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## SURVEY

# A Comprehensive Review on Generative AI for Education

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**ABSTRACT** Artificial Intelligence (AI) has immense potential for personalized learning experiences, content generation, and vivid educational support. This paper delves into generative AI (GAI) and its potential applications within GAI, specifically mentioning generative adversarial networks (GANs). The article delves into the transformative impact of GAI in education, underscoring its expertise in creating diverse instructional materials, from texts and images to videos. Adaptive learning, one of the chief abilities of GAI, has been highlighted, emphasizing its capability to select content customized to individual student profiles, learning habits, and preferences. The paper further explores the fusion of GAI with innovative education systems, highlighting how these models can mimic conversational interfaces, promoting an engaging, customized learning journey. The exploration doesn't stop at the benefits; it delves into challenges like ensuring data privacy, mitigating biases, and ensuring accountability in AI-driven educational systems. The conclusion contemplates the potential limitations and assurances of embedding GAI within educational setups. An appeal has been made for more profound research and enhancement of AI's educational function. The intersection of pedagogical insights and effective human-AI collaboration is pivotal in this journey. This paper serves as a compass, guiding educators, researchers, and policymakers toward harnessing GAI's potential to sculpt enriched, immersive educational landscapes.

**INDEX TERMS** GAI, education, applications, case studies, challenges, metaverse.

## I. INTRODUCTION

The intelligence contained within AI has been making great leaps and bounds in today's time and age. Many efforts are being made to link everything with some ML algorithm. In all these fields, GAI has become one of the most popular and has outperformed all the existing AI and ML technologies by proving its capabilities to all. GAI is a set of AI algorithms that utilize existing content like text, audio files, or images to create new content [1]. It allows computers to abstract the underlying pattern related to the input and then use that to generate similar content. Nowadays, GAI technologies available in the market are specialized to do specific tasks, which have been categorized

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on the criteria of what they generate. Figure 1 gives a brief overview of it.

Some research groups that should be credited for making GAI very popular due to their outstanding research and products include OpenAI, Hugging Face, Alphabet (Google), Microsoft, Synthesis AI, and Cohere. GPT [2], Dall-E [3], Bard, Midjourney, Stable Diffusion, diffusion models [4], [5], and Synthesia are some of the products that have made a breakthrough in this technology. These products have been quite popular in the market since their release due to their valuable service, which has attracted the attention of various research groups. Much active research has been conducted in this area recently, in which researchers have tried to analyze and study these products to benefit the world and make modern technology even better.

Products based on GAI, such as ChatGPT, hold the capacity to revolutionize multiple sectors, including education, potentially propelling these areas into a future that is more reliant on technology, with all its associated advantages and drawbacks [6]. Such AI can enhance human analytical and decision-making skills, potentially elevating levels of creativity.

The importance and excitement for GAI could be established through the following facts mentioned below:

- OpenAI's ChatGPT exceeded one million users five days after its launch, and DALL-E took 2.5 months to reach 1 million users [7].
- Microsoft's GitHub Copilot had 400,000 subscribers within the first month of its release [7].
- In the United States, the adoption of GAI in the workplace is the highest for Gen-Z at 29% [7].
- In 2021, the AI market was valued at approximately \$59.67 billion USD and is projected to reach roughly \$422.37 billion USD by 2028 [7].
- In 2021, there was \$93.5 billion USD of private investments in AI-related companies, which is double compared to 2020 [7].
- Developers of Deloitte found using Codex helpful as it leads to 20% improvement in code development tool [7].

Some of the expectations of the research groups and experts regarding GAI for the future are as follows:

- By 2025, 30% of the outbound messages of large organizations will be generated by the GAI, compared to 2% in 2022 [7].
- By 2025, 10% of all the data produced will be produced by GAI, compared to 1% in 2021 [7].
- The revenue forecast for the AI market is \$1.8 trillion USD by 2030 [7].

GAI has made notable strides in various fields, such as dentistry, vehicular networks, medicine, etc. With the help of GAI, the researchers can identify a new field called Dentronics, which focuses on the inception, setup, and deployment of robotic solutions in dentistry [8]. Such impressive results in other fields encourage researchers to apply GAI in education. While GAI has shown promising results in other fields, its application in the field of education is still limited. This study highlights the potential of GAI in education and encourages researchers to explore its implementation in educational contexts. Additionally, it seeks to consolidate the usage of GAI throughout the students' careers; it demonstrates its importance from education to seeking good jobs and entrepreneurial endeavors. GAI provides many advantages and benefits that the traditional systems fail to provide. Some of them include:

- Traditional educational systems fail to give students a curious heart. A curious heart is essential for proper learning and growth in an academic career. If the students are not curious about learning new concepts, they ultimately lose in the race to become strong students. On the other hand, GAI promises to provide

**TABLE 1.** Major abbreviations used in the survey.

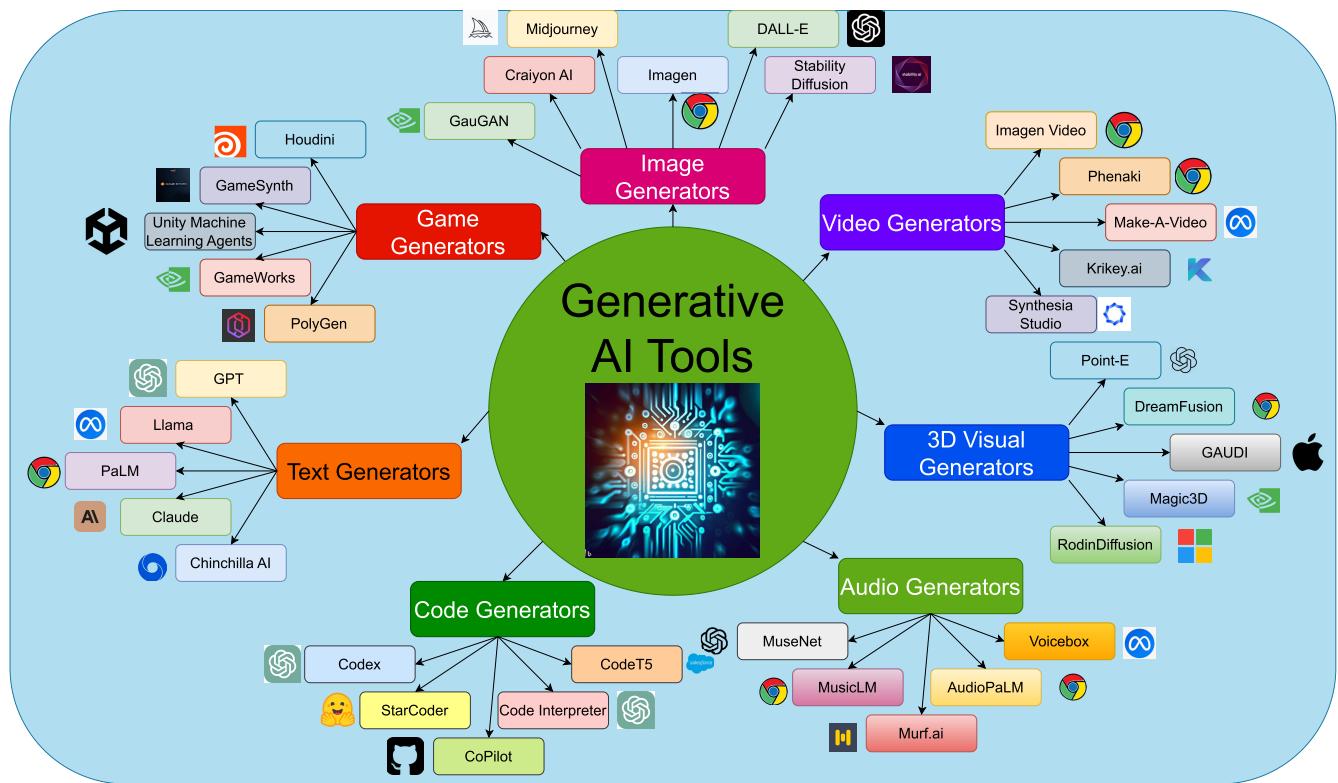
Word	Abbreviation
Artificial Intelligence	AI
Artificial Neural Networks	ANN
Deep Learning	DL
Deep Neural Network	DNN
Generative Artificial Intelligence	GAI
Generative Adversarial Networks	GANs
Gaussian Mixture Models	GMM
Generative Pre-Trained Transformer	GPT
Hidden Markov Models	HMM
Latent Dirichlet Allocation	LDA
Large Language Model Meta AI	LLaMA
Large Language Models	LLMs
Machine Learning	ML
Non-Player Characters	NPC
Pathways Language Model	PaLM
Variational Autoencoders	VAEs

students with a curious heart, which many studies have also shown in the past [9].

