning performance and educational outcomes.
- Another limitation is the lack of research focusing on the use of generative AI as a teaching aid for educators (e.g., to design and evaluate assessments to monitor student performance in class, to use generative AI insights on research areas, or to improve pedagogical practices). Understanding its impact on teaching methodologies and instructor-student dynamics remains largely unexplored.
- Several surveys [e.g., 1,2,4,5,6,8,9,13,14,15,17 and 18] fail to provide a comprehensive discussion of the results, hindering a thorough understanding of the implications and limitations of generative AI in educational contexts.
- Existing literature predominantly centers around the usage and adoption of ChatGPT, overlooking other large language models and multimodal generative AI models (such as Gemini, Bard, etc.). This bias restricts the breadth of insights into the diverse applications and nuances of generative AI in education.

Table 1 Major Limitations of Current Generative AI Surveys.

Ref	GenAI application domains	Output type of GenAI models	Tools explored	SLR	Research methodology	Validated impact	Impact of GenAI on student learning	Guidelines to use GenAI	Implications	Limitations and threats
[49]	5-6 domains	Text only	ChatGPT	✓	Weak	×	✓	×	✓	×
[18]	1 domain	Text only	ChatGPT	✓	Weak	×	✓	×	✓	✓
[19]	3 domains	Text only	ChatGPT	✓	Strong	×	✓	×	✓	✓
[20]	1 domain	Text only	ChatGPT	×	Weak	×	×	✓	✓	✓
[21]	1 domain	Text only	ChatGPT	×	Weak	×	✓	✓	×	✓
[22]	3-4 domains	Text, image, speech, video and 3D	ChatGPT	×	Weak	×	✓	×	✓	✓
[23]	1 domain	Text only	ChatGPT	✓	Strong	×	✓	×	✓	✓
[24]	3 domains	Text only	ChatGPT	×	Weak	×	×	×	✓	✓
[25]	3 domains	Text only	ChatGPT	×	Weak	×	×	×	✓	✓
[72]	1 domain	Text and image	ChatGPT, BARD	×	Strong	×	✓	×	✓	✓
[26]	1 domain	Text, image, audio, 3D and video.	GPT3, GPT4, BERT, LaMDA, StyleGAN, BigGANs, DALLE, DALLE2, MuseNet, WaveNet, NeRF	×	Strong	✓	×	×	✓	✓
[27]	1 domain	Text only	ChatGPT	✓	Strong	×	×	×	✓	✓
[28]	1 domain	Text only	Bing Chat, Bard, Ernie, and ChatGPT	×	Weak	×	✓	✓	✓	✓
[29]	Not addressed	Image, Audio, video and 3D.	GLIDE, DALL-E, StyleGAN-3, BigGANs, StackGANs, WaveGAN, WaveRNN, StyleGAN-V, and GAF.	×	Weak	×	×	×	✓	✓
[30]	3 domains	Text Image, Audio, and video	Google's Gemini and OpenAI Q*.	×	Weak	×	×	×	✓	✓
[31]	8-9 domains	Text Image, Audio, video, and 3D.	ChatGPT, BERT, OpenAI, DALLE-2 , Lumen5, Soundraw, Looka, Podcastle, Gen-1, Lala.AI, Deep Nostalgia, Murf, Legal Robot, Cleanup.pictures, Fireflies, Podcastle, Krisp, Synthesia, and Claude.	×	Strong	×	×	×	✓	✓
[58]	1 domain	Text and image	ChatGPT and BARD.	×	Weak	×	✓	×	×	×
[32]	10 domains	Text, image, code.	ChatGPT, GitHub Copilot, and Amazon CodeWhisperer.	×	Weak	×	✓	×	✓	✓

1.2 Key Contributions of Our Umbrella Review

Motivated by the above research limitations and gaps, this systematic literature review of reviews (i.e., umbrella review) aims to conduct a thorough examination of the application of generative AI across various academic disciplines. This review of reviews discusses the positive impact of generative AI on student learning and performance. Moreover, it highlights how instructors utilize generative AI to improve their pedagogical and assessment strategies. The review also summarizes a taxonomy of the main challenges of using GenAI in education, comprising theoretical, technical, ethical, financial, and political obstacles. The scientific contributions of our umbrella review include the following:

- We provide an umbrella review that focuses on the broader scope of generative AI usage in education, with a focus on teaching and learning.
- Our research broadens the scope of generative AI investigations, shifting the emphasis from medical and healthcare education to encompass a more comprehensive exploration of its applicability in other academic disciplines.
- We follow the PRISMA guidelines for systematic reviews to enhance transparency and rigor in research methodologies and address a notable gap in existing GenAI studies.
- We provide an in-depth discussion on student academic performance and attributes post the integration of generative AI, facilitating a holistic understanding of its impact on educational outcomes.
- We fill the critical gap in existing research by examining the use of generative AI as a teaching aid for educators, shedding light on its impact on teaching methodologies and the dynamics between instructors and students. This aspect represents a valuable contribution to the current body of knowledge.
- We explore large language models beyond ChatGPT to achieve a more comprehensive understanding of generative AI in teaching and learning, thus expanding insights into the diverse applications of this modern technology in education.

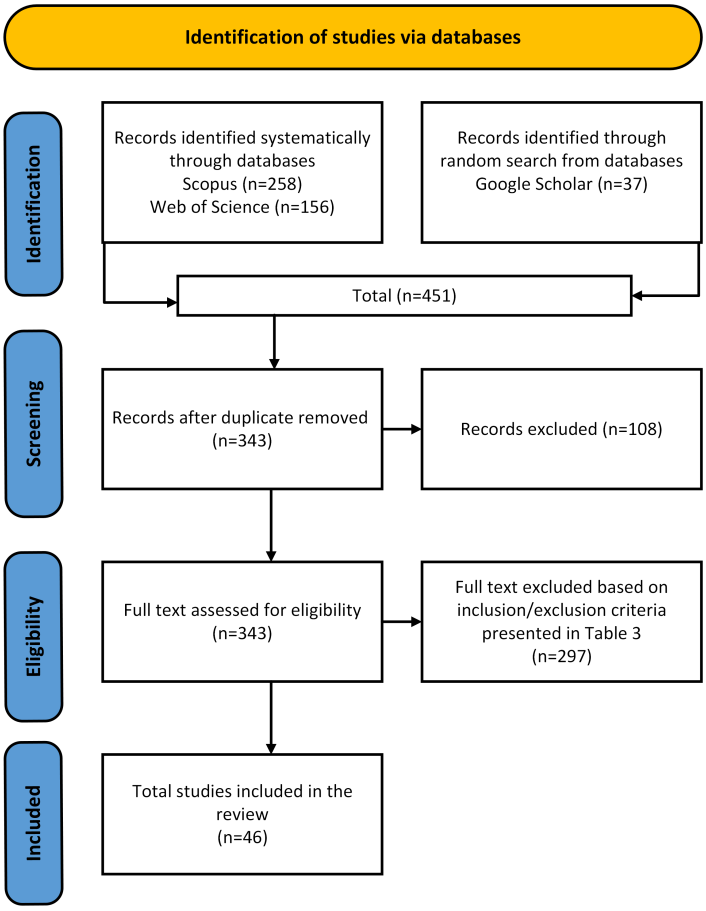


Fig. 1 A flow diagram of the PRISMA quantification process.

Table 2 A mapping between research questions, existing weaknesses in literature, and our research contributions (RQ= Research Question).

RQ	Weakness to Address (based on our analysis of existing surveys)	Research Contributions
RQ1	Existing surveys/reviews focus on the use of GenAI in healthcare education, ignoring other academic disciplines where generative AI is applicable and beneficial.	We explore the diverse academic fields where generative AI has been applied successfully in teaching and learning. We will conduct a bibliometric analysis of generative AI to showcase the recent trends.
RQ2	Existing surveys/reviews emphasize on text-based input and output, with limited attention to other modalities, such as image, audio, video, code, and 3D outputs.	We focus on the broader impact and potential use of multimodal generative AI in various educational scenarios.
RQ3	Existing surveys/reviews focus on the benefits of generative AI for student learning, with insufficient emphasis on student performance and progress attributes within educational contexts.	We identify how generative AI can enhance student personalized learning experiences and academic performance.
RQ4	Existing surveys/reviews lack an in-depth exploration of generative AI tools usage by instructors in education.	We investigate how generative AI is leveraged by educators to empower adaptive learning materials, personalized content creation, and automated grading systems.
RQ5	Existing surveys/reviews identify the challenges of adopting GenAI in medical and enterprise disciplines but lack a comprehensive coverage of GenAI obstacles in other academic disciplines.	We propose a taxonomy of challenges that impede the adoption of generative AI in education.

2 Umbrella Review Methodology

Recent literature contains extensive systematic reviews and surveys focusing on generative AI in education. Unlike prior works, we provide a comprehensive umbrella review. An umbrella review is a comprehensive synthesis of evidence derived from multiple existing reviews and surveys [82]. Umbrella reviews facilitate comparison between different individual reviews. Using diverse sets of evidence, researchers can easily identify patterns, discrepancies, and consistencies across multiple studies. This comparative analysis enhances our understanding of a specific topic and highlights areas of convergence or divergence among various research findings. Moreover, umbrella reviews can address broader questions and can be useful for comparing interventions and developing guidelines [83].

To increase and maintain the accuracy of our review, we applied the preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 guidelines for conducting systematic literature reviews (SLRs) [80]. PRISMA provides a standard methodology that uses a guideline checklist to plan and conduct systematic reviews to ensure that all essential information is captured. Moreover, it helps to assure the quality of the review process. A review protocol is developed, describing the article eligibility criteria, information sources, search strategy, selection criteria, data extraction, and data analysis procedures. The systematic literature review process [103] following PRISMA guidelines involves a comprehensive analysis of candidate articles by considering the review protocol. In our study, we carried out a literature search of reviews using Google Scholar, Scopus, and Web of Science academic databases. Our systematic search focused on studies published in English between 2020 and 2024 to capture advances and recent trends in generative AI research.

In this section, we formulate the research questions, search process, inclusion/exclusion criteria, and quality assessment process. To begin the review process, it is crucial to identify research questions (RQs) as they define our research scope and motivations. This review is motivated by five fundamental questions that serve as the basis for the literature review search strategy. Table 2 presents a simple mapping between our research questions, existing weaknesses in relevant studies, and our research contributions. Our research questions are outlined below.

RQ1. What academic disciplines have used multimodal generative AI to enhance the quality of their learning and teaching practices?

RQ2. How is multimodal generative AI, beyond text-only large language models (LLMs), used in education?

RQ3. How does multimodal generative AI impact student learning and performance?

RQ4. How is multimodal generative AI used by educators/instructors to enhance their teaching and assessment strategies?

RQ5. What challenges and limitations hinder the adoption of multimodal generative AI in teaching and learning?

Table 3 Our inclusion (IC) and exclusion (EC) criteria.

Inclusion Criteria	Exclusion Criteria
IC1- Research studies on Generative AI applications in academic/educational domains.	EC1- Research studies that did not discuss Generative AI or applied to domains other than education, such as healthcare and e-commerce.
IC2- Research studies of type survey or review only.	EC2- Original research articles published in journal and conference venues.
IC3- Research studies that are published from January 2020 to January 2024.	EC3- Articles published before 2020 and studies that did not include the full text of the study report.
IC4- Research studies that are peer-reviewed and published in journals or conference proceedings.	EC4- Studies published in preprints and gray literature, including theses, dissertations, technical reports, opinions, discussions, editorials, viewpoints, comments, tutorials, lessons, pilot studies, and presentations.
IC5- Research studies written in the English language.	EC5- Research studies that are not published in the English language.
IC6- Surveys or reviews that focus solely on education, teaching, and academia.	EC6- Surveys or reviews that discuss a mix of domains, including education/academia.
IC7- Research studies that are directly relevant to our research questions.	EC7- Research studies that do not contribute toward answering any of our five research questions.

2.1 Eligibility Criteria

Candidate reviews and surveys were evaluated based on their titles and abstracts. Each candidate article had to focus on generative artificial intelligence and be of type survey, review, or SLR to be considered in our umbrella survey. Specific key terms used for the search are listed in the next section. Only English-language articles published between 2020 and 2024 were selected for inclusion in our umbrella review. Moreover, the search process was restricted to scholarly peer-reviewed articles published in journal venues and conference proceedings. The specific inclusion and exclusion criteria applied to guide our selection of relevant reviews are listed in Table 3.

2.2 Information Sources

In the design of the review process, we began by searching for keywords in three top electronic digital libraries, namely, Google Scholar, Web of Science, and Scopus. The size of these academic databases was estimated to be around 389 million indexed records, 100 million, and 60 million, respectively [104]. Using the search options available on these academic databases, we focused our search on the title, abstract, and index terms to find candidate journal and conference articles. It is worth noting that the search syntax had to be varied among the three academic databases to retrieve candidate review articles.

2.3 Search Strategy

To ensure comprehensive and bias-free searches, the population intervention comparison outcome (PICO) framework [81] was adopted to formulate research questions and to plan search strategies. The PICO framework is used to develop well-structured search methods and to shape well-constructed search queries using four components. Moreover, it is used to categorize the search keywords by grouping and narrowing down a research issue into a searchable query. PICO components help to identify search terms/concepts to utilize in literature searches. Based on the PICO model, we chose the following search terms:
Population: “education”, “academic”, “academic disciplines”, “educational domain”, “students”, “educators”, “instructors”.
Intervention: “Generative Artificial Intelligence”, “Generative AI”, “GenAI”, “Multimodal generative AI”, “Large language model”, “LLM”.
Comparison: “Traditional learning”, “Conventional learning”, “Classroom instruction”, “e-learning”.
Outcome: “Learning”, “Performance”, “Teaching”, “Assessment”, “Challenges”, “Issues”
Table 4 shows the keywords in our research questions along with PICO elements and search phrases. The search strings were developed by combining the search terms from different categories using boolean operators (AND, OR). Each digital library has its specific requirements and syntax for the search phrases. Each search term in education or academic discipline yields a high number of results, but the search strings have been limited to the articles that contain the words “survey”, “review”, and “systematic literature review” in their title or abstract.

Table 4 Keywords in research questions along with PICO elements and search phrases.

RQ	Keywords in Question	PICO Elements	Search key terms/phrases
1	What **academic disciplines** have used **multimodel Generative AI** to enhance the quality of its **teaching and learning**?	"P: Academic disciplines I: Multimodal generative AI C: Conventional or traditional approaches O: Improved teaching and learning"	"Academic disciplines / generative Artificial Intelligence / generative AI / GenAI / Teaching OR Learning"
2	How is **multimodal Generative AI**, beyond large language models, used in **education**?	"P: Education I: Multimodal generative AI, large language models C: Conventional or traditional approaches O: Improved academic performance"	"Education Generative Artificial Intelligence / generative AI / GenAI / multimodal generative AI / large language models"
3	How does **multimodal generative AI** impact **student** learning and performance?	"P: Students in the educational domain I: Multimodal generative AI C: Conventional or traditional approaches O: Improved learning and performance"	"Students in the educational domain Generative Artificial Intelligence / Generative AI / GenAI Multi-modal Generative AI / large language models"
4	How is **Generative AI** used by **educators/instructors/teachers** to enhance their teaching and assessment strategies?	"P: Educators/instructors I: Generative AI C: Conventional or traditional approaches O: Improved teaching and assessment strategies"	"Educators/instructors Generative Artificial Intelligence / Generative AI / GenAI"
5	What **challenges and issues** hinder the use of **Generative AI** in **teaching and learning**?	"P: "Teachers and Students I: Generative AI C: Conventional or traditional approaches O: Challenges and issues"	"Teachers and Students Generative Artificial Intelligence / Generative AI / GenAI"

2.4 Selection Process of GenAI Reviews

In this step, the most relevant journals and conference proceedings are selected for our systematic review. A systematic review involves four phases of the article selection process: identification, screening, eligibility, and inclusion [80]. In the identification phase, we identify the total number of articles extracted from databases. During the screening phase, duplicate papers are manually excluded based on their title. The manual selection process involves choosing titles that include the terms "Generative AI", "teaching", and "learning". After this step, the number of articles is further reduced. In the eligibility phase, the articles are screened by assessing content-based or full-text for eligibility. After excluding irrelevant studies based on our inclusion and exclusion criteria, we determined 46 relevant publications. Figure 1 depicts the complete PRISMA quantification process from the identification of studies via databases to the final list of studies to be included in our umbrella review.

2.4.1 Data Extraction

Data extraction involves the collection of relevant information from the selected studies. It helps to generate significant evidence by assembling large data collection. Selected studies are read and examined thoroughly to answer the posited research questions and fulfill the identified gaps. Subsequently, the selected publications were documented for analysis with the following fields for key elements of research questions: author(s), survey type, year, focus of survey, domain of application, findings, strengths, and weaknesses. Moreover, we extracted specific data items to answer our five research questions, including academic disciplines, tools, modalities, concepts understanding, skills, motivation, assessment, course content preparation, learning outcome, progress, and challenges.

3 Results

3.1 Bibliometric Analysis

This section presents a comprehensive bibliometric analysis of the general Artificial Intelligence reviews explored in this umbrella review. By visualizing the bibliographic data, we aim to highlight trends, influential entities, and the interconnectedness within the GenAI field. The subsections cover analyses of keywords, universities, countries, authors, citations, and co-citations, each illustrated through network graphs.

3.1.1 Keyword Co-occurrence Analysis

VOSviewer software offers a feature to perform keyword co-occurrence analysis, an analysis that maps out the connections between keywords and terms found in the selected reviews [79]. Moreover, researchers can visually explore how these terms relate to each other. By using co-occurrence analysis, researchers can create a network map of terms to highlight the dominant research trends and create a conceptual structure of a particular field (GenAI in our case). We created a co-occurrence network that included all articles' keywords, with at least two occurrences for each keyword. Table 5 shows

that 37 keywords appeared in the reviews. In keyword co-occurrence analysis, a link signifies the

Table 5 A list of keywords, their frequency of occurrence (Oc), and total link strength.

Keyword	Oc	Total link strength	Keyword	Oc	Total link strength
Computer Science	44	427	Biology	9	90
Psychology	37	360	Epistemology	8	95
Political Science	26	294	Data Science	8	93
Engineering	26	284	Field (Mathematics)	8	91
Law	24	278	Pure Mathematics	8	91
Artificial Intelligence	23	209	Medical Education	7	92
Mathematics Education	22	206	Medicine	7	92
Engineering Ethics	21	234	Curriculum	7	91
Pedagogy	19	204	World Wide Web	7	67
Sociology	15	149	Operating System	6	80
Medline	13	166	Management Science	6	71
Social Psychology	13	145	Transformative Learning	6	66
Generative Grammar	13	136	Chatbot	6	41
Knowledge Management	12	143	Process (Computing)	5	68
Systematic Review	11	146	Scopus	5	60
Philosophy	11	114	Inclusion (Mineral)	5	59
Higher Education	10	118	Paleontology	5	49
Social Science	10	96	Language Acquisition	5	33
Mathematics	9	108			

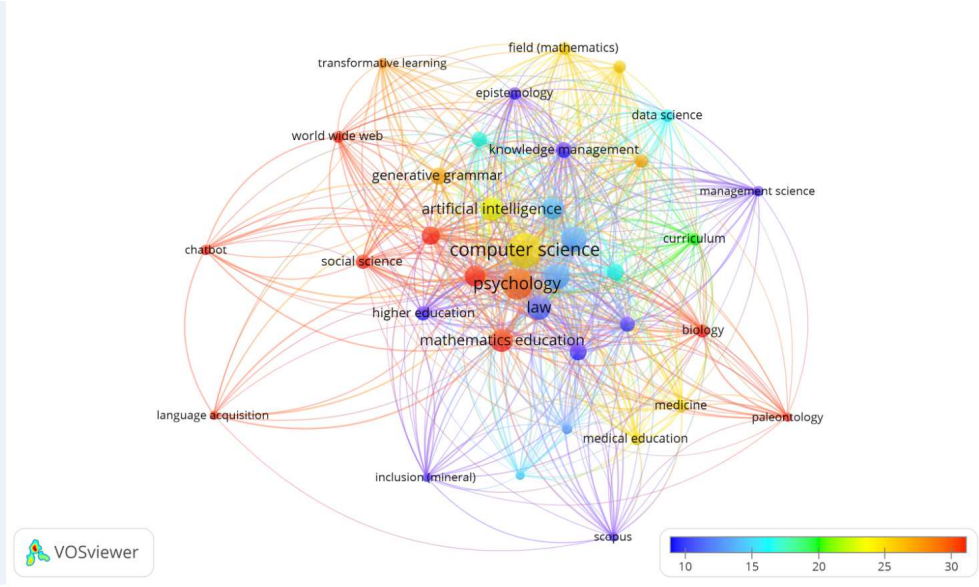


Fig. 2 A network visualization of keyword co-occurrence analysis.

relationship between two keywords that occur together in the literature. Figure 2 presents a visual display of words in different sizes, highlighted by a notable circle among other linked components. The size of a circle within a network visualization correlates to how often a term appears in the literature. Moreover, each color denotes a cluster where keywords in the middle have more frequency than keywords on the outer side. Figure 2 shows that Computer Science, Engineering, Psychology, Mathematics, Political Science, and Law are the most reported keywords by generative AI reviews.



Fig. 3 A network visualization of country analysis.

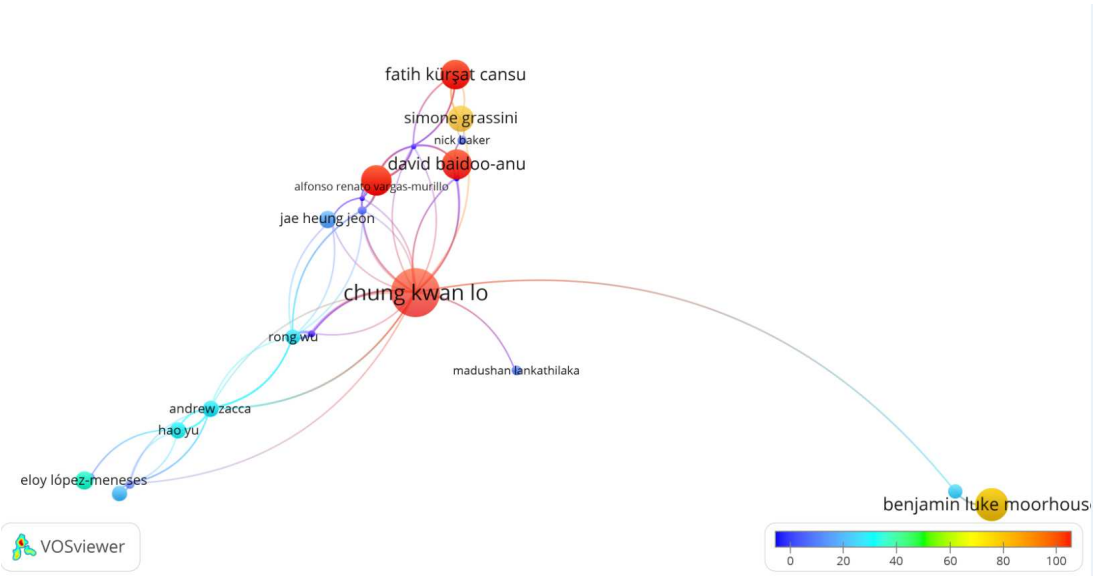


Fig. 4 A network visualization of citation analysis.

Table 6 A list of universities, number of published GenAI reviews, citations, and total link strength.

Country	Published Reviews	Citations	Total link strength
Education University of Hong Kong	2	412	58
Hong Kong Baptist University	2	129	46
Izmir University of Economics	2	103	23
Shaanxi Normal University	2	40	7
Hannam University	2	36	195
Indiana University Bloomington	2	36	195
State University of Padang	2	1	0

3.1.2 Universities Analysis

A university network analysis enabled us to check the frequency of universities publishing GenAI surveys and visually discover how these universities collaborate with each other. In this analysis, an organization map includes all universities that have appeared in at least two review articles. Our analysis identified 7 universities that have appeared in the generative AI literature. A link signifies

the relationship between two universities that appear together in the literature. Figure 8 presents a visual display of universities in different colors. Each color denotes a cluster, where universities in the middle have more collaborations than universities on the outer side. We can observe that two universities in Hong Kong lead the collaboration graph with the highest number of citations, followed by Izmir University of Economics and Shaani Normal University.

Table 7 A list of countries, number of published GenAI reviews, citations, and total link strength.