- In the traditional settings of schools, the teachers cannot pay attention to all the students, and they are ultimately unable to look into the demands of each student, due to which students suffer. However, GAI has the unique feature of providing personalized attention to everyone, and it can also keep track of the progress of every student and provide growth at their required pace.
- Most of the time, the lectures at schools and universities become boring, and the teachers also don't have a way of making the lectures interesting. GAI can help in this area by providing engaging and immersive learning content to the students, which would make learning fun.
- GAI can easily adapt to the teaching style of each individual, which the teachers in the traditional setting cannot do.
- GAI models are efficient, and they could efficiently and easily help the teachers generate various quizzes and assignments for the students and help the teachers in their corrections, which otherwise is a very long and tedious task.

Hence, GAI plays a very significant role in revolutionizing the traditional form of education to a new level, where the students can learn new concepts easily, with much more attention, in an interactive, immersive, and engaging way. GAI will also help make teaching fun and engaging, not boring, as it used to be in traditional settings. According to an article in Forbes [10], the teaching job is tough, and it is sometimes titled to be beyond hard. Former Indian President, Dr. APJ Abdul Kalam, said that the teachers are the pillars upon which all aspirations become realities. Hence, it is necessary to make teaching fun and engaging, and the teachers love the job, not hate it, which can be served by the help of GAI. GAI could help reduce the teachers' workload and help them in various ways, ultimately providing them extra time for leisure and family time.

In the following study, first an overview of the GAI Models (Section 2 III) has been discussed, followed by various previous research works done in the field of GAI (Section 3



**FIGURE 1.** Categories of GAI products.

IV). After that, some preliminaries of GAI (Section 4 V) have been discussed. Section 5 deals with the need for GAI 3, Section 6 deals with applications of GAI 4, section 7 deals with various case studies of GAI VIII, depicting how GAI has been applied in the real world in the field of education. Section 8 deals with the confluence of metaverse with GAI IX, section 9 deals with various limitations and countermeasures of GAI 5, and section 10 deals with the future research directions of GAI in the field of education XI.

## II. METHODOLOGY

This section discusses the review protocol followed, the paper selection method, and the criteria for selecting the research papers.

### A. RESEARCH QUESTIONS

To precisely define the scope of the research, the following questions have been defined, which form the basis of the whole study. They are:

- What is the need for the integration of GAI in the field of education?
- What areas could GAI be used, and what benefits would it provide to the students and the teachers?
- What are various challenges and countermeasures in the integration of GAI in the field of education?
- Is there a scope for integrating the two cutting-edge technologies of GAI and Metaverse? If so, how can they

provide better experiences for students and teachers in the field of education?

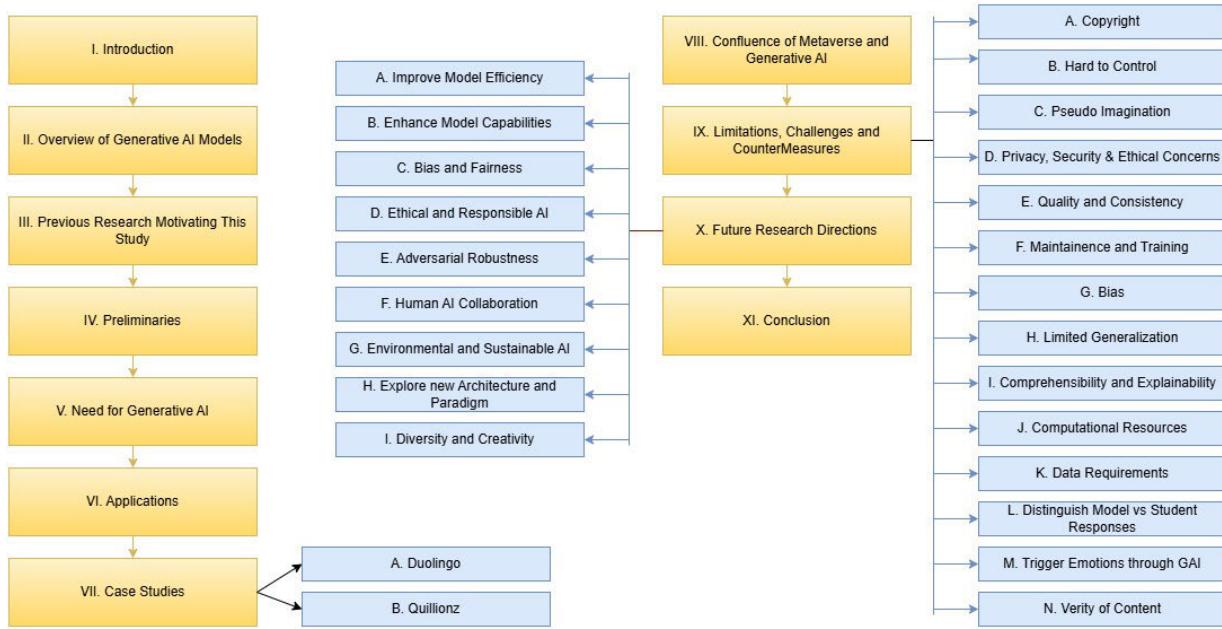
- What future research directions does the integration of GAI in education open up?

### B. CONDUCTING THE RESEARCH

To select the research papers to be included in this study, the authors searched many databases, including Google Scholar databases, IEEE, ACM Computing Surveys, and Springer. Various carefully designed search strings were used to sort the relevant research papers. The intention behind searching these databases was to have quality research papers published in reputed journals, conferences, magazines, workshops, symposiums, etc. The team used the following strings to sort out the research papers: Q1 = (“Generative AI”) AND (“Education” OR “Personalization” OR “Students” OR “Teachers”). Q2 = (“Generative”) AND (“AI” OR “ML”) AND (“Metaverse” OR “Virtual Reality” OR “Augmented Reality”).

### C. PAPER SELECTION PROCESS

After searching the databases, we rejected the papers whose titles were irrelevant to the study, and the remaining papers were passed on to the next stage. In the next stage, the team went through the abstracts and conclusions of the papers. In this stage, we rejected those papers which were not in line with our research goals. The papers passed were finally



**FIGURE 2.** Overview of the survey.

considered for review, and the team thoroughly read and studied those research papers.

### III. AN OVERVIEW OF GENERATIVE AI MODELS

GAI models are classified based on the types of output they generate. They can be broadly classified in text, images, video, audio, and 3D visuals, as depicted in the figure 1.

GAI models that generate texts include large language models (LLMs) such as GPT 3.5 and GPT 4 by OpenAI [11], Llama and Llama 2 by Meta and FAIR, PaLM and PaLM 2 by Google, Claude, and Claude 2 by Anthropic, Chinchilla AI by DeepMind, etc. These models accept a text prompt as an input and produce another text as an output. These models are trained on large datasets using deep learning models such as GANs [12] and Transformers [13].

GAI models which generate images include Midjourney Art generator, Dall-E, Dall-E 2, and Dall-E 3 by OpenAI, Craiyon AI generator [14], Stability Diffusion by Stability AI, Imagen by Google, GauGAN and GauGAN 2 by Nvidia, etc. These models take text as input, which is a description of the image, and as an output, they generate an image that matches the description of the image or the input. Several times, they generate multiple images as well. They are trained on various pairs of text and images over deep learning models such as GANs.

GAI models that generate videos include Imagen Video and Phenaki by Google, Make-A-Video by Meta and FAIR, Krikey.ai, Synthesia Studio, etc. These models take images or text as an input and generate a video as an output, which matches the description given as an input. These models are trained on image generators over

text, audio, and video datasets. These models produce multiple images simultaneously, forming a video when combined.

GAI models that generate audio include Murf.ai, AI voice generator MuseNet by OpenAI, MusicLM [15] and AudioPaLM [16] by Google, Voicebox by Meta, etc. These GAI models perform various functions, such as speech generation from text prompts, music generation, voice modulation, audio enhancement, etc. These models have been trained over multiple deep learning models and are then evaluated using metrics such as signal-to-noise ratio [17] and mean-opinion-score [18].

GAI models that generate 3D visual objects include Point-E by OpenAI, DreamFusion by Google and UC Berkeley, GAUDI by Apple, Magic3D [19] by Nvidia, Rodin Diffusion [20] by Microsoft, etc. These models take text or images as input and generate corresponding 3D images. These models are trained in high-end GPUs, which are suitable for dealing with complex computations of 3D data.