Country	Published Reviews	Citations	Total link strength
Hong Kong – China	2	412	1
China	8	198	2
United Arab Emirates	3	152	0
Canada	4	130	2
Turkey	2	103	1
United States	7	80	5
Spain	3	39	0
South Korea	2	36	2
Indonesia	4	19	0

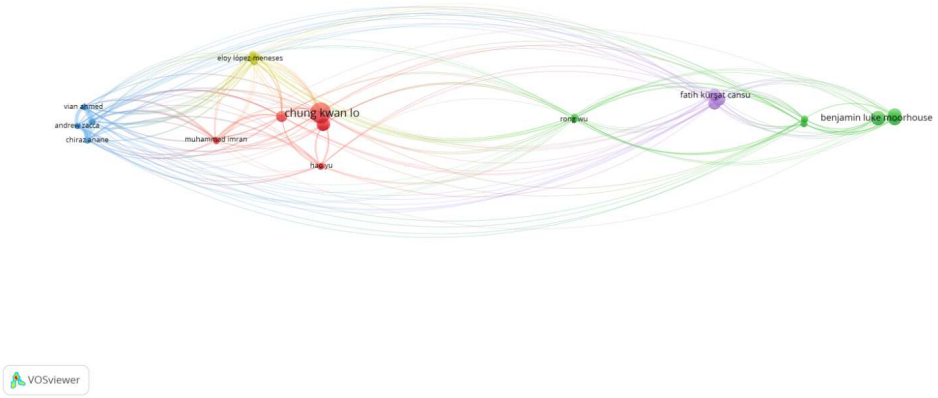


Fig. 5 A visualization network of bibliographic coupling analysis of authors.

3.1.3 Countries Analysis

A countries analysis enabled us to explore the frequency of countries with the most generative AI publications in our pool of articles. Moreover, this analysis maps out the connections between countries and the number of citations found in the literature. We created a network map of all countries that published at least two GenAI reviews. A link signifies the relationship between two countries that appear together in a published work. Figure 3 presents a visual display of countries in different colors. Each color denotes a cluster, where countries in the middle have more GenAI articles than countries on the outer side. We can see that the United States is at the center of collaboration between three clusters, while Hong Kong and China lead the number of citations. The analysis identified 9 countries that have appeared in the generative AI literature, as listed in Table 7.

3.1.4 Citation Analysis

A citation analysis enabled us to explore the connections between published surveys in the generative AI landscape. The citation analysis graph visualizes the dominant articles of GenAI in education

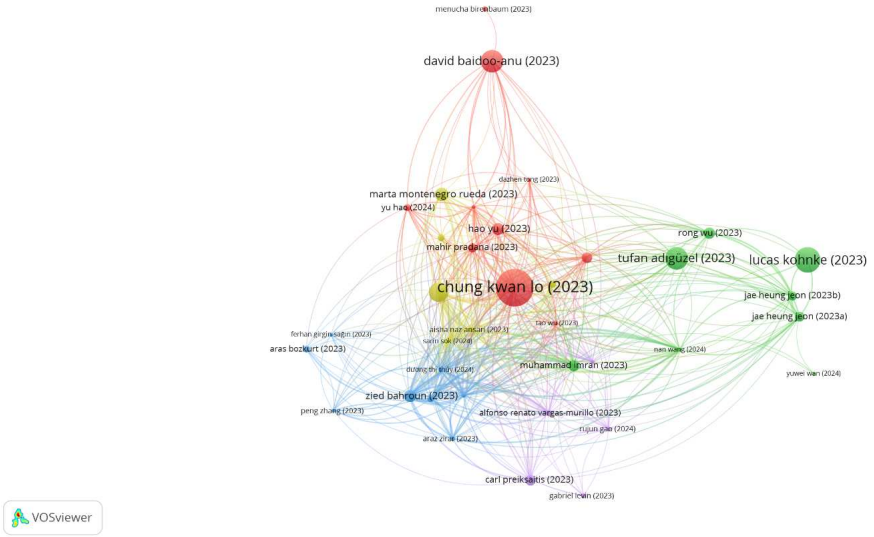


Fig. 6 A visualization network of bibliographic coupling analysis of articles.

Table 8 A list of authors, their citations, and total link strength.

Articles	Citations	Total link strength
Chung Kwan Lo	284	383
Benjamin Luke Moorhouse	129	111
Di Zou	128	94
Lucas Kohnke	128	94
David Baidoo-Anu	105	96
Leticia Owusu Ansah	105	96
Faith Kursat Cansu	103	280
Mehmet Haldun Kaya	103	280
Tufan Adiguzel	103	280
Andrej Thurzo	101	164
Jana Surovkova	101	164
Kelvin I. Afrashtehfar	101	164
Martin Strunga	101	164
Renata Urban	101	164
Simone Grassini	80	432
Eloy López-Meneses	37	169
José Fernández-Cerero	37	169
José María Fernández Batanero	37	169
Marta Montenegro Rueda	37	169
Seongyong Lee	36	541
Jae Heung Jeon	36	541
Hao Yu	31	170
Yanwen Guo	31	170
Andrew Zacca	29	1034
Chiraz Anene	29	1034
Vian Ahmed	29	1034
Zied Bahroun	29	1034
Rong Wu	28	175
Zhonggen Yu	28	175
Muhammad Imran	25	312
Norah Alsarraf	25	312

and how the published articles relate to each other. Figure 4 presents a visual display of articles in different colors. Each color denotes a cluster, where articles in the middle have more citations than articles on the outer side. The analysis identified 15 review articles that received more than 80 citations. A detailed list of GenAI reviews can be found in Table 8. In Figure 4, we can see that a

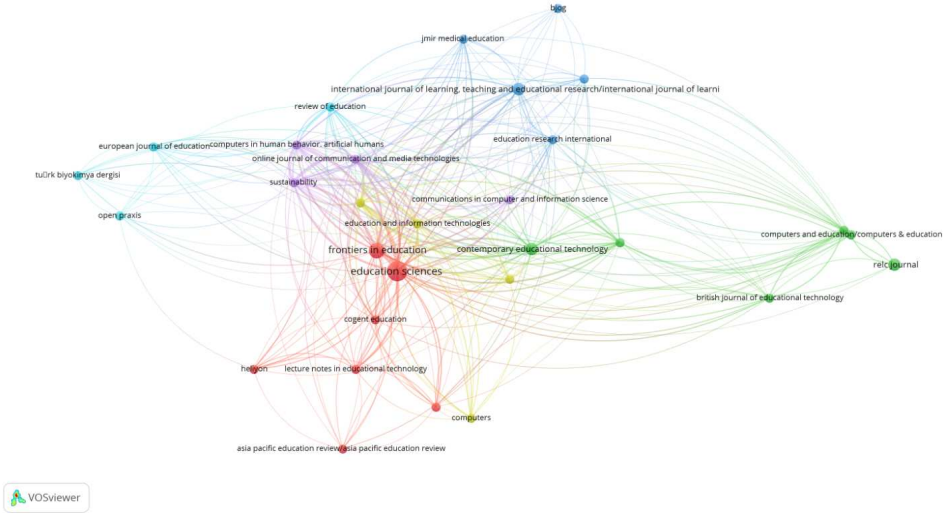


Fig. 7 A visualization network of bibliographic coupling analysis of journals.

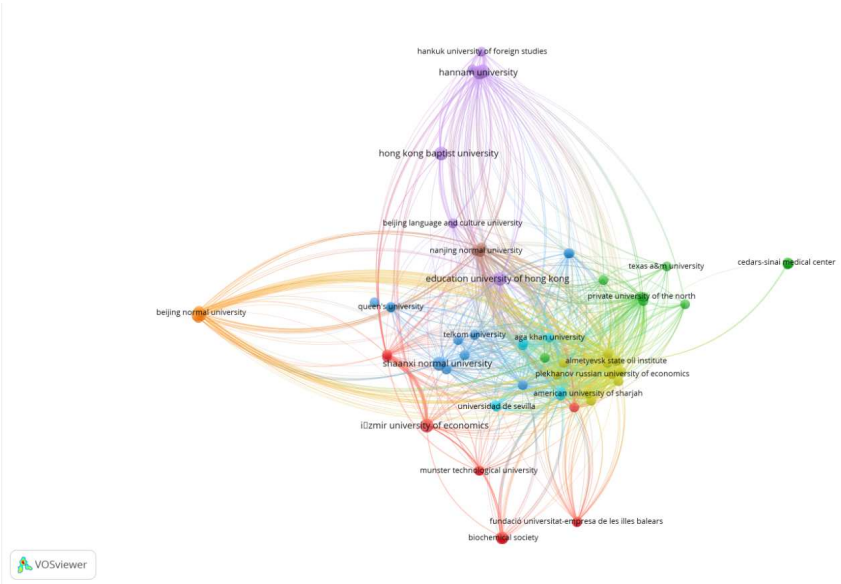


Fig. 8 A visualization network of bibliographic coupling analysis of universities.

rapid review by Chung Kwan Lo published in MDPI Education Sciences (2023) attracted the highest number of citations and has the strongest link in our review dataset.

3.1.5 Author Coupling Analysis

An author coupling analysis enabled us to explore the connections between two authors citing the same references. By using a bibliographic coupling network, we could visualize the influential authors being cited in generative AI. The coupling map includes all authors with at least 25 citations. A detailed list of 31 authors can be found in Table 8. A link signifies the relationship between two authors in terms of bibliographic coupling in the literature. Figure 5 presents a visual display of five author clusters in different colors. Each color denotes a cluster, where authors in the middle have more citations than articles on the outer side. Thus, we see that Chung Kwan Lo is the most bibliographically coupled author in the GenAI datasets.

3.1.6 Co-Citation Reference Analysis

A link signifies the relationship between two articles in terms of reference co-citations in the literature. Figure 6 presents a visual display of articles in different colors. Each color denotes a cluster, where articles in the middle have more co-citations than references on the outer side. Thus, we can see three main clusters of co-citations in the datasets, including 34 references with 2 co-citations or more.

3.1.7 Co-Citation Source (Journal) Analysis

A source analysis helps map out the connections between two sources, citing the same references from the literature. A link signifies the relationship between two journals in terms of article co-citations. Figure 7 presents a visual display of co-cited sources in different colors. Each color denotes a cluster, where the journal source in the middle has more co-citations than the journals on the outer side. Thus, we can see there are six clusters in the datasets, with Education Sciences as the most bibliographically coupled journal in the datasets.

3.1.8 Co-Citation Author Analysis

A co-citation author analysis enabled us to check the frequency with which the review of an author is co-cited with another author in citing articles. A link signifies the relationship between two authors in terms of co-citations in the literature. Figure **??** presents a visual display of authors in different colors. Each color denotes a cluster, where the source in the middle has more author co-citations than articles on the outer side. Thus, we can see three clusters in the datasets. The analysis of this figure shows that Chung Kwan Lo is the most co-cited author.

In the next sections, we answer each of our five research questions using identifiable trends extracted from the final set of review articles.

3.2 Academic Disciplines Implementing Generative Artificial Intelligence

In this section, we revisit our first research question and attempt to shed light on the academic disciplines that use generative AI to enhance student learning and teaching. Our first question states: What academic disciplines have used multimodal generative AI to enhance the quality of their teaching and learning?

As anticipated, our analysis reveals an increase in publication trends starting from 2023 within the domain of generative AI in education. Figure 9 illustrates this rising trend over the last two years. Country-wise, the USA and China are the top contributors to the GenAI field in terms of the number of surveys and reviews. Moreover, Indonesia, UAE, Canada, and Spain have made significant research contributions to generative AI in teaching and learning, as depicted in Figure 10. Multimodal generative AI has found its way into teaching and learning across various academic disciplines. Overall, it satisfies diverse educational needs and enhances the teaching and learning practices. Various academic disciplines utilize generative AI to improve the learning experience for both students and teachers. These academic disciplines include computer science, engineering, medicine, nursing, non-STEM domains, tourism, marketing, communication, higher education, general education, second and foreign languages, language learning, and early childhood education. Figure 11 shows the focus of recent reviews explicitly on a single domain, and Figure 12 shows the use of generative AI across various education levels.

Generative AI is frequently used in language learning of second or foreign languages [36],[42],[55],[66],[67],[78]. For non-native speakers, generative AI acts as a personal language tutor [42][55], and universities have integrated multimodal generative AI into language learning programs, serving as conversational partners, feedback providers, and resource facilitators. Moreover, speech-recognition chatbots are valuable generative AI tools to support language learning. For example, according to the study in [78], these chatbots have proven effective for illiterate users, such as preschool children and beginner-level second language learners who have yet to learn reading and writing. Moreover, in the classroom, teachers may ask students to interact with Call Anie for role-play activities and to learn communication by practicing this tool before communicating with peers. Our analysis found that generative AI is also used in medical education [72], [77]. In medical education, multimodal generative AI is implemented at undergraduate and postgraduate levels, offering personalized learning paths and immediate feedback based on individual student performance [72].

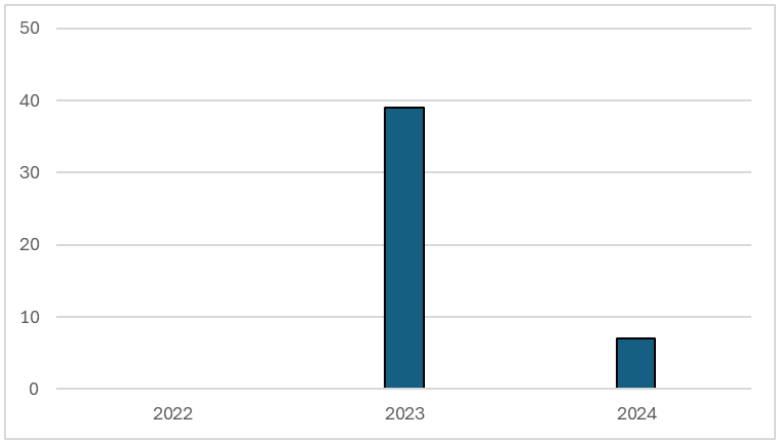


Fig. 9 Year-wise publication trend of generative AI in education.

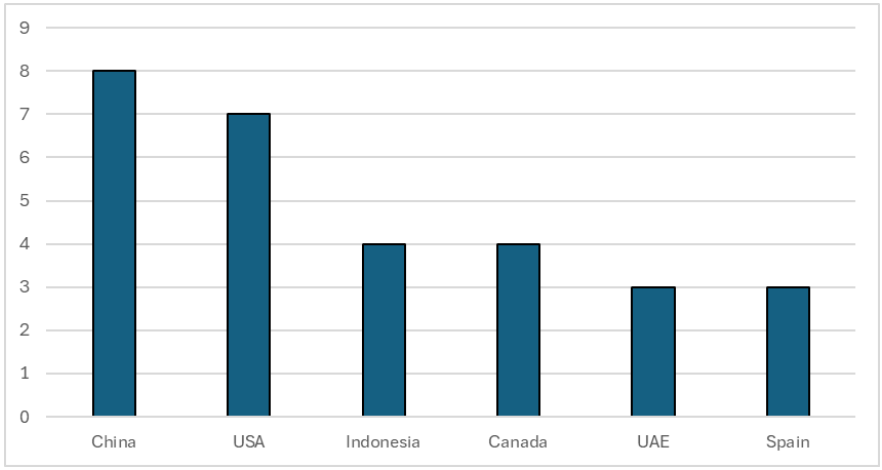


Fig. 10 Country-wise publication trend for generative AI in education.

Overall, generative AI is used by various disciplines to improve teaching and learning. Table 9 summarizes the prominent academic disciplines that have used multimodal generative AI to enhance different aspects of teaching and learning.

Several survey studies provided a review of generative AI in multiple disciplines. For example, the authors in [49] provided a content analysis on how generative AI impacts educational domains, such as engineering and medical education. They discussed the applications of generative AI in computer science, engineering, nursing, communication, and general education. Similarly, the authors in [43] provided a rapid literature review on the impact of ChatGPT across various domains during the first three months of its release. In their findings, the authors suggest that ChatGPT's performance varies across subject domains, ranging from outstanding (e.g., economics) and satisfactory (e.g., programming) to unsatisfactory (e.g., mathematics). In [71], the authors conducted a systematic literature review and found that English language learning is the most accountable domain in previous research, followed by health education and computer science. The authors also revealed that Generative AI is used in engineering education, business management, chemistry, sports management, tourism, construction, academic advising, education for sustainable development, chemistry education, science education, geography education, and math education. Moreover, generative AI supports students with special needs across various disciplines, including those with weaker conceptual understanding, limited access to educational resources, and disabled or special education needs (SEN) learners [40], [41], [54]. For instance, a first-year medical student struggling with understanding acid-base balance can seek assistance from a generative AI tool like ChatGPT. In response, ChatGPT assesses the student's knowledge, provides personalized learning materials, and offers feedback tailored to the student's understanding level. Similarly, generative AI aids students with SEN, as evidenced by its application in health education for individuals with Down syndrome, highlighting its significance in cognitive development and social interaction [49]. Generative AI can identify student strengths, weaknesses, and preferences and then adapt the learning content accordingly. For example, if a first-year

Table 9 A summary of academic disciplines using multimodal generative AI to enhance the quality of their teaching and learning.

Academic Discipline	Reviews	Focus of Review	Key Observations/Insights
Higher Education	[33], [34], [37], [38], [39], [40], [41], [47] [74], [75], [76], [78], [57], [60], [62], [64], [65], [66], [69], [71]	Supporting specific content learning or analysis, Academic writing tasks, Language tutoring for non-native English speakers, Personalized learning experiences, Curriculum development	Examples: Thousands of international students benefit from AI-driven language tutoring [38], AI tools adapt content based on student preferences [40],
Medical Education	[72], [77]	Various aspects of medical education	Examples: AI in medical education benefits undergraduate and postgraduate students [72], AI applications in medical and nursing fields,
Dental Education	[48]	Application in dental education	Example: Most of the students use generative AI to enhance their dental practices [48]
Language Learning	[36], [42], [55], [66], [67], [78]	Language learning support, L2 speaking proficiency	Example: Chatbots enhance L2 speaking proficiency [78]
Physics	[50]	Application in middle and high schools	Examples: Students use generative AI to solve physics numerical problems [50]
Computer Science, Engineering, Medical, Nursing, Communication, Academia, General Education	[49]	Application in various disciplines, with emphasis on health education	Example: Significance in cognitive development and social interaction [49]
Education with special needs	[46],	Accessibility for disabled students	Example: AI supports accessibility for disabled students [46]
Science Learning, Second and Foreign Languages	[65], [66]	Application in science learning and teaching languages	Example: Students use these tools to learn a second language without any tutors [66]

Table 10 A summary of generative AI tools used in education.

Generative AI Tool	Modalities	Studies	Key Insights with Examples
ChatGPT	Text	[34], [35], [38], [40], [41], [43], [44], [45], [47], [48], [49], [50], [51], [52], [53], [54], [56], [72], [77], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [75], [76], [71]	Academic and scientific writing assistance, language teaching and learning, language translation, personalized language tutor, writing dialogue, personalized quizzes, grading short answer responses. For example, it helps students with academic writing, such as the formulation of research questions, hypotheses, methodology, and manuscript writing. It also aids in translation for real-time communication in different languages. Aid educators by offering personalized learning plans, study plans, guides, quizzes, assignments, and projects. It also assists teachers in academic writing and provides technical assistance in outlining, structuring, and references.
Bard	Text and image	[58], [72]	Gemini is used to provide realistic, natural language responses to user questions.
DALL-E	Text, and image	[59]	Help users to create or edit images by generating visually appealing content. Aid in marketing content such as design elements, ad content, and visual inspiration.
Midjourney	Text and image	[59]	Midjourney is used for visual content generation like ads, design elements, etc. to align with ad campaign goals.
Speech chatbots	Image, video, voice	[55], [78], [36]	Facilitate speech interaction with students or educators to provide personalized and enhanced language learning proficiency.
Bing AI	Text and speech	[70]	Assist students by responding to students through generated text-based answers as well as based on uploaded images by combining with real-world information from the internet

medical student expresses difficulty understanding acid-base balance and the relationship between buffering systems in the body, they may prompt ChatGPT for help. In response, ChatGPT would involve asking various questions to assess student knowledge of a specific topic. It would then provide personalized reading materials, learning resources, and feedback based on this assessment [53].

3.3 The Use of Multimodal Generative AI in Education

In this section, we attempt to explore how multimodal generative AI, beyond large language models, is used in education (Research Question 2). In teaching and learning, various large language models, including ChatGPT, DALL-e, Bard, Bing AI, Speech recognition chatbots, and Midjourney are utilized to generate a personalized and precise learning experience, novel image generation, music generation or composition, and story generation based on user textual input. Among these, ChatGPT

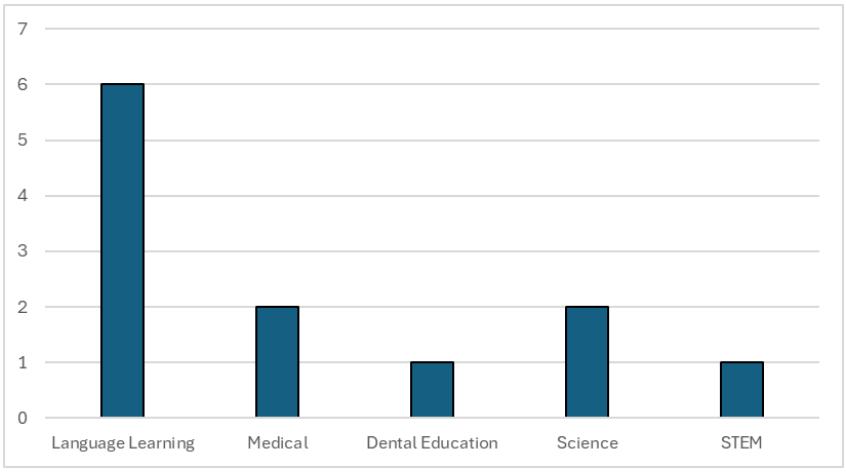


Fig. 11 The use of generative AI across various academic disciplines.

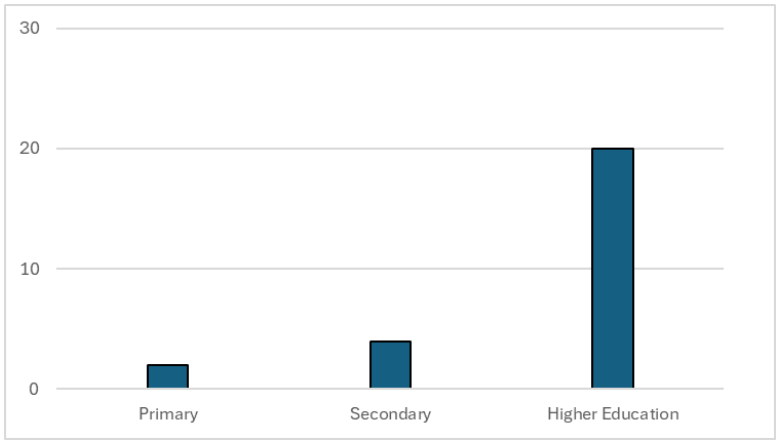


Fig. 12 The use of generative AI across various education levels.

is most commonly used by students and teachers in their educational practices, as presented in Figure 13. The use of generative AI tools in education across various disciplines helps students with advanced and customized educational resources by making the learning process more effective and engaging. There are several AI tools, including Notion, QuillBot, Aitists, Autogradr, Repl.it, ALEKS, Carnegie Learning, Knewton, Duolingo, and Squirrel AI are used across educational disciplines to perform various teaching and learning tasks. These AI software aim to enhance comprehension, collaboration, and problem-solving. They improve interaction and engagement across various aspects of learning and teaching using personalized content generation and adaptive assessments of educational content. Generative AI, such as ChatGPT, has become a prominent tool that is significantly utilized in various applications across educational disciplines [34], [35], [38], [40], [41], [43], [44], [45], [47] [48], [49], [50], [51], [52], [53], [54], [56], [72], [77], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [72], [75], [76], [77], [71]. ChatGPT helps university students in the generation of educational content, like research questions, research design, hypotheses, methodology descriptions, experiments' protocols, data analysis, and academic and scientific writing of manuscripts [34], [64], [69]. ChatGPT, along with Notion and QuillBot, are used by educators to generate new content, ideas, explanations, simplifications of complex concepts, presentations, course materials, and the creation of emails and announcements[40].