GAI models that provide an excellent platform for developers for developing games include Houdini, GameSynth, Unity Machine Learning Agents, Nvidia GameWorks, PolyGen [21], etc. These models can generate various important aspects of games, including characters, NPCs, objects, environments, audio-visual effects, sounds, music, etc. These models can produce these things dynamically while the user is playing the game. These models are trained using reinforcement learning and deep reinforcement learning [22]. These models are rigorously trained and tested, and these models are sometimes the packages of various other GAI models.

GAI models for generating codes include StarCoder by HuggingFace and ServiceNow, Codex by OpenAI, CoPilot and CoPilot X by GitHub, Microsoft, and OpenAI, Code Interpreter by OpenAI, CodeT5 [23] by SalesForce, etc. These models have been trained to take a text with a problem statement as input, and they produce the code for that input in the user's desired language. They have been trained to generate both the snippets of the code and all the functions. These models have been trained on vast amounts of public code available on various websites, and they are specially designed to assist human developers.

#### IV. MOTIVATION FOR THIS STUDY

The adoption of GAI in the educational sector lags behind its active adoption in other fields like medicine, finance, and e-commerce. Moreover, there's a noticeable gap in comprehensive research focused on the implications of GAI in education. Thus, it's crucial to consider educators' viewpoints on this topic. A preliminary study with European educators revealed a favorable stance towards AI in the educational sphere, highlighting their keen interest in integrating AI-related content into curricula [24]. Concurrently, research on Nigerian educators [25] underscores their readiness and enthusiasm to support AI-driven technologies within the classroom setting. A South Korean survey [26] found that educators with progressive beliefs are more inclined to adopt AI educational tools than their counterparts with traditional teaching mindsets. Another study [27] reflects these sentiments, mainly focusing on the fusion of chatbots in education. The findings suggest that educational chatbots are user-friendly and beneficial, paving the way for their increased incorporation into the learning environment.

#### V. PREMILINARIES

Navigating the realm of GAI brings forth fundamental questions: What exactly is AI, and how does it differ from ML? At its core, AI focuses on crafting intelligent agents – systems that can reason, evolve through learning, and function autonomously. On the other hand, ML stands as a distinct subset of AI. It pertains to systems that train a model using input data to make meaningful predictions on new, unseen data. Delving deeper into ML, we find two primary categories: supervised learning, which depends on labeled data, and unsupervised learning, which relies on unlabeled data [28].

Deep Learning (DL) propels this understanding further by employing artificial neural networks (ANN), enhancing the system's ability to solve intricate patterns beyond the scope of conventional ML [29]. Within DL, there's also semi-supervised learning, where the neural network is nurtured using a modest volume of labeled data combined with a substantial batch of unlabeled data. This method allows the network to grasp foundational task concepts through labeled data while using the unlabeled data to generalize to new scenarios [30].

GAI is a specialization within DL. It adeptly exploits ANNs and processes labeled and unlabeled data, employing supervised, unsupervised, and semi-supervised techniques. Moreover, LLMs are an intrinsic part of DL [31].

Breaking down DL models further:

- Discriminative models aim to categorize and predict labels for data points. Primarily developed on labeled data, they recognize the relationship between the data's features and their labels.
- Generative models' capability lies in creating new data instances, drawing from a probability distribution of the existing data. In essence, they craft fresh content [32].

To encapsulate, GAI seeks to understand data patterns to generate unique content. The hallmark of GAI is its ability to naturally produce content ranging from language to images and audio.

#### A. DEFINITION

GAI is a specialized form of AI that produces new content by concluding previously existing material. This learning process, therefore, culminates in forming a statistical model [33]. GAI taps into this model to anticipate a response when presented with a prompt, creating fresh content. Unlike traditional AI and ML methods prioritizing identifying patterns and insights within data, GAI emphasizes producing novel data not directly derived from the existing dataset or training materials [34].

GAI is broadly segmented into generative models and GANs. Models like variational autoencoders (VAEs) [35], gaussian mixture models (GMM) [36], hidden Markov models (HMM) [37], and latent Dirichlet allocation (LDA) [38] fall under generative models. These models internalize the data distribution from training and subsequently produce new instances from this learned distribution. Conversely, GANs operate with two intertwined neural networks: the generator, which formulates new data points, and the discriminator, which differentiates between the artificially generated content and genuine data from the training set. The simultaneous training of these networks ensures the generator refines its outputs to be increasingly authentic.

With its unparalleled ability to craft new content, GAI holds the potential to revolutionize sectors, including education, by ushering in a new era of tailored and inventive learning opportunities.

#### VI. NEED FOR GENERATIVE AI

GAI is one of the fastest-growing fields in AI and ML. Having GAI has many advantages in the field of education, which the traditional education system lacks. Some of them are discussed below. They have also been described in figure 3.

##### 1) FOSTERING INQUIRY AND ESSENTIAL SKILLS IN STUDENTS

The potential of GAI to encourage essential traits and skills in students, such as the inquiry spirit, is crucial for student achievement, preparing them to become future



**FIGURE 3.** Need for GAI in education.

educators and engage effectively in worldwide and scientific discussions. A study by *Abdelghani et al.*, [39] highlighted how GPT-3 could become an educational tool to replicate children's inherent curiosity and improve their ability to formulate questions. This research focused on creating automated prompts that encourage questioning, leading to more sophisticated inquiries.

These findings emphasize the importance of GAI in promoting a desire for knowledge-based learning [40]. Such technologies create an environment conducive to nurturing curiosity. Establishing strong connections between teachers and students and introducing young minds to knowledge requires the skill to ask relevant questions. As GAI plays a vital role in developing these abilities in students, it is of particular significance in educational institutions. Traditional educational systems often fail to ignite curiosity among students, resulting in limited participation in class discussions. This issue is persistent in many schools and colleges, where only a handful of students ask questions, while others miss the chance to be actively involved in classroom discussions [41].

## 2) PERSONALIZATION

GAI significantly enhances personalized education by customizing content, learning pace, and complexity to meet each student's unique requirements, learning styles, and preferences. Digital tools like ChatGPT and similar GenAI technologies serve as effective digital tutors, offering instruction in various subjects to a varied student population. Traditional education systems often fall short of providing sufficient attention to each student. Notably, students from

different geographic or cultural backgrounds may struggle to adapt to the teaching methods and environment of their new schools [42]. In such scenarios, GenAI can assist these students in adapting to the local educators' teaching styles. It can offer tailored strategies to help students understand and adjust to their new educational surroundings, ensuring a smoother and more effective learning experience.

## 3) ENGAGEMENT AND INTERACTIVITY

GAI has the potential to revolutionize educational experiences by crafting engaging and immersive learning environments. This includes the creation of simulations, virtual reality scenarios, and gamified elements that enhance student engagement and eagerness to learn new concepts. It is a common observation that students often lose interest in certain classes or topics due to the subject matter or a lack of engaging teaching methods [43]. In these instances, traditional educational systems struggle to maintain student interest and facilitate effective learning [44]. However, GenAI can significantly assist students and teachers in this regard. GenAI can rekindle student interest and participation by introducing interactive and captivating educational tools, leading to improved learning outcomes.

## 4) ADAPTABILITY

GAI can adjust teaching methods according to a student's progress and achievements, offering personalized feedback, recommendations, and learning paths. This guarantees students the right level of support and challenge, promoting efficient learning and growth. In research conducted by Zhu et al. [45], the effectiveness of an AI-powered feedback system was evaluated. This system incorporated automated grading methods in high school assignments related to climate studies. The results of this study suggest that such AI-driven feedback helped students improve their scientific argumentation skills.

## 5) EFFICIENCY AND ACCESSIBILITY

GAI algorithms can automate various tasks, such as generating worksheets, tutorials, evaluations, and feedback. This significantly reduces the workload for teachers, enabling them to devote more time and attention to catering to students' individual needs and enriching their overall learning experience.

## 6) CREATIVITY AND INNOVATION

GAI empowers students to delve into their creative side, facilitating the creation of unique artworks, music, or written pieces. It nurtures inventive thought processes and offers platforms for individual expression.

## VII. APPLICATIONS

GAI has enormous application in today's education age across all levels, from primary school students to graduates and post-graduates. Some of them are mentioned in this section and have been depicted in the figure 4.