Generative AI tools, such as ChatGPT, BARD, and DALL-E, assist students and teachers in producing personalized educational content based on the context of a given prompt [40], [56], [57], [58], [59], [61], [62], [68], [70]. Furthermore, ChatGPT, along with Bard and Midjourney, offers personalized feedback based on the context of a given prompt [59], [64]. Teachers use ChatGPT and Google Bard to evaluate student assignments, which helps them reduce effort and save time. Utilizing these tools in assignment assessment helps to automate the grading process and provide efficient and consistent feedback [56], [59], [64], [70]. Additionally, these tools offer personalized and effective learning and teaching models, methods, plans, course materials, instructional activities and remote learning

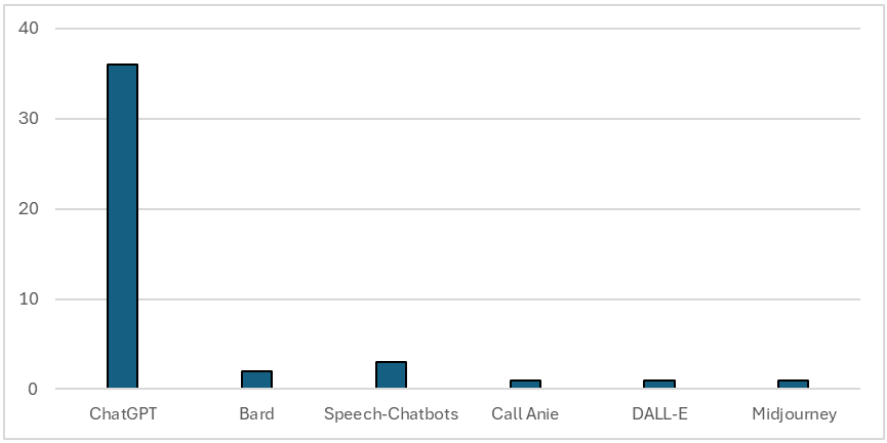


Fig. 13 Types of generative AI tools used in education.

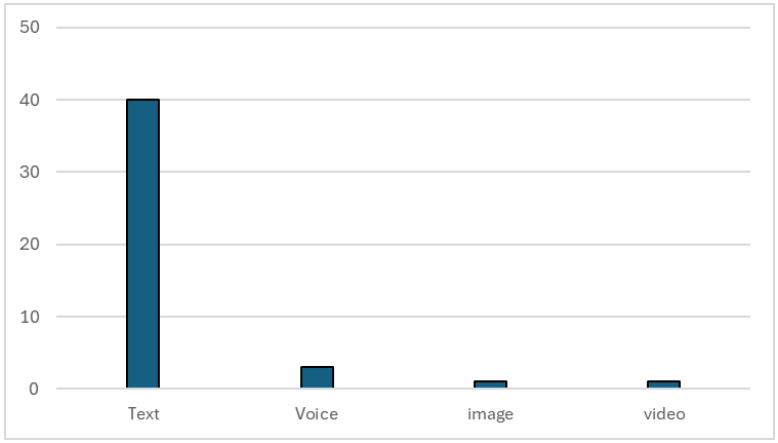


Fig. 14 Modalities of generative AI used in education.

experiences and explanations for individual students and teacher needs [56], [72], [63], [64], [65], [69], [70]. ChatGPT analyzes the performance of individual students and generates personalized learning materials based on their weaknesses. For instance, if a student struggles with a particular medical concept, the language model can generate additional resources or exercises to aid them in understanding the concept [72]. Moreover, it can provide a language translation facility for educational materials, ensuring that international learners can understand and engage with the educational content easily through an accessible and multilingual learning environment [57]. For example, ChatGPT translates text from one language to another in real time, and users can participate in educational conversations in the language that is most natural to them, even though the language of the resource or the instructor may be different [41]. ChatGPT is also utilized to improve methods for instructing and assessing second and foreign languages [66]. It generates distinct assessments that range from assignments and quizzes to projects and essays, answer questions, language practice, problem solution, and text summarization [64] [68] [69]. Moreover, it prepares teachers to conduct oral assessments, presentations, or interviews. Finally, generative AI supports administrative assistance and productivity [69], asynchronous communication, personas, task delegation, and cognitive offload [64].

Multimodal generative AI combines information from multiple modalities, such as text [34], [35], [38], [40], [41], [43], [44], [45], [47] [48], [49], [50], image [59], voice/speech [55], [78], [36], and video contexts [36], and can transform education by offering more engaging and tailored learning experiences. Our investigation shows that text is the most popular modality of generative AI that is used to support teaching and learning, as illustrated in Figure 14. In academic and scientific educational settings, generative AI, such as ChatGPT, acts as a writing tool, supporting various tasks like research question formulation, introduction writing, and proofreading to ensure accuracy [34]. Moreover, undergraduate and graduate students use GenAI across different disciplines to perform numerous learning tasks, such as comprehension, coding, mathematics, writing, research, and visual production [4, 6]. For example, the authors in [55] compared the effects of chatbots on children's

reading comprehension and engagement with or without dialogic strategies and human partners with or without dialogic strategies.

Teachers utilize generative AI tools to enhance their teaching practices and academic writing and to design personalized learning experiences [84], [85], [86]. Additionally, it provides technical assistance in research studies to perform various tasks, such as outlining, structuring, and referencing [85], [87], [48], [75]. Educators use generative AI to write dialogue or various categories of text subjecting to a single topic [42]. The formation of diverse marketing materials, such as blog posts, ad copies, social media posts, hashtags, captions, and headlines, is accomplished using different AI tools. Tools like Anyword, Jasper, Hypotenuse AI, CopyAI, and Writesonic facilitate content creation and translation. Other tools like Anyword and Jasper aid in analyzing historical data to predict the effectiveness of different words and copies on brand and consumer responses. Other large vision models, like Midjourney, Stable Diffusion, Dall-E, Adobe Firefly, and Aitist are used to create or edit images, resulting in the creation of visually appealing content.

For foreign language speakers, generative AI acts as a personal language tutor as it provides personalized learning experiences in English language preparation and learning [38], [74]. Moreover, it acts as a personal mindset coach [47] and provides grading for short answers and essays in an online learning environment by evaluating language proficiency and improving student scores [33], [38]. Moreover, it answers multiple-choice questions in medical examinations and displays a passing grade [77]. The benefits of LLMs are emphasized in automating education tasks, such as knowledge representation, immediate feedback, content generation, profiling/labeling, detection, grading, teaching support, prediction, and recommendation [88], [73], [57]. For example, Carnegie Learning's AI-powered mathematics tutoring system creates customized learning paths and provides immediate feedback based on students' strengths and weaknesses. The system provides interactive instruction and practice problems and monitors student progress based on individual learning speed and needs [53]. As reported in [74], the authors in [89] studied the case of AI-assisted feedback in simulation-based learning. Intelligent teaching systems, such as Yixue Education's tutoring system, employ AI and facial recognition to construct teaching plans and personalized course content based on students' learning and performance. In contrast, an intelligent speech interaction system exploits natural language processing and generative AI for interactive learning [54].

Students utilize models of GenAI to create instructional content for different disciplines [35]. According to a study [90], ChatGPT helps undergraduate students in different learning domains by enhancing their problem-solving skills and engagement levels [65]. For example, as reported in [50], "ChatGPT-4 provides an accurate answer for solving a physics scenario-based question given as an input: An electron is placed at a position on the x-axis, where the electric potential is + 10 V. Which idea below best describes the future motion of the electron? (a) The electron will move left (-x) since it is negatively charged. (b) The electron will move right (+x) since it is negatively charged. (c) The electron will move left (-x) since the potential is positive. (d) The electron will move right (+x) since the potential is positive. (e) The motion cannot be predicted with the information given. In this case, ChatGPT-4 provided an accurate answer by explaining facts and conditions facts to support the answer: Answer: (e) The motion cannot be predicted with the information given. Knowing only the potential at the electron's position is insufficient to determine its future motion. We also need to know the electric field and its changes in that area because the force acting on the electron depends on the electric field, not just the potential".

Moreover, generative AI aids in creative programming education and clinical and dental learning materials to improve decision-making and support surgical training [49]. Using LLMs enhances peer learning, resource search, study plan, attention, memorization, repeating, and mnemonics [48]. These tools aid students in language learning by improving grammar, spelling, and writing skills without directly copying and providing detailed feedback and act as a communication facilitator and learning resource in k-12 education [40], [46], [59], [44]. For example, as discussed in [91] study, results showed the applicability and affordability of ChatGPT in a writing practicum study [59]. Generative AI can produce unique assessments, like quizzes, for students based on their learning requirements [72]. Embodied chatbots, irrespective of their representation as humans, teachers, supervisors, shopkeepers, or animated characters [92], [93], provide language learners with immersive environments and personal bond formation [78], and are used by TC school principals to generate score templates, analyze different data segments and findings representation, and highlight progression lines [45].

Table 11 A summary of student use of multimodal generative AI.

How Generative AI is Used by Students	Studies	Focus of Studies	Key Insights
Understanding difficult concepts	[33], [37], [40], [51], [53], [72], [75], [57], [58], [59], [61], [66], [68]	Personalized learning, immediate feedback, enhanced learning experience, comprehension of complex notions	Highlight the areas for improvement by offering additional resources and explanations. Assists students in simplifying complex concepts and offers instant feedback and discussions, promoting critical thinking and problem-solving among students. Offer learning materials tailored to individual student's needs and learning styles.
Language learning and domain knowledge	[33], [43], [44], [49], [50], [51], [53], [75], [76], [61], [64], [66], [68], [69], [70]	Critical thinking, analytical thinking, and problem-solving	Assist students in acquiring domain-specific knowledge, such as language learning, digital literacy, or medicine. Help students learn languages and improve their writing skills by providing grammar, spelling, and punctuation feedback. Helpful in language proficiency, creativity, and critical thinking.
Improving productivity and efficiency	[33], [34], [37], [41], [43], [45], [52], [76], [64], [69], [70]	Assistance in text generation, brainstorming ideas, summarizing literature	Enhance productivity and efficiency in writing tasks by assisting in text generation, initial drafts, ideas, and summaries of literature. Offers more consistent and accurate grading and evaluation of the student's work, which leads to more efficient learning of the student and saves teachers effort and time. Assist students in monitoring their progress. Improve efficiency and accuracy in research.
Motivation and engagement	[33], [37], [46] [51], [78], [59] [61]-[66] [68]	Personalized learning, immediate feedback, interactive learning, self-efficacy, listening and speaking proficiency	Help to increase student motivation, engagement, and attainment of learning outcomes in the course. Enhance conversational social skills and foster contextual language development for young children. Improves students' learning, self-regulation, interaction clarity, and concentration.
Assessments Preparation	[33], [40], [43], [45], [53], [72], [75], [76], [77], [57], [59], [61], [62], [64], [70]	Preparation of Assessments such as assignments, quizzes, projects, study plans, Programming assessments, practice exercises	Provide immediate feedback on writing assignments for assessments. Helps the students to revise concepts and facilitates exam preparation by offering practice exercises and questions. Also assists in assignments, projects, academic homework, and exam-style questions.

3.4 The Impact of Generative AI on Student Academic Performance

This section addresses an important aspect concerning the impact of GenAI on student performance. Hence, we answer the question of how generative AI impacts student learning and performance, contributing to a comprehensive understanding of educational outcomes (Research Question 3). Table 11 shows how generative AI impacts students' learning performance and educational outcomes. It acts as an innovative approach to encourage students to learn through the generation of personalized educational content and assessments based on specific student input. Moreover, it offers innovative content creation and personalized learning experiences to facilitate a more dynamic and effective educational environment. Generative AI helps students understand concepts and offers personalized and engaging learning experiences. Figure 15 shows how students use Generative AI to improve their learning and performance. Students utilize Generative AI for various purposes, including automated assessment systems to support conceptual understanding and provide explanations based on analysis of student's contents [33]. Students also make use of Generative AI to learn about medical education [72]. For instance, as evidenced by [94], [95], generative AI, like ChatGPT, simplifies complex concepts to boost student understanding [75]. Generative AI evaluates students' dialogues and responds to their needs by providing personalized reading materials, learning resources, and effective feedback [40]. AI chatbots could reduce the anxiety of secondary school students in foreign languages, and authors reported that the use of chatbots reduces anxiety and depression among university students [37]. AI tools, such as Grammarly, InstaText, QuillBot, and Codecademy, offer tailored and immediate feedback based on work analysis and learning processes [51]. From the evidence presented, timely feedback by these tools encourages self-learning, reflection, and regulation. Moreover, it also contributes to creating personalized learning materials based on individual student's needs and learning styles, as shown by Smart Sparrow [53]. ChatGPT specifically supports science learning through text generation, language understanding, and dialogue systems [65]. Additionally, AI platforms like Midjourney enable users to learn and browse e-learning resources [59]. Students utilize various Generative AI tools such as ChatGPT, Bard, and Midjourney [41], [57], [58], [59] [62], [65], [66] to create personalized content in areas like math and programming, academic homework, science learning and understanding, language translation, summarization, and completion based on learning needs and progress, and offer feedback [96], [97], [98], [99] recommend learning resources, and real-time learning advice, and encourage collaborative learning. Moreover, these tools help students in comprehension of concepts and content creation, such as images using Midjourney [100]. Additionally, it helps students to create knowledge maps and conceptual summaries and practice what they have learned,

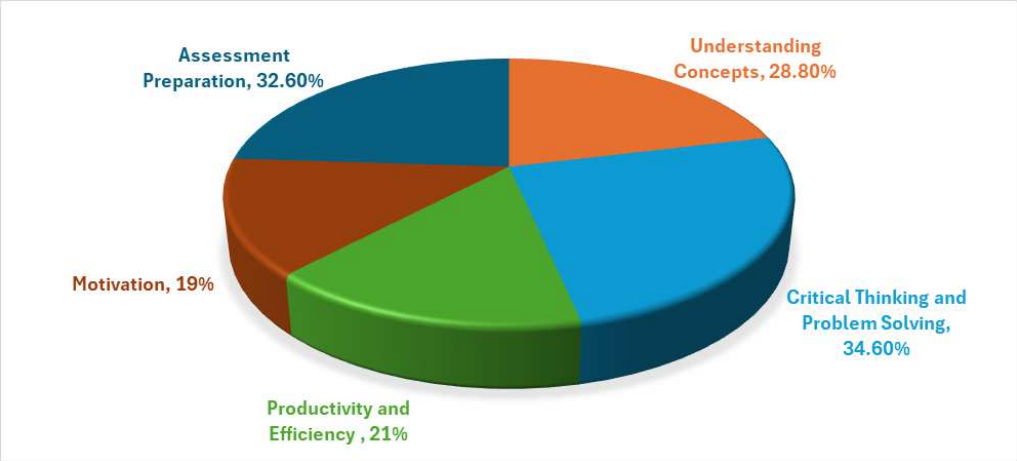


Fig. 15 The key benefits of using generative AI for students.

generate financial reports and summaries, document classification, sentiment analysis, and named entity recognition in financial documents, programming explanations, and examples [61].