**TABLE 2.** Comparisons of various research papers in the field of GAI in education.

Year	Title of Research Paper	Citations	Special Contributions
2023	The Use of Generative AI in Education: Applications and Impact	Abunaseer et al. [46]	The study provides a comprehensive evaluation of the potential of GAI to transform education. It analyzes various applications of GAI in personalized learning, adaptive testing, predictive analytics, and interactive chatbots. It also addresses various ethical concerns and limitations associated with the use of GAI in the field of education.
2023	Generative AI in Education and Research: Opportunities, Concerns, and Solutions	Alasadi et al. [47]	The research paper provides a comprehensive analysis of various critical aspects in the topic of implementing GAI in education to advance the goals, address various ethical concerns in various scientific publications, and evaluate the implications of the content generated by GAI in professional activities.
2023	Generative artificial intelligence empowers educational reform: current status, issues, and prospect	Yu et al. [48]	The research paper analyzes the potential of GAI to transform education by evaluating its applications, identifying key challenges such as data privacy and algorithmic fairness. The paper also proposes various solutions to enhance personalized and effective learning experiences.
2024	A Systematic Review of Generative AI for Teaching and Learning Practice	Ogunleye et al. [49]	This research paper provides a comprehensive synthesis of existing research and identifies various critical gaps in the integration of GAI in the field of education in various institutions. It also outlines various future directions for interdisciplinary collaborations and implementation in teaching and learning
2024	Advancing the generative AI in education research agenda: Insights from the Asia-Pacific region	Wong et al. [50]	The study provides a nuanced exploration of the evolving role of GAI in education. It offers various intellectual advancements in the Asia-Pacific region and invites global conversations on the intersection of GAI and education.
2024	A Cybernetic Perspective on Generative AI in Education: From Transmission to Coordination	Griffiths et al. [51]	The study presents an argument, urging the shift of educational systems from traditional educational models to a cybernetic approach. It emphasizes the need for coordinated interactions between educators and GAI systems to enhance learning processes and outcomes.
2024	GPT-3-driven pedagogical agents to train children's curious question-asking skills	Abdelghani et al. [39]	The study highlighted how GPTs could become an important tool to replicate children's inherent curious nature and improve their ability to formulate questions. The research focused on creating automated prompts that encourage questioning among the students, leading to much more sophisticated inquiries.

The methodology used while writing the applications is as follows. A human being's journey in education starts at the age of when he gets engaged in play school. The applications of GAI for such students have been described in the early education section. From 2 to 18, a student remains in school, and the applications for such students have been mentioned under the heading "Revolutionize education across all levels." Then, the students get university admission. In university, we have majorly chosen engineering and medical disciplines because these two disciplines deal with the most abstract concepts, complex theories, and complicated practical examinations. Other than this, history and geography are two such disciplines that students usually find boring; hence, they have also been mentioned, highlighting the exclusive benefits of GAI. After completion of university, a student majorly takes two paths: search for a job, for which the section on skill development has been mentioned, or become an entrepreneur, for which a section named entrepreneurship education has been mentioned. Other than that of students, some applications for teachers have also been mentioned, as well as some general applications.

#### A. EARLY EDUCATION

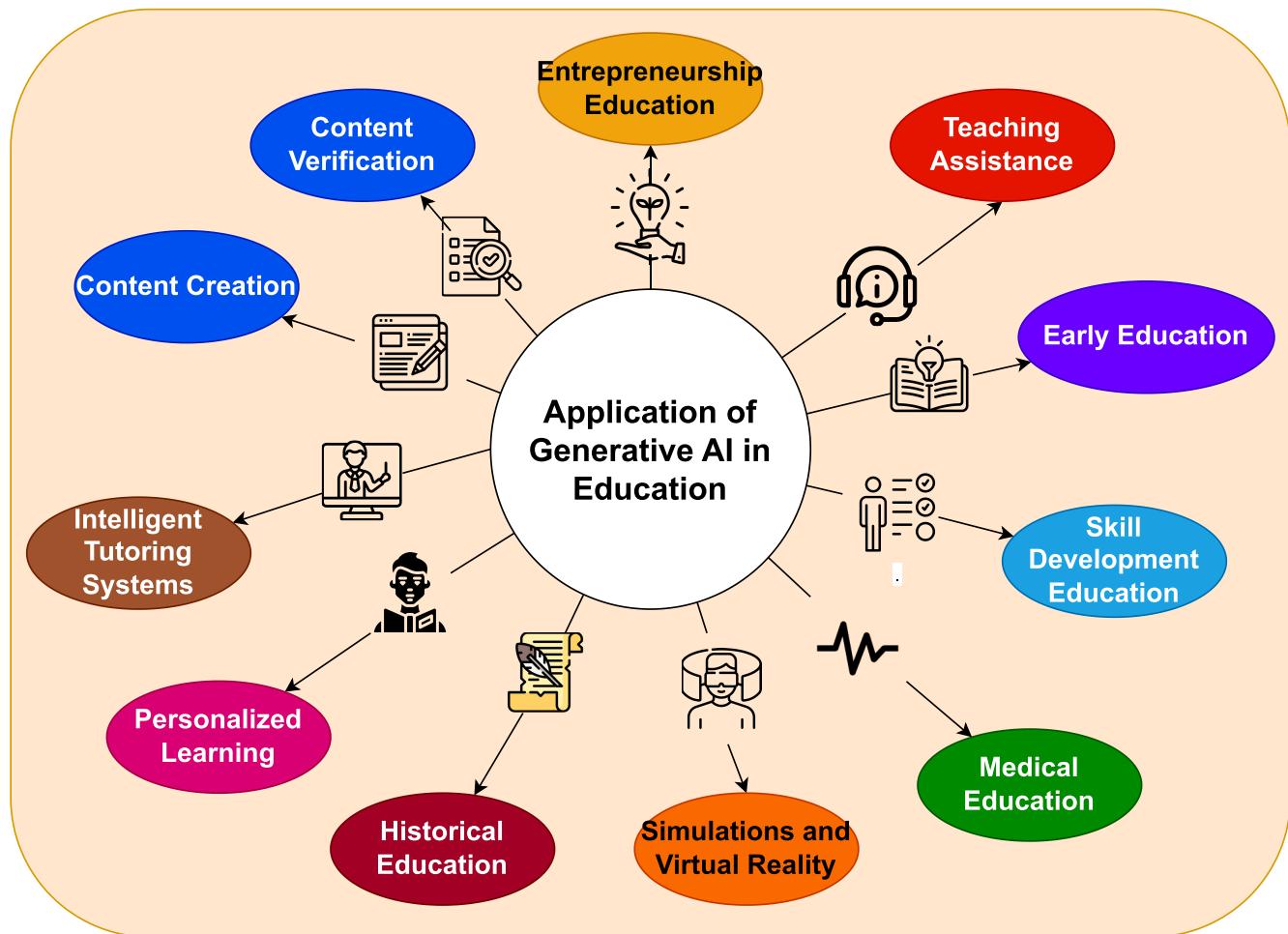
Grooming children aged 2-7 demands systematic, patient, and directed learning. During this critical phase, children grasp fundamental concepts such as language, environment, and relationships. GAI models can offer personalized guidance tailored to each child's needs. To help the model recognize a child's personality traits, a questionnaire can be filled out by the guardians, which will allow the AI to recommend specific teaching methods based on the child's learning style: visual, auditory, or kinesthetic [58].

Previously, preschools relied on many charts, cassettes, storybooks, and props. With an intelligent board powered by GAI, teachers can instantly present educational materials, reducing the need for physical resources. Audio-visual aids, which have been proven to impact children's creativity positively [59], can be seamlessly integrated into smart boards. The AI can result in videos with vibrant visuals and catchy rhymes, simplifying subjects like alphabets, stories, and counting, making learning enjoyable.

Children benefit from diverse repetitions of concepts, reinforcing neural connections and aiding retention [60].