Various studies highlight the importance of generative AI in learning domain-specific knowledge and constructing a positive impact on students' knowledge. Generative AI supports domain knowledge by providing language learning, digital literacy, and medicine [33]. Besides, it enhances critical thinking capabilities by generating precise and relevant responses [43], [49]. Generative AI, like ChatGPT, assists in the development of critical thinking skills via grammar analysis and argument evaluation [53]. Additionally, it empowers students to generate content for topics by strengthening critical thinking and analytical aspects of writing topics [75]. Generative AI assists brainstorming, creative writing, discussions, tutoring, and interactive language learning. Moreover, it assists in critical thinking and creativity by promoting self-directed learning [68], [69], [70]. It also aids in student group creation and promotes group work on assignments and projects by enhancing time management and effectiveness. Generative AI nourishes motivation and support, especially by delivering helpful resources and information [[68] [69] g19]. It offers immediate feedback by identifying areas for improvement and promotes communication skills, problem-solving, logical thinking skills, practical skills, and comprehensive problem-solving methods [44], [50], [76], [70]. Lastly, generative AI contributes to diagnosing and solving technical problems [61], analytical thinking, written proficiency, and advancing language skills [66].

To improve student learning experience and performance, generative AI helps to improve student cooperation, motivation, and engagement in lectures by providing access to learning resources [95]. These tools offer personalized learning experiences, explanations, and feedback based on individual needs to track academic progress. Evidently, personalized learning experiences help to adjust study strategies in real-time and self-efficiency in understanding complex concepts [33], [51], [61] [62] [63] [64], [65], [68], [69]. AI tools, notably in flipped classrooms, enhance comprehension, engagement, and motivation [66]. AI chatbots are shown to increase interest among college and secondary school students in English learning and language proficiency [37], [78]. Additionally, generative AI tools like ChatGPT promote teamwork, communication skills, and motivation [46]. Furthermore, generative AI assists students in conducting independent research and learning [59], [70], reducing motivation for cheating and supporting student learning.

Apart from enhancing student motivation and engagement, GenAI assists in improving students' listening and speaking abilities in different ways [44]. For example, it helps in the acquisition of foreign language skills through speech recognition and pronunciation correction [51]. It highlights listening and speaking proficiency with regard to various aspects, including perceptions, language proficiency, learner behaviors, and learner differences [55]. Furthermore, authors in [101] stated that the multimodal presentation of chatbots assists them in bridging the missing parts of the information by making listening passages less difficult and more understandable [78]. Moreover, generative AI contributes to improving English language proficiency, assessment performance, learning efficiency, quality, conversational social skills, better concentration, self-regulation, and interaction clarity [57], [58], [59], [61], [63]. Generative AI motivates learners to enhance their speaking, listening, reading, and writing proficiency, with improvements in grammatical accuracy and vocabulary expansion [64], [66]. Finally, it helps in language translation and editing to overcome language barriers in academic

work [68]. It supports the development of language and writing skills and the generation of new ideas [69].

In education, research, and academic writing these tools play a vital role in increasing efficiency, productivity, and accuracy by providing personalized content, immediate feedback, initial drafts, ideas generation, and literature summarizing [33], [34], [37], [43], [45], [52], [76], [64], [69]. Tools like ChatGPT assist teachers in accurate and consistent grading by reducing effort and providing more time for critical responsibilities [41]. In research, it contributes to improved efficiency and accuracy in terms of titles and abstract screening [70]. These AI tools also help to improve the efficiency of academic writing [69]. Students utilize AI tools in the preparation of their course assessments, such as assignments, quizzes, presentations, and projects [33], [40], [43], [72], [76]. Students utilize these tools in test preparations by asking for review questions and practice quizzes [45]. It also generates programming assessments [57], creation of articles, papers, and essays, to a vast array of content and ideas. It goes beyond to promote effective exam preparation by the generation of tailored study guides, plans, quizzes, assignments, exam questions, and projects based on individual preferences [59] [61] [62] [64] [69] [70]. Moreover, it assists students with exam and test preparation by providing practice exercises and different question formats to learn and strengthen topic understanding [40], [43], [44], [72], [75]. GenAI contributes to concept checking by providing feedback on grammar, spelling, and syntax in written assignments [53]. Additionally, students can access learning resources and clarify their understanding of medical education, test preparation, and medical assessments [77]. As evidenced by [98], [102], GenAI assists students in improving their coursework and meeting learning outcomes before submitting their work for summative assessment [70].

3.5 The Use of Multimodal Generative AI by Instructors

In this section, we address the fourth research question (RQ4): How is generative AI used by educators/instructors to enhance their teaching and assessment strategies? Educators, instructors, and teachers utilize generative AI for various purposes, like preparing course contents, designing assessments, monitoring learner progress, evaluating student outcomes, enhancing pedagogical efficacy, providing feedback, preparing for classes, and honing their teaching methodologies [34], [43], [44]. Figure 16 summarizes the trends in how teachers utilize generative AI in their teaching practices. Multimodal generative AI supports teachers across different modes, such as text, speech, images, and video contexts. By leveraging generative AI, teachers can streamline the process of developing course materials, like course syllabi, weekly plans, lecture notes, quizzes, curriculum designs, and other supplementary resources [34], [43], [44], [47], [63], [64]. For instance, a teacher might request, "I am teaching a graduate course on 'History and Current Applications of Stem Cell Use.' Can you create a 16-week training plan suitable for 15 medical graduate students?" to promptly receive the desired plan [40]. Generative AI also assists teachers in brainstorming various teaching aspects, including specific lectures, drafting initial materials, summarizing information, and generating assessment tools, thereby saving time. Consequently, teachers can focus more on teaching and pedagogical skills, offering personalized learning experiences to students. For example, a teacher could request test items in history about Julius Caesar and the Roman Empire for 7th-grade students. In response, a Generative AI tool like ChatGPT can generate the desired test items [40]. Furthermore, teachers can enhance the critical thinking of 7th-grade students by generating discussion topics. For instance, prompting "Please suggest topics for classroom discussions to promote critical thinking in history for 7th graders, focusing on Julius Caesar and the Roman Empire" would yield relevant output from ChatGPT [45]. See Figures 17 and 18 for more details.

Generative AI empowers teachers to prepare diverse course assessments, such as automatically-graded quizzes and exams without textual feedback [33], [51], [75], [65], [66], [67]. For example, prompts like "Can you create 20 MCQs to evaluate the basic knowledge of students on the topic of cell membrane for 12th-grade students?" or "Can you design a case presentation for proper understanding and discussion questions to evaluate student performance?" would yield the desired assessments, saving teachers time [40],. These tools also generate learning evaluations like monthly tests, semester tests, projects, or assignments to assess learner progress [69]. Generative AI chatbots enable teachers to monitor learner progress, helping them keep track of student performance and streamline activities. For example, platforms like AutoGradr and Repl automatically grade homeworks and tests, allowing teachers to dedicate more time to lesson planning, student support, and professional development aimed at enhancing their teaching [51]. While assessing student's learning progress, Generative AI tools improve three different aspects of learning, including affective, cognitive, and psychomotor

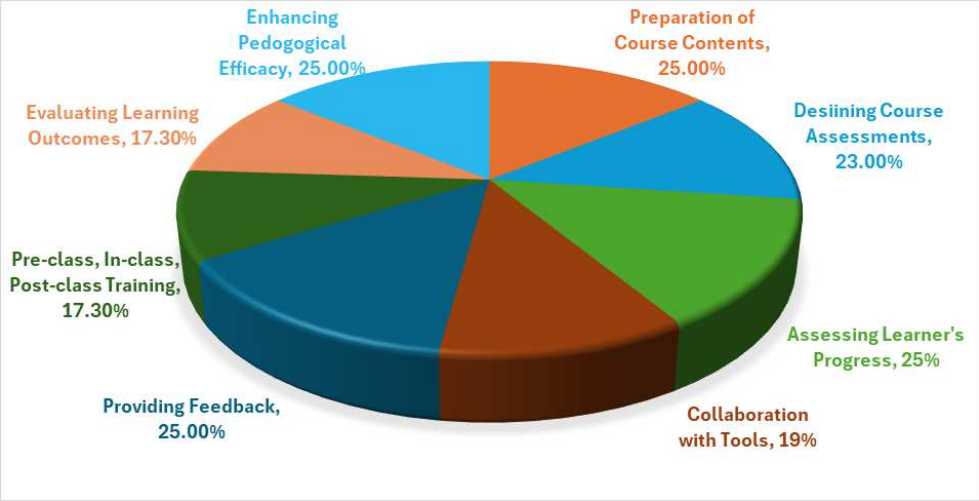


Fig. 16 Use of generative AI by teachers.

Table 12 A summary of the benefits of applying generative AI by teachers

How is GenAI used by teachers?	Reviews	Focus of Reviews	Key Insights
Preparation of course contents (e.g., generating lecture notes, lesson plans, study guides)	[34], [40], [57], [59], [62], [66], [68], [70]	Streamlining course material generation, saving time for educators, enhancing teaching quality	Personalized learning plans, instructional activities, and assessments
Designing course assessments (e.g., generating quizzes, exams, assignment tasks)	[40], [43], [51], [75], [59], [64], [66], [69], [70]	Automating assessment creation, reducing grading time, improving student engagement	Automation of course assessment activities
Assessing learner's progress (e.g., tracking the student performance, providing feedback)	[35], [40], [51], [75], [58] [59] [62] [63] [64] [69] [70]	Monitoring student learning, capturing data on learning progress	Enhanced student collaboration and accessibility
Evaluating learning outcomes (e.g., grading assignments, providing feedback)	[33], [37], [40], [75], [62], [63], [66], [69], [70]	Automating grading, providing personalized feedback, improving learning outcomes	Support assessment and evaluation of learning outcomes
Enhancing pedagogical efficacy (e.g., assisting in teaching methodologies and promoting student engagement)	[[35],[40], [51], [75], [59] [62], [66] [68] [69]	Advancing teaching quality, fostering learning environment, encouraging independent learning	Offer ideas and resources for new teachers
Providing rigorous feedback (e.g., personalized feedback on student work, assessment scoring)	[33], [40], [51], [75], [62], [66], [69], [70]	Providing timely and personalized feedback, improving student engagement	Add an iterative approach to feedback
Assisting in Pre-class, in-class, and post-class training (e.g., supporting course planning, facilitating workshops)	[40], [44], [75], [61], [62]	Supporting educators in various training phases, promoting collaboration	Enhancing professional development opportunities
Collaborating with AI tools to improve teaching (e.g., integrating AI tools into curricula, utilizing AI for lesson planning)	[40], [44], [75], [59], [62], [64], [70]	Integrating AI into teaching practices, enhancing teaching methods	Inclusion of AI practices into teaching philosophies

[65]. Teachers also use generative AI tools to provide rigorous feedback. For example, a teacher may give a prompt such as "Please evaluate this student's answer regarding the methods used in the determination of hemoglobinopathies and give a paragraph of feedback". According to the study [35], GenAI tools such as ChatGPT enhance the pedagogical efficacy of educators [37]. The authors revealed an investigation into how pre-service teachers perceived the value of learning knowledge after using Generative AI chatbot-based feedback systems. Moreover, these chatbots reduce teachers' administrative workload by evaluating students' assignments, scoring them, and providing feedback. This enables teachers to focus specifically on their teaching methodologies and practices and interact with students more frequently [50]. Moreover, teachers use Generative AI tools as assistants to enhance their teaching practices and promote student learning. They attempt to integrate tools such as ChatGPT into their curricula and utilize them to generate detailed, inclusive lesson plans, receive feedback, and prepare classroom resources. For example, authors found that ChatGPT serves as a

User: Could you please suggest test items in history about Julius Caesar and the Roman Empire, for 7th graders?