**TABLE 3.** Evaluation and discussions of various research groups on GAI in education.

Year	Title of Research Paper	Citations	Description
2020	The effect of automated feedback on revision behavior and learning gains in formative assessment of scientific argument writing	Zhu et al. [45]	This research study evaluated the effectiveness of the AI-powered feedback system. The study incorporated automated grading methods in high school assignments related to climate studies. The study results show that an AI-driven feedback system helped the students improve their scientific argumentation skills.
2021	Evaluating Artificial Intelligence in Education for Next Generation	Joshi et al. [52]	This study examines the perceptions of the students and the teachers about the use and effectiveness of GAI in education. This study found that GAI has the potential to enhance learning and teaching. Still, some concerns are related to ethical use and the need to integrate GAI into educational institutions responsibly.
2023	Revolutionizing education with AI: Exploring the transformative potential of ChatGPT	Adiguzel et al. [53]	This research study examined the current state of the use of GAI among the students and also presented the importance of having a targeted educational system. The study emphasizes the need for having a structured approach while integrating GAI into educational institutions, ensuring that the students will develop a comprehensive understanding of the capabilities and limitations of GAI.
2024	Evaluating the Impact of Students' Generative AI Use in Educational Contexts	Wood et al. [54]	This study evaluated the impact that GAI had on the learning experiences and perceptions of the students through a master's level course in educational technology and instructional design. The study concluded that the integration of GAI helped the students to increase their comfort in education and learning and their understanding of its ethical implications. The AI-ICE framework was used to assess students' cognitive engagement, demonstrating that the students were at the initial engagement level and, with the integration of GAI, helped them increase their awareness of AI's limitations and ethical issues. The study also highlighted themes like improved teaching strategies, personal growth, and the practical challenges of integrating GAI responsibly.
2024	Towards Responsible Development of Generative AI for Education: An Evaluation-Driven Approach	Jurenka et al. [55]	The research paper presents a collaborative, multi-disciplinary effort to translate the principles from learning science to various practical benchmarks, which are essential to assess the pedagogical capabilities of GAI in the field of education. The research paper introduces LearnLM-Tutor, a fine-tuned version of Gemini 1.0. The model evaluates its performance against a prompt-tuned Gemini 1.0 using a collection of seven diverse benchmarks, which included various quantitative, qualitative, automatic, and human evaluations. The results showed that educators and learners consistently prefer the model LearnLM-Tutor, demonstrating its improved pedagogical capabilities. The research paper aims to serve as a stepping stone to develop a comprehensive educational evaluation framework, enabling progress in maximizing GAI's positive impact on education.
2024	Generative Artificial Intelligence in Education: From Deceptive to Disruptive	Alier et al. [56]	The study examines the potential of GAI to transform the field of education by analyzing various applications and its implications in teaching and learning. It also highlights the need to implement various ethical practices that use GAI models to ensure that the technology supports and enhances students' learning experience. The study presents an argument that GAI has emerged as a promising technology capable of creating original content such as images, text, video, etc., and it can potentially be a disruptive force.
2024	Fight Fire with Fire: How Much Can We Trust ChatGPT on Source Code-Related Tasks?	Yu et al. [57]	The study was conducted on the coding skills of the GPTs. It was found that even GPT-4 predicts its erroneously generated code as correct. The code generation accuracy of GPT-4 is 77%, and that of GPT-3.5 is 65%. The probability of predicting an incorrect code as correct is 55% in GPT-4 and 84% in GPT-3.5.



**FIGURE 4.** GAI applications in the context of education.

GAI can suggest innovative teaching methods, such as games or musical recitations. For instance, teachers might request the AI model for “Game ideas for 5-year-old students to teach single-digit addition.” The experiment was performed on ChatGPT 3.5, and some of the most exciting and fun ideas resulted. Some of them being

- Number Line Hopscotch - In this game, a big number line is drawn on the ground with chalk, and the teacher calls out a specific addition problem, and the child has to hop to that particular number.
- Math Puzzles In this game, simple jigsaw puzzles can be made in which, on one end, numbers are there, and on the other hand, the sum of these numbers is written. The students can match these numbers with their sum.
- Number Bingo - In this game, bingo cards can be made with numbers from 1-9. Then, the teacher can call out an addition problem, and the students can cover the sum card on their bingo cards. Whoever does it first can call out “Bingo!”

Moreover, fostering collaboration between teachers and parents is essential for early education. Most parents lack

formal training in childhood education [61]. A GAI-powered application can bridge the gap here. Teachers can upload progress reports, and the system suggests home activities to parents based on these reports, ensuring a cohesive learning experience.

#### B. REVOLUTIONIZE EDUCATION ACROSS ALL LEVELS

GAI's evolving role in education is increasingly recognized for its significant promise and continuous development. Its applications span various educational stages, offering unique benefits from elementary to university education. GAI enhances writing and reading skills for younger students by detecting grammatical and syntactic errors, thus improving their language abilities. Additionally, educators can use GAI to create animated instructional content, providing a captivating learning experience that ignites students' academic curiosity and keeps them engaged [62]. In middle and high school, where students learn advanced theoretical knowledge, GAI improves understanding and learning by providing teachers and students with audio-visual content and tools to visualize and easily apply the theory. It makes subjects

like history and geography more accessible, especially when combined with metaverse technology, allowing students to experience these disciplines virtually [63], [64] [65]. This approach offers hands-on experiences, increasing both engagement and understanding [66].

GAI is invaluable for university students when visualizing abstract and complex topics. Tools like DALL-E and Midjourney create imagery representing intricate subjects, enhancing visual understanding and demystifying challenging academic concepts [67], [68]. Moreover, GAI facilitates peer-to-peer interactions in group and distance learning settings, encouraging active participation and collective learning. It adapts to individual students' inputs, providing personalized instruction, thereby enhancing the effectiveness of distance learning [69]. Significantly, GAI also assists individuals with disabilities by offering rapid text-to-speech and speech-to-text capabilities, ensuring fair and equal educational opportunities. This technology provides tailored support, enabling their full engagement in educational experiences [70]. In conclusion, GAI offers significant benefits for students at all levels, irrespective of their intellectual capabilities, redefining the education landscape with its versatile and inclusive applications.

### C. MEDICAL EDUCATION

GAI can develop lifelike virtual patients and a range of clinical scenarios, from joint consultations to unusual and intricate medical cases, offering students a secure setting for learning and practicing without the risk of real-life consequences [71]. Surgical training provides detailed and realistic simulations, enabling students to refine their surgical techniques in a virtual space before performing actual surgeries. This technology also supports medical students in research endeavors by analyzing extensive medical literature and data, a crucial factor in understanding emerging treatments, drugs, and healthcare trends [72].

Moreover, GAI is crucial in enhancing clinical communication skills among medical students through natural language processing (NLP). This includes simulations of interactions with patients, which would be used to practice conveying relevant diagnoses, treatment plans, and empathetic care to the patient [73]. AI algorithms offer immediate feedback on theoretical knowledge and practical skills, helping students pinpoint areas needing further development [74].

GAI also contributes to navigating ethical challenges and professional obstacles in medicine, preparing students for the complexities they may encounter in their careers [75]. In drug discovery, its algorithms can expedite the process by predicting various chemical compounds' behavior and potential effectiveness, thus reducing development time and costs [76]. Additionally, it aids in teaching students the interpretation of medical imaging, such as X-rays, MRIs, and CT scans, by generating a wide range of medical images for practice, including those depicting rare conditions, thereby enriching the educational experience.

### D. HISTORY EDUCATION

To safeguard the accumulated knowledge of historical events and civilizations, it is essential to preserve historical academic materials and educate students on them occasionally. Unfortunately, this knowledge is at the risk of becoming outdated because of its decreasing relevance in the present day [77]. But despite all these things, some people, as highlighted by a report by the United Nations Conference on Trade and Development [78], are trying hard for the protection and sustenance of the foundational principles of traditional educational systems. Esteemed institutions, including libraries, archives, and digital repositories, are actively engaged in the meticulous digitization process to safeguard these assets [79].

The advent of GAI offers a novel approach to this preservation problem. While the immediate applicability of these archived materials may appear limited in a modern context, GAI can transform them into dynamic, interactive academic content [80]. This technology can serve as a way to facilitate the synthesis of traditional teaching methodologies with contemporary educational paradigms [81]. Through a rigorous analysis of the historical trajectory of educational practices, researchers can identify and address inherent deficiencies, which will lead to the formulation of a more holistic and robust academic framework [82].

Furthermore, such analytical endeavors provide invaluable insights into the complexity of human cognitive processes. For instance, historical data suggests that solutions were devised when confronted with an educational anomaly denoted as  $x$ , represented by the variable  $y$ . The patterns discerned from such historical instances can be instrumental in developing sophisticated systems adept at identifying and rectifying discrepancies in teaching, thereby fostering continuous academic advancement [83].

### E. ENTREPRENEURSHIP EDUCATION

In Entrepreneurship Education, the application of GAI is paving the way for more innovative and effective teaching methodologies. One of its primary roles is to provide customized learning experiences. By analyzing individual students' learning styles and progress, GAI enables educators to tailor the curriculum to accommodate various learning paces and preferences. This personalization is especially beneficial in entrepreneurship education, where students come from diverse backgrounds and possess different skill sets [84].

Another significant application is the creation of interactive business simulations. GAI can craft realistic and complex business scenarios, allowing students to engage in decision-making processes that mimic real-world entrepreneurial challenges. This hands-on experience is invaluable in teaching students how to navigate the uncertainties and complexities of starting and managing a business [85].

Moreover, GAI's capability in market trend analysis and predictions is a boon for entrepreneurship students. It helps them understand market dynamics and consumer behavior

and adapt their business strategies accordingly, a crucial skill required for entrepreneurs [86], [87]. In addition to market insights, GAI can significantly contribute to idea generation and innovation workshops. It can offer a broad range of ideas and perspectives, encouraging creativity and innovative thinking, which are central to entrepreneurship [88].

The AI's guidance in developing business plans and strategies is another critical application. It can provide students with suggestions, templates, and examples of successful business strategies, enhancing their ability to create comprehensive and effective business plans. Lastly, GAI facilitates networking and collaboration by connecting students with mentors and industry professionals based on shared interests and goals. This aspect of GAI not only aids in learning but also helps build a professional network, which is an integral part of entrepreneurial success. Thus, GAI is emerging as a pivotal tool in entrepreneurship education, revolutionizing how entrepreneurial skills are taught and learned [89].

#### **F. SKILL DEVELOPMENT EDUCATION**

Skill development in adults is pivotal for personal and national growth, leading many governments to prioritize it in their policies [90]. GAI offers transformative solutions in this domain. One significant confusion that youth go through is which career option to choose. In a report by The Great Disconnect, it was found that 32% of the 9636 participants said they were “very unclear” on what they needed to do in their careers. In the survey, 63% of the people were college students, which included employed and unemployed graduates. The survey was conducted across 140 countries [91]. In such cases, GAI can suggest potential career paths by analyzing various job trends, individual career preferences, and existing skill sets. It can also recommend multiple courses and training programs, which can help enhance the student's skill sets and chances to find a beautiful career in that field.

GAI can also create platforms for adaptive learning to help identify individual strengths and weaknesses and provide help accordingly. It could also offer real-time feedback to the user, which would cater to effective learning [92].

Based on specific individuals, the model can also frame specific relevant questions, which would help the user work on improving their shortcomings. From a large set of problems, the model can easily search through and identify the issues the user should address to boost their skills. One of the use cases may be in competitive programming preparation, in which websites like LeetCode (2000+ questions), CodeForces (2000+ questions), CodeChef (2000+ questions), etc. have a considerable question set. Still, it is often confusing for users to choose the right questions to practice and avoid repetitive and irrelevant questions. Hence, GAI would also help save students time. The model can dynamically craft and even present the questions in such a way that the level of difficulty is in increasing order. At the same time, the AI can also figure out that even if the user has

solved a particular problem correctly, at what point or at what concept does the user lacks proper understanding or practice, which can be easily computed by tracking the activities of the user, as at what time does the user take the most time, or what all mistakes do the user repeatedly corrected, etc. It will help the user to prepare well. Secondly, when a specific goal is being fixed by the user, such as being an HR in Google, then the GAI will slowly and steadily raise the level of the user and will take the user to the level where he can easily qualify for the goal he has set.

In essence, GAI can revolutionize adult skill development, offering efficient and personalized tools and ensuring students get the most out of their educational endeavors.

#### **G. EXPLORE PROSPECTS FOR TEACHING**

GAI models are poised to revolutionize the educational landscape, offering substantial assistance in teaching methodologies [62]. This technology excels at crafting individualized curricula incorporating feedback, enabling educators to effectively address learning gaps and ensure no student is left behind. By using GAI, teachers can provide personalized attention to each student, thereby improving the quality of education. This approach streamlines the evaluation of student abilities and mitigates common human errors in manual analysis, ultimately saving educators valuable time and energy [93].

Furthermore, GAI empowers teachers to develop captivating lesson plans and activities tailored to their students' needs. Educators can create comprehensive lesson plans and engaging activities by inputting relevant documents into the system [94]. This technology also aids in producing short, educationally driven videos and films to enhance students' understanding [95]. GAI's ability to generate quizzes aligned with instructional goals and facilitate assessments is particularly beneficial. This method addresses the challenge of grading students with diverse skills, as quizzes can be customized based on the previous responses of the individuals. It also enables the creation of tests that cater to the varying intellectual levels of all students.

In language classes, GAI significantly aids students in thoroughly understanding the language. It enhances the efficacy and efficiency of research and writing tasks by identifying and correcting grammatical inaccuracies, ensuring the precision of written text. Moreover, it can detect and highlight semantic inconsistencies, offering suggestions for improvement and identifying opportunities to refine the content's style to suit the subject matter better [47].

Lastly, GAI is crucial in supporting teachers' professional development. It gives them valuable insights, summaries, and explanations about new teaching methods, technologies, and materials. Access to these resources allows teachers to stay alongside the latest trends in education, enhancing their teaching effectiveness [96].

In summary, GAI is a promising tool for personalized curricula, offering individualized attention and improved teaching quality. It aids educators in creating lesson plans,

activities, and quizzes based on student feedback. It is a resource for continuous professional growth, keeping teachers up-to-date with the latest educational methodologies and technologies.

#### **H. TEACHING ASSISTANCE**

Students frequently engage with platforms such as Chegg and Duolingo to grasp novel concepts, find solutions to questions, and obtain support for their academic endeavors. These digital resources have effectively demonstrated their proficiency in personalized learning with the help of GAI, which can be established by the fact that in 2022, these platforms boasted over 320 million registered users, with Duolingo emerging as a leading educational application, which received 100 million installations [97]. The integration of GAI into these platforms has further amplified their capabilities, as mentioned in [VIII-A](#).

Visual aids and simulations can articulate intricate ideas more effectively than mere text. Enhanced audio-visual explanations can be synthesized utilizing large language models (LLMs), image generation, and video generation models. Such a framework yields comprehensive explanations, integrating diagrams, graphs, charts, mind maps, mnemonics, pseudocode, imagery, GIFs, auditory clips, and video simulations.

Effective way of teaching requires spreading knowledge and fostering interactions with students. Optimal understanding of the subject is achieved when students can both constitute and respond to questions. Beyond mere information delivery, AI-empowered virtual educators can proactively query students, thereby clarifying ambiguities. For instance, teaching assistants can be programmed to furnish exhaustive explanations in reply to student inquiries. Udacity envisions leveraging GPT-4 to instantiate an intelligent virtual tutor capable of dispensing personalized guidance and feedback. This entity tailors its responses to align with individual students' learning tendencies, explaining complex assignments and technical jargon.

Furthermore, AI algorithms can be deployed to formulate standardized assessments, generate academic reports, and monitor student progression. Intelligent models can measure the capacity of the students to grasp the concepts, attention span, areas requiring improvement, learning trajectories, and recurrent mistakes based on their input. Consequently, the AI model evolves to dispense tailored assistance, enabling educators to cater distinctively to each student. For students with limited English proficiency, GAI emerges as a boon. The virtual mentor can seamlessly translate topic-specific content or solutions into the student's vocabulary, promoting enhanced understanding.

#### **I. CONTENT CREATION**

GAI offers immense potential in curating educational resources in diverse formats. The possibilities are vast, from auto-generating tests, quizzes, and assignments that free

up educators' time to crafting educational clips, interactive simulations, and virtual worlds for in-depth learning. For instance, with advanced models like GPT-3.5 Turbo, one could prompt it for a brief description of the Amazon rainforest and then request a few relevant questions. A study by [98] presented a methodology to produce assessment questions in data science education. By refining the GPT-3 model using text-centric learning resources and subsequent manual assessment by experts, the results showcased the generated questions positively. This underscores the valuable role of GAI in advancing educational methodologies.

#### **J. CONTENT VERIFICATION/CORRECTION**

GAI offers a valuable tool for evaluating student submissions. Through its analysis, it can detect errors in student assignments, provide instant feedback, and propose corrective measures. This not only aids students in recognizing and rectifying their mistakes but also enhances their writing proficiency in the long run [99]. Furthermore, by automating the assessment process, GAI eases the workload for educators, enabling them to allocate their time and energy to more pressing educational tasks [100].

#### **K. INTELLIGENT TUTORING SYSTEMS**

GAI has the potential to revolutionize education by creating advanced tutoring systems and offering tailored feedback and guidance to students. Beyond feedback, it can craft solutions, provide hints, and explain complex concepts. Additionally, GAI can generate answer keys for many examinations, from school and university assessments to competitive exams like IIT-JEE, GRE, and TOEFL. Leveraging the power of few-shot learning, a study demonstrated that OpenAI's Codex model excelled in presenting diverse programming tasks. This included accurate solutions, automated tests validating student submissions, and supplementary code clarifications [101].