ChatGPT: Sure, here are some possible test items in history for 7th grade students about Julius Caesar and the Roman Empire:

1. Who was Julius Caesar and what was his role in Roman history?
2. Describe the political situation in Rome during Julius Caesar's time.
3. What were some of Julius Caesar's major accomplishments as a leader of Rome?
4. What was the significance of the Roman Republic, and how did it differ from the Roman Empire?
5. What factors contributed to the decline and fall of the Roman Empire?
6. How did Julius Caesar's death impact the future of Rome?
7. Describe the social structure of ancient Rome and the roles played by different groups in society.
8. What was the significance of the Pax Romana, and how did it affect the Roman Empire?
9. What were some of the major cultural achievements of the Roman Empire, and how did they influence Western civilization?
10. What was the impact of the Roman Empire on the development of Christianity?

These questions can be modified and expanded upon to create a more comprehensive test on Julius Caesar and the Roman Empire for 7th grade students.

Fig. 17 How a teacher may use ChatGPT to generate test items according to the student's level for a specific topic [45]?

User: Hello! Could you please suggest topics for classroom discussion to promote critical thinking (in history for Grade 7 about Julius Caesar and the Roman Empire)?

ChatGPT: Sure, here are some topics for classroom discussion on Julius Caesar and the Roman Empire that could promote critical thinking among Grade 7 students:

1. Was Julius Caesar a hero or a tyrant? Why?
2. Did Julius Caesar really deserve to be assassinated? Why or why not?
3. What were the reasons behind the fall of the Roman Empire? Was it inevitable?
4. How did Julius Caesar impact the Roman Republic, and what changes did he bring about?
5. What were the key achievements of the Roman Empire during Julius Caesar's rule, and what were its limitations?
6. What lessons can we learn from the Roman Empire's successes and failures, and how can they be applied to contemporary society?
7. How did Julius Caesar's military campaigns shape the course of Roman history, and what were the consequences of his conquests?
8. How did Julius Caesar's leadership style compare to other leaders in ancient and modern history, and what were the strengths and weaknesses of his approach?
9. What role did the Roman Empire play in shaping Western civilization, and how has its legacy continued to influence us today?
10. What were the key factors that enabled Julius Caesar to rise to power, and how did he maintain his authority over the Roman Empire?

Encourage your students to critically evaluate different perspectives and sources, analyze primary and secondary sources, and make evidence-based arguments to support their viewpoints. Good luck with your discussions!

Fig. 18 How a teacher may use ChatGPT to generate topics for classroom discussion for a specific topic [45]?

pedagogical tool in language education, including language assessments and daily language practice [59].

Generative AI supports teachers with pre-class, in-class, and post-class training. For example, teachers can obtain necessary information about which educational tools or techniques can be used while teaching crucial concepts or mechanisms or which discussion questions should be asked by prompting [40]. Similarly, teachers may answer a student's question that they do not know or customize their response according to the learner's capability by prompting the Generative AI tool during the class based on the specific understanding and learning capability of the respective student. Teachers also collaborate with Generative AI tools to improve their teaching skills and student progress. For example, the author in [55] pointed a comparison of the experimental group that used chatbots for part of in-class activities with the control group that was taught by human teachers without chatbots and found that these tools may be useful in promoting second language speaking skills while collaborating with them. Moreover, students and teachers can collaborate to design individualized lesson plans that will be implemented in the classrooms. Workshops and seminars could also be organized collaboratively with Generative AI tools to motivate the students toward learning [44]. Table 12 shows a summary of how Generative AI is used by teachers to enhance their teaching and assessment strategies.

3.6 Challenges of Adopting Multimodal Generative AI in Teaching and Learning

In this section, we answer the question concerning the challenges and issues that hinder the use of generative AI in teaching and learning (Research Question 5). Implementing multimedia GenAI tools in educational settings and domains faces multiple obstacles. These obstacles limit the acceptance and adoption of generative AI tools in education. We categorize these challenges into foundational/core challenges, student-related challenges, teacher-related challenges, and common challenges that occur both in teaching and learning. Table **??** outlines a summary of these challenges.

3.6.1 Core Challenges

Theoretical Research Challenges: Based on our findings, extensive theoretical research challenges hinder the adaptation of generative AI in teaching and learning. Students use Generative AI tools in writing misuse. On one side, this seems to be not a challenge, but multiple tools detect AI-generated text and do not recommend its use in educational concerns, hence not utilizing its full capabilities [38]. The second concern is transparency and accountability in AI models, specifically of deep learning modes. This opacity may be problematic for students and teachers, as they may accept inaccurate recommendations from generative AI tools without understanding the underlying theories and logic. This may lead to the propagation of false information, concepts, and clinical misjudgments among students and teachers, specifically in medical education. Moreover, generative AI tools lack in providing calculation-based and problem-solving queries. This may lead to the inapplicability of these tools in advanced mathematics and synthesis knowledge of chemistry [44].

Technical Research Challenges: Generative AI also suffers from technical challenges in the context of teaching and learning. These tools may not provide up-to-date information [50], [52], [72], [62]. Consider that ChatGPT, which was last trained in 2021, may not provide the latest needed information, hence limiting its reliability. Similarly, these tools exclude the most recent scientific knowledge, which may lead to the dissemination of old information. Second, Generative AI tools may provide hallucinations. For example, the authors in [72] revealed that generative AI tools, such as ChatGPT, provide inaccurate answers with significant confidence. [52] found that 30% of the outputs generated by neural summarizing applications suffer from hallucination problems. One more technical research challenge of Generative AI in teaching and learning is the inaccurate detection of AI-generated text [42], [44], [45]. This involves distinguishing between AI-generated text and human-generated text. As Generative AI tools mimic the writing and language pattern styles of human-generated text, it leads to the challenge for teachers and detection tools to detect AI-generated text. Researchers are continuously working to detect AI-generated text to reduce academic misconduct, but on the other hand, the Generative AI capabilities continue, which leads to a race between detection tools and Generative AI, making accurate detection of AI-generated text more challenging.

Ethical Challenges: Generative AI brings serious concerns about ethics, such as data integrity, bypassing plagiarism detectors and bias [42], [43], [44], [52]. GenAI platforms are widely used for generating text for unethical and dishonest purposes in education [46]. Such platforms might bypass plagiarism detectors with their ability to produce seemingly human-generated and genuinely novel text [47]. This may lead to serious academic breaches. In the study [44], authors revealed that these tools, such as ChatGPT, have weaknesses in terms of bias for k-12 education. They stated that students have reported mistakes and biased answers in response to their prompts. Moreover, these tools not only produce misinformation or biased information but also be used to respond to multiple-choice or subjective questions to exploit cheating in tests, assignments, and exams [72]. Finally, another ethical concern in the use of Generative AI in education is the replacement of AI technology with human educators, which will severely result in the financial stability of teachers and educated personnel [53].

Political Challenges: Generative AI is programmed by humans, who are often biased positively toward the members of their social group and implicitly or explicitly biased negatively toward members of outer groups. Due to this, generative AI tools may provide politically biased information. As evidenced by [47], generative AI tools like ChatGPT are unaware of the quality of media resources, leading to the provision of biased information. Similarly, the authors found that the information provided by ChatGPT is politically biased as well as based on gender, race, religion, etc. According to the study [51], the deputy director general of the European Consumer Organization (BEUC) raised some serious issues about how ChatGPT might manipulate and deceive people. This study also stated

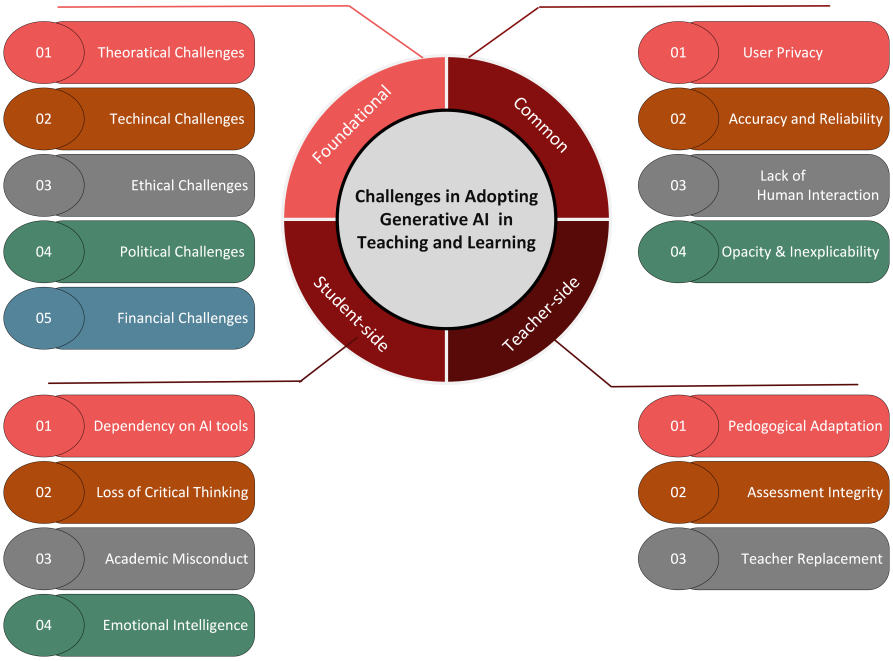


Fig. 19 A taxonomy of challenges hindering the adaptation of generative AI in teaching and learning.

that it is banned in China, Russia, Iran, Venezuela, and Belarus because of spreading US political propaganda. **Financial Challenges:** Students and teachers face financial challenges while utilizing Generative AI in their teaching and learning process [41],[45],[47]. For example, ChatGPT only works with internet connectivity. This means that students with financial constraints with no Internet facility may not be able to use it. Second, to fully utilize their capabilities, a paid subscription is required, such as ChatGPT 4 [45]. Some schools use Generative AI to analyze knowledge levels, interests, and learning styles to provide personalized plans and tools, but it may lead to their learning achievements being inferior to those of other students who might not afford these tools [55]. On the teacher's side, Generative AI tools may help to reduce their workload and improve their teaching and pedagogical efficacy on one side, but it could also lead to job cuts [47], which may cause financial constraints [54]. According to the study [52], AI will replace humans. The authors found that Generative AI, like ChatGPT, could lead to 300 million job losses worldwide. However, aside from the education domain, researchers estimate that while AI might replace 7% of jobs in the US, it could also complement 63% of them and leave 30% unaffected. Overall, AI could boost the global economy by 7%. Automation technology, like AI, is expected to handle repetitive tasks in fields such as programming and debugging. Moreover, according to [64], ChatGPT may not have the same level of understanding, creativity, and empathy as humans and so may not make humans easily replaceable.

3.6.2 Student-related Challenges:

Dependency on AI tools: The use of Generative AI tools such as ChatGPT by students in educational settings may concern a serious issue of student overreliance, dependency, and addiction to these tools [35]. Students' excessive use of ChatGPT and other Generative AI tools in writing assignments may lead to a significant breach and overreliance. Students may become dependent on Generative AI tools for writing their assignments, leading to plagiarism and a lack of original work and may also lead to decreases in critical thinking [69]. The study [59] reveals that over-dependence on Generative AI causes a lack of critical thinking. According to the study [49], Generative AI tools can undermine students' algorithmic comprehension due to the excessive dependency of students on automated coding through these tools.