#### **L. IMAGE AND VIDEO SYNTHESIS**

GAI is an expert at producing realistic images and videos. This capability significantly enhances education in fields such as arts and crafts, thereby stimulating greater creativity among students [68]. It also plays a crucial role in creating customized instructional videos to meet specific curriculum needs. In subjects like biology and physics, GAI can visualize complex ideas, such as cellular processes or particle physics, in a way that simplifies understanding. It can vividly recreate historical events, figures, or places for history classes, making the subject more engaging and visually rich compared to traditional text-based learning [102].

This technology can visually interpret scenes from novels, plays, or poetry for language and literature education, aiding students in grasping abstract or complex literary works. In Geography and Astronomy, GAI produces various geographical and astronomical events, facilitating a visual exploration of Earth and space [103]. GAI's ability to

**TABLE 4.** GAI applications in education for the students belong to various disciplines, along with the future research potential.

Discipline	Applications	Future Research Potentials
Early Education	GAI could offer personalized help for each student's needs. The model could provide a detailed description of how to train a child and help them get a good start. It can also provide various interactive materials like charts, cassettes, storybooks, etc. Fun interactive games could be designed with the help of the model to help the child learn through gaming.	GAI models provide vague results when provided some input, especially when they are engaged in making images. Much more efficient models could be made, which could help provide effective results, helping the students and the teachers.
Middle-School and High School Education	In these years, the students are usually familiar with certain theoretical topics and are taught how to visualize them. GAI can help the students visualize the theoretical subjects by creating audio-visual effects. With the combination of the metaverse technology, the students could even feel subjects like history, geography, etc., strengthening their hold and interest in the subjects.	Metaverse technology is not very developed yet, and its integration with GAI is also not practically available. Active Research could be conducted to make these two technologies robust and practically applicable.
University Education	University education deals with complex and theoretical topics. AI could help the students visualize the topics and concepts. They will also help foster peer-to-peer interactions and help the students learn how to interact with their peers, which forms one of the most important aspects of university education.	Significant steps could be taken to improve the quality of the outputs of the GAI models.
Entrepreneurship Education	GAI models could help create various business simulations for the students, which will help them learn and perform better in real-world interviews. They can help improve the decision-making skills by creating various scenarios for the entrepreneurs.	Explainable AI should be promoted and integrated into the generative models to ensure that the models provide correct decisions and can be evaluated later, preventing wrong information flow.
Skill Development Education	GAI can help students decide what career to choose by analyzing various job trends, individual career preferences, and existing skill sets. It can also help identify various strengths and weaknesses of the individual and provide the plan accordingly, which can help maximize the skill set and efficiency. It can also help search and sort the resources available online, which can help save the students' time and provide them with the same or even more qualifications that the students might have achieved otherwise. It can also identify various mistakes of individuals and can provide a program that would systematically remove those repeated mistakes.	GAI models are usually biased, inherited from their datasets. In this case, the bias present could force the individuals towards a single or a biased job preference, including other aspects. Further research could be conducted to remove any bias and provide a transparent platform. Research should be conducted to create a model that could help remove any copyright problems from the models.
Medical Education	GAI could provide a virtual platform for virtual patients, where the students could learn how to operate in front of the patients. It could provide a realistic simulation of the operation theatre and the surgeries. It also helps analyze the vast amount of medical literature and could help conduct much smoother research. It can also help in improving the clinical communication skills of the students.	research could be conducted to increase the quality of the simulations and integrate them with metaverse technology so that the students can easily dive into virtual reality.

generate a variety of art styles and designs enhances the teaching of different artistic techniques and principles, encouraging creativity and innovation in art and design students [104].

In scientific subjects, such as chemistry and physics, GAI can simulate experiments that might be too risky, costly, or impractical to perform in a classroom setting, allowing for safe and informative visual learning [105]. Integrating AI-generated visuals into educational materials,

such as interactive e-books, online courses, and learning apps, makes these resources more engaging and interactive.

GAI's creation of visuals and videos depicting diverse cultures, environments, and ecosystems fosters global and environmental awareness among students [106]. It is also valuable in professional and vocational education, providing realistic simulations for training in fields like medicine, engineering, or architecture [107]. In online learning, GAI

enhances course appeal and comprehensibility with rich visual content [108].

Beyond traditional education, GAI has applications in video game design, virtual reality, cinematic effects, and educational deepfakes [109]. OpenAI's DALL-E, for example, offers visual representations of complex and abstract subjects, assisting in better comprehension. This technology is also critical in upscaling low-resolution images to higher qualities, such as 4K. It is invaluable in restoring vintage videos and lectures, including those featuring prominent scientists, for educational use [110].

#### M. PERSONALIZED LEARNING MATERIAL

GAI can profoundly reshape personalized education. It can produce textbooks that adapt to students' learning pace and interests, ensuring content is always relevant. Worksheets can evolve in difficulty based on a student's performance, offering challenges or foundational exercises as needed. The technology can also craft real-time interactive lessons, quizzes, and simulations to engage students. Post-evaluation, the AI can offer tailored feedback and resource recommendations. Moreover, it can weave in a student's passions, like music or art, into their curriculum and cater to diverse linguistic and cultural needs. Through GAI, education becomes more individually adjusted, engaging, and effective [48], [111], [112].

#### N. DATA PRIVACY PROTECTION FOR ANALYTICAL METHODS

A key benefit of GAI is its capability to develop training data, which helps preserve student information's confidentiality. It is crucial to secure student data, as breaches or unauthorized access can expose their details, potentially resulting in specific threats or escalated crimes against them [113]. AI models can craft synthetic data from real-world patterns, offering a veil of anonymity and safeguarding student data [114]. Such AI-generated synthetic datasets serve as practical training tools for other models and uphold stringent security standards, ensuring they're trustworthy and safe [115].

#### O. TEXT GENERATION, LANGUAGE LEARNING, AND TRANSLATION

GAI boasts the capability to translate text and audio among abundant natural languages, making it a pivotal asset in educational and international contexts. Within education, it has the potential to create exercises, exams, tutorials, and lectures in various languages, addressing the needs of students from different linguistic origins. This AI technology can formulate language exercises, aid in speech synthesis for proper pronunciation, and offer immediate translation assistance. Such features democratize access to language education and elevate students' proficiency. Moreover, it can produce additional study materials and exercises in multiple languages, promoting a more inclusive educational

atmosphere. This guarantees that students, regardless of their language background, receive content that aligns with their cultural and linguistic sensibilities, enhancing both understanding and involvement [116].

#### P. SIMULATIONS AND VIRTUAL REALITY

GAI can craft lifelike simulations and virtual reality settings that mimic real-world situations for educational and training endeavors. It can produce virtual lab experiments, medical training simulations, and recreations of historical events, offering a rich and engaging learning environment [117].

#### VIII. CASE STUDIES

GAI is one of the most advanced forms of ML and AI, and it offers immense benefits that are difficult for the industry to avoid. In this section, some case studies have mentioned how GAI is used in the industry to boost educational setups and approaches.

##### A. DUOLINGO

Duolingo, a leading language learning platform, has strategically incorporated OpenAI's GPT-4 technology to enhance the learning experience for its users. By integrating GPT-4, Duolingo has introduced innovative features that leverage the capabilities of this advanced language model [118].

One critical application of GPT-4 on Duolingo is in language tutoring and feedback. The platform utilizes the model to provide personalized explanations to users about why their answers are correct or incorrect. This feature, known as Explain My Answer, offers detailed and tailored feedback, resembling the guidance provided by a human tutor. By understanding the variations of users' responses, GPT-4 enhances the learning process, helping users grasp language concepts more effectively [119].

Moreover, GPT-4 is instrumental in Duolingo's adaptive learning modules. The platform analyzes users' strengths and weaknesses, tailoring language exercises and tests based on performance. By generating custom learning materials, GPT-4 ensures that users receive targeted practice, reinforcing their language skills where they need it the most. This adaptive approach enhances learning efficiency, allowing users to progress at their own pace while focusing on areas that require improvement [120].

Duolingo uses GPT-4 to create interactive dialogue scenarios. Users can engage in simulated conversations with the language model, practicing real-life language skills. GPT-4's natural language understanding capabilities enable dynamic and contextually relevant interactions, providing users with valuable conversational practice [121].

Additionally, GPT-4 is integrated into Duolingo's content creation tools. The platform employs the model to assist users in generating creative content, such as writing exercises, essays, and dialogues. GPT-4's language generation abilities enhance users' ability to express themselves in the target language, fostering creativity and language fluency [122].

By harnessing the power of GPT-4, Duolingo enriches its language learning ecosystem, offering users personalized, interactive, and dynamic language learning experiences. The integration of this advanced language model underscores Duolingo's commitment to providing innovative and effective language education to millions of students worldwide [123].