Lack of critical thinking: Students using Generative AI tools to write assignments and quizzes may lose their critical and creative thinking and do not constitute the generation of original work. Authors in [68] reveal that the use of Generative AI decreases students' critical thinking skills and independent problem-solving abilities. The authors in [75] revealed a comparison of two groups of students. First, who used ChatGPT assistance, and the second, with a group that did not, in the context of writing essays. The authors found that although the time taken by both groups was similar,

Table 13: A summary of challenges hindering the adaptation of generative AI in teaching and learning

Type	Main Challenges	Key Observations
Technical challenges	ChatGPT cannot produce the latest information due to its limited time frame.	ChatGPT's limitation in providing up-to-date information.
	ChatGPT struggles with complex calculations and high-level application problems.	Limitations of ChatGPT in handling advanced tasks.
	ChatGPT-4 lacks the ability for image representation.	Lack of image processing capability in ChatGPT-4.
Theoretical challenges	Incorporating ChatGPT into educational frameworks sparks discourse on its impact on conventional methodologies.	ChatGPT's influence on traditional educational methods.
	The complexity of Generative AI models makes it hard for students to understand decision-making processes.	Difficulty in explaining AI-generated outcomes.
	Integration of Generative AI may lack emotional intelligence, impacting responses to learners' emotional needs.	Limitations of AI in comprehending emotional cues.
Ethical challenges	Concerns about students resorting to ChatGPT for academic assignments, leading to academic dishonesty.	Ethical implications of students using AI for assignments.
	Ethical concerns raised about using ChatGPT in education, including fears of cheating and impact on assessment.	Ethical dilemmas surrounding the use of ChatGPT.
	Privacy concerns highlighted regarding the use of ChatGPT, leading to bans in certain countries.	Privacy issues associated with ChatGPT usage.
	Risk of reliance on potentially unauthentic information generated by ChatGPT, contributing to ethical considerations.	Risk of unethical reliance on AI-generated content.
Financial challenges	AI replacing human jobs may lead to job cuts and financial constraints for teachers.	Financial implications of AI replacing human jobs in education.
Political challenges	Bans on ChatGPT in certain countries due to concerns about privacy and political propaganda.	Political implications of AI usage in education.
Student-side challenges	Students may become excessively dependent on ChatGPT, leading to diminished critical thinking skills.	Impact of ChatGPT on student dependency and critical thinking.
	Limitations of ChatGPT in providing emotional intelligence, affecting student-teacher interaction.	Lack of emotional intelligence in AI, affecting student-teacher interaction.
	Students may exhibit irrational behavior and lack critical thinking due to dependency on ChatGPT.	Influence of AI dependency on student behavior and critical thinking.
	Students may depend on AI-generated content for assignments, leading to plagiarism and a decline in critical thinking.	Risks of plagiarism and reduced critical thinking due to AI reliance.
Teacher-side challenges	Teachers face challenges in conveying complex AI concepts to students and ensuring critical evaluation.	Difficulty in teaching AI concepts and fostering critical evaluation.
	Concerns about the role of teachers being replaced by AI and the need to maintain human elements in education.	Debate over AI replacing human teachers and the importance of human interaction.
	Risk of job cuts for teachers due to AI's potential to replace human tasks, leading to financial constraints.	Potential financial impact of AI replacing human jobs in education.
	Teachers may face challenges in grading and combating academic dishonesty with AI tools.	Challenges in grading and combating academic dishonesty with AI tools.
Common challenges	The complexity of Generative AI models makes it difficult to explain generated outcomes.	Difficulty in explaining AI-generated outcomes.
	Challenge of maintaining critical thinking and problem-solving skills due to excessive reliance on AI.	Impact of AI reliance on critical thinking skills.
	Risk of academic dishonesty and challenges in grading student comprehension when using AI tools.	Challenges in grading and combating academic dishonesty with AI tools.

the group with the assistance of ChatGPT achieved slightly lower scores due to a higher frequency of inaccuracies in their essays. This might be a result of almost no critical and creative thinking when writing their essays. According to the study in [68], the excessive use of Generative AI tools like ChatGPT reduces problem-solving abilities and critical thinking of students, plagiarism, and cheating. Students use Generative AI tools for cheating purposes and generate assessed work rather than going through the learning process. This may lead to a loss of problem-solving skills in critical thinking and analysis.

Academic misconduct: In [69], authors referred to a debate on the ethical use of Generative AI tools in education. They found that these tools could be used for cheating and would impact assessment. Academic misconduct is another challenge of Generative AI, which is a misuse of creating an unfair academic assessment. Those students who have access to these tools could generate

additional advantages, such as grades, over those students who do not have access or do not want to use them due to ethical considerations. This difference can make grades and academic recognition unfair, making it undermine the value of hard work and personal efforts. According to [69], students use Generative AI for cheating in assignments, quizzes, and exams, which leads to academic misconduct and discrepancies in learning results that lose the quality of teaching and learning.

Emotional intelligence: Another notable challenge of integrating Generative AI in educational settings is the lack of emotional intelligence. While Generative AI excels in generating information and responses, it often struggles to comprehend and respond to the refined emotional cues and needs of learners [73]. Generative AI tools do not understand and respond to the feelings and emotions of the students as compared to human teachers who have critical thinking skills, feelings, and emotional intelligence, hence responding to each student's emotional needs [45]. According to the study in [52], OpenAI reveals Generative AI is limited in complex reasoning problems and problem-solving abilities, such as selecting projects, empathy and understanding, and providing coaching and emotional assistance.

3.6.3 Teacher-related challenges:

Pedagogical adaptation: The use of Generative AI in education has triggered a complicated discussion about how it affects traditional teaching methods [35]. A primary challenge in the use of Generative AI in teaching and learning is a requirement of pedagogical adaptation. For example, teachers must find some methods to convey these concepts to clinical audiences. This will ensure that physicians will understand and critically evaluate these Generative AI tools in the future. There is a need to change pedagogical approaches to develop new strategies for assessing learning that focus on critical thinking, problem-solving, and knowledge application rather than traditional assessment methods.

Assessment integrity: According to [33], there are limitations in automated assessments using Generative AI as compared to human assessments. AI algorithms that are reported to be biased lead to inaccurate and unfair assessments for those teachers who use these tools. This is because of AI algorithms' training data, which may be biased, which leads to biased assessments in the output [53]. As reported by [72], Generative AI tools such as ChatGPT generate fake citations and references. This may also cause difficulties for teachers in judging whether the references written in the student assignments are valid or not, leading to inaccurate assessments of certain students. In study [75], the authors found that students use ChatGPT as a shortcut to complete their assessment tasks. These students find real-time assistance from ChatGPT during exams, such as classroom tests and quizzes, whether in-person or online. Moreover, students choose ChatGPT for open-book assignments due to its ability to generate human-like text responses, which raises concerns about accurate assessments, academic dishonesty, and cheating.

Teachers replacement: Generative AI tools can assist teachers in reducing their current workload to promote more research and learning activities, such as improving the overall quality of the teaching and implementing innovative practices during the class; however, they could also lead to job cuts [47]. This means that outsourcing to the machines of a large portion of paid employment may cause financial constraints for teachers. As we mentioned earlier, authors in [52] revealed that generative AI tools could eliminate 300 million jobs worldwide, which may be a serious concern to lecturers. However, [53] suggested that Generative AI should not replace human educators. This is because of their unique contribution, which no tool can provide in the classrooms, which is their humanity. The authors stated that none of the generative AI tools can provide meaningful learning experiences related to ethical norms and values, self-reflection, or understanding of oneself, history, and society.

3.6.4 Common challenges:

There are some common challenges that both students and teachers encounter during their teaching and learning practices. The most common is user privacy [59], [64],[68], [69], [70]. According to [44], the use of Generative AI raises academic integrity and user privacy concerns. The study in [51] reveals that Italy is the first Western country to ban ChatGPT because of privacy concerns. The study [57] pointed out certain weaknesses of Generative AI, such as misinformation and the privacy of users [52]. Another common challenge is incorrect and fake information. Moreover, these tools, specifically ChatGPT, are unable to provide accurate references. In [45], authors infer that ChatGPT is inconsistent in providing accurate bibliographic references. Out of the 82 references mentioned in their conversations, only 60% were cited correctly or with minor errors (41 and 8 items, respectively).

The remaining 40% could not be found using Google or Google Scholar. In [39], authors reported a more concerning case where the only reference mentioned by ChatGPT in a scientific essay was untraceable through Google.

Moreover, Generative AI is not able to provide students and teachers with up-to-date knowledge, decreasing its reliability in both teaching and learning [72], [26]. The third common challenge for teachers and students is the lack of human interaction [52],[57]. Overreliance on AI tools may reduce the personal connection between educators and students, which may impact the learning experience. Generative AI can reduce the meaningful interaction and engagement of teachers with students. This may hinder the teachers from providing personalized support and interactive learning experiences to the students. The last challenge common to educators and learners is opacity and inexplicability [34]. Due to the complex nature of generated AI models, it is challenging to explain the decision-making process and the rationale behind generated results. For example, there are Generative AI tools that teach English grammar. When a student gives a prompt, this tool provides corresponding rules and explanations of grammar [54]. Despite its effective answer, students may not be able to learn why the AI tool provided this specific grammar structure and what is the base for it [54]. Finally, this opacity may raise serious concerns because students and teachers may accept the recommendations from LLM tools without knowing the underlying rationale, which may lead to misjudgments.

4 Implications

Based on our findings on the role of multimodel generative AI in teaching and learning, several implications emerge for instructors, students, policymakers, and researchers. First, teachers need to adapt their teaching methodologies by effectively integrating Generative AI. Teachers should integrate these tools into their lesson plans and also ensure that students develop critical thinking while using them. Educators should also strike a balance between leveraging Generative AI and developing students' problem-solving abilities. Additionally, pedagogical approaches should evolve to emphasize assessment methods that evaluate critical thinking, creativity, and knowledge application rather than solely relying on traditional assessments [35], [72], [73].

Educational institutions should organize seminars and workshops to educate students about the responsible use of Generative AI tools. This will help reduce the risks of plagiarism, overreliance on these tools, and the loss of critical thinking skills. These institutes should implement strict policies and programs for the ethical use of Generative AI tools and emphasize the importance of originality and critical thinking in academic practices. Moreover, students should be encouraged to develop a comprehensive understanding of the limitations and biases in AI models to make informed decisions about their use [36], [37], [58].

In the context of policies, there is a need for regulations and guidelines for the ethical use of Generative AI in educational settings. Policymakers should collaborate with educational stakeholders to create standards for AI tools development usage and their integration into educational settings. Moreover, precautions should be taken to protect the privacy of students and teachers and prevent the dissemination of biased or inaccurate information through AI-generated content.

Researchers play a crucial role in addressing several challenges (e.g., theoretical, technical, etc.) that impede the adoption of multimodal generative AI in educational practices. However, more research is needed to improve the accuracy, reliability, and transparency of generative AI tools. Effective strategies to integrate these tools into teaching and learning are also needed. Furthermore, researchers should focus on identifying best practices for evaluating student learning outcomes and teachers' pedagogical adaptations and assessing the impact of GenAI on educational quality and equity.

5 Limitations of Our Umbrella Review

Admittedly, this SLR has several limitations in terms of scope, which suggest directions for further research. First, in terms of scope, we included only surveys, reviews, and SLR articles, neglecting the original research. However, we have carefully extracted critical information from these reviews. Second, we have not explored articles focusing on the real application of generative AI in medicine, engineering, business, etc; rather, our exploration focused on education only. Hence, further research is needed to explore the benefits and challenges of generative AI revolutionizing human life. Additionally, unpublished and pre-print studies were ignored during the screening process, which may lead to a loss of crucial research insights and findings. We have also excluded those reviews that have

not been published in English. Therefore, researchers may consider a follow-up analysis by considering preprints and non-English studies to comprehensively analyze the use of generative AI in the educational domain. Finally, the educational impact of generative AI tools depends on their application and integration within existing teaching and learning methodologies. Therefore, researchers should focus on investigating the effective utilization and incorporation of these tools within different educational practices and scenarios.

6 Conclusions

We aspired to provide a comprehensive review of reviews, surveys, and SLRs focusing on the utilization of multimodal generative AI in education (i.e., teaching and learning). We extracted and reviewed 46 articles retrieved from Scopus, Web of Science, and Google Scholar academic databases. Our analysis addressed five research questions and revealed that GenAI plays a significant role in enhancing student learning and academic performance in their educational journeys. Teachers also utilize generative AI tools to design course assessments, provide student feedback, assess student learning outcomes, and improve pedagogical efficacy. However, serious concerns hinder the acceptance and adoption of generative artificial intelligence in teaching and learning. Educational practitioners and researchers must collectively address these concerns to establish standards and innovate new technologies that safeguard both teachers and students, preserving their problem-solving abilities and nurturing critical thinking skills.

Declarations

- **Data availability** My manuscript has no associated data.
- **Competing interests** The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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