### B. QUILLIONZ

Quillionz is an AI-powered platform designed to generate questions and quizzes based on textual content. Its GAI capabilities enable educators and content creators to transform text into meaningful, contextually relevant questions. Quillionz has utilized the capabilities of GAI to a great extent by using it in automated question generation, content adaptation, contextual relevance, educational resource creation, providing time efficiency, and providing adaptive learning support [124].

Quillionz automatically utilizes GAI to generate various questions from a given text. These questions vary in complexity, including multiple-choice, short-answer, and essay-type questions [125]. The AI understands the context of the content and generates questions that challenge students' comprehension [126].

The platform's AI algorithms adapt itself and then generate the questions based on the complexity of the input text. For instance, if the input text is a scholarly article, Quillionz can generate higher-level analytical questions [127]. Conversely, more straightforward texts generate questions suitable for foundational understanding. It also cares about making the questions generated relevant to the input text, which helps in enhancing the overall learning experience [128].

By automating the question generation process, Quillionz saves educators significant time. They can quickly generate various questions without manually reading and formulating them, allowing for more efficient lesson planning and content creation [128].

Beyond questions, Quillionz can generate prompts for discussions, study guides, and supplementary materials. Educators can use these generated resources to enhance classroom discussions and create comprehensive learning materials [129].

Quillionz can generate adaptive quizzes, adjusting the difficulty of questions based on individual student performance. This personalized approach ensures that students receive questions that match their proficiency level, optimizing the learning process [130].

## IX. CONFLUENCE OF METAVERSE AND GENERATIVE AI

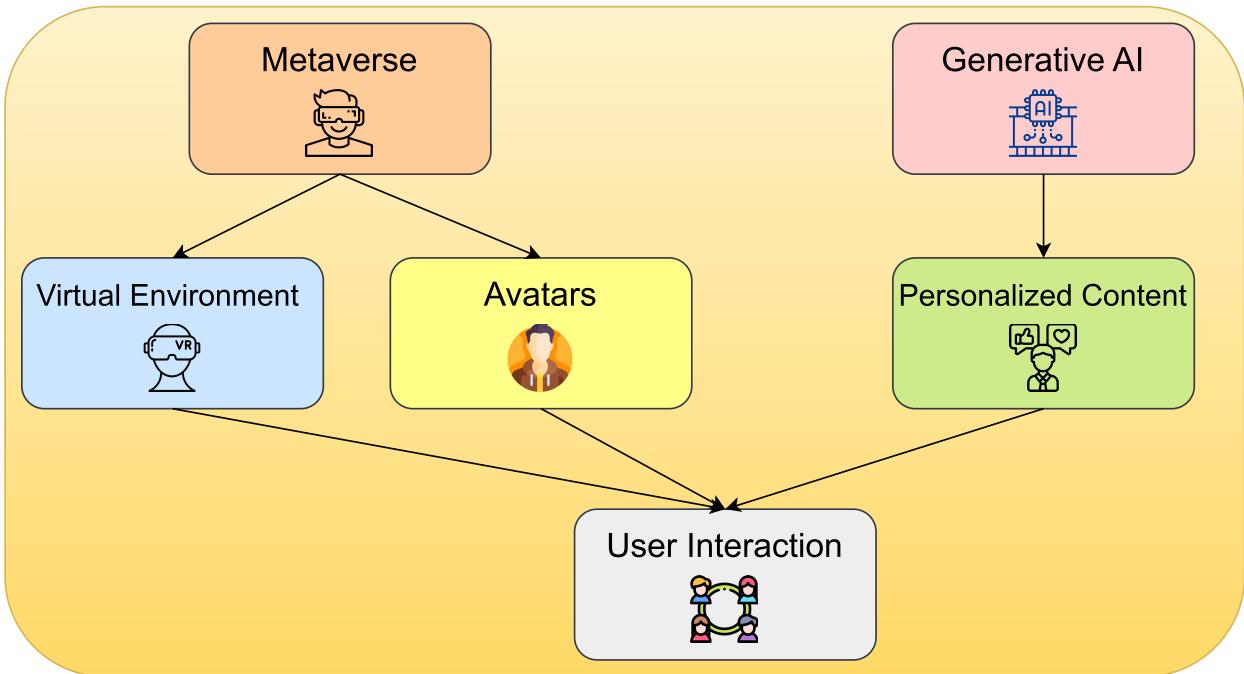
In today's advanced age, we see the merging of two groundbreaking technologies: GAI and the metaverse [131]. Together, they have the potential to redefine our understanding of creativity, interaction, and spatial experiences. According to data from Tech Market Reports [132], the global market for GAI within the metaverse is projected to reach \$428.9 million by 2032, growing at a compound annual rate of 31.5% for the metaverse 2032. This growth underscores the

significance of their intersection, especially in the educational sector. The benefits of GAI, including personalized learning, artistic expression, and content generation, can be further enhanced by integrating augmented reality (AR) and virtual reality (VR) [133].

The Metaverse is more than just a 3D internet—it's a rich fusion of shared spaces and collective experiences of limitless digital worlds where individuals have virtual representations, or avatars, that live, work, and play. Whether gaming, socializing, learning, teaching, or business, the metaverse transforms these activities, making them immersive and lifelike [134].

The convergence of the metaverse and GAI offers many opportunities to enrich the field of education.

- Immersive Learning Environments - With the metaverse and GAI integration, traditional education can be converted into a metaverse-based, immersive education environment. Within this advanced framework, students can engage in an immersive educational environment where historical events are dynamically represented, scientific principles manifest tangibly, and intricate theories are explained through three-dimensional visualizations [135]. For instance, one could conceptualize the molecular architecture of solids by examining their atomic configurations at a granular level while being wholly engaged in the experience. Furthermore, the intricate configurations of atomic structures and electron orbitals can be comprehended by navigating alongside electrons within their respective trajectories [136].
- Personalized Education - As described in VII-M, GAI can generate a tailored curriculum specific to individual students. When integrated with the metaverse, this curriculum becomes even more sophisticated. Students engage with this personalized curriculum within the metaverse environment, facilitating a more immersive and comprehensive learning experience [137].
- Realistic Simulations - Within education, the metaverse can offer simulations that mirror real-world situations. Through GAI-driven simulations on the metaverse, students can engage with problems and learn within a secure yet dynamic environment optimized for their developmental and educational progression. This immersive methodology augments their hands-on competencies and analytical thinking abilities, preparing them more effectively for real-world challenges [138]. To explain it further, consider an individual aspiring to learn aviation skills. The metaverse would furnish a virtual environment in such a context while GAI supplies the required simulation scenarios and difficulties. With the help of these technologies combined, students can conveniently sharpen their piloting capabilities by moving the aircraft within this virtual space and confronting potential errors they might commit during actual flight operations. This combined approach complements theoretical knowledge with practical application and



**FIGURE 5.** Confluence of generative AI and metaverse.

minimizes potential mishaps. Training students on various conceivable and inconceivable human errors through GAI enhances safety and proficiency in the task. Also, it instills confidence in the students' hearts that they are ready.

- Ethical and Responsible Tech Explorations - At the intersection of GAI and the metaverse, students have the unique opportunity to gain direct insights into the ethical considerations of AI technologies. This immersive experience fosters confidence in students and underscores the importance of adhering to the ethical guidelines and standards associated with technological advancements.

## X. UNVEILING THE HURDLES: EXPLORING CHALLENGES AND RISKS IN GENERATIVE AI

This section discusses various challenges that GAI faces, which act as hurdles to implementing to create personalized content. Challenges have also been proposed in this section. The table 5 briefly summarizes the limitations and countermeasures.

### A. COPYRIGHT

Training GAI models with specific prompts for educational content, like quizzes, summaries, and reading materials, raises copyright policies and plagiarism concerns. The answers generated might accidentally violate government copyright regulations. Additionally, there's a risk of the model using and storing input provided by users as training examples without explicit permission. These challenges underscore the need for robust ethical guidelines and

technological safeguards to protect intellectual property and user data while training and deploying GAI systems in educational contexts [139]. The copyright issue could be raised in applications such as Early Education, Revolutionize Education at all levels, Medical Education, Historical Education, Entrepreneurship Education, Skill Development Education, content creation image and video synthesis, and text generation because in all these applications, it is expected that the GAI model would produce some output, generate some quizzes, or test papers, which can lead to copyright issues. The issue could also be raised in applications such as Explore Prospects for Teaching and Teaching Assistance because, in all these applications, some material has to be generated, which could be ultimately used for teaching purposes.

To prevent such issues, the following measures could be taken.

- Compliance with copyright terms for the open-source content.
- The prompt should specify the inheritance and details of the usage of the content generated.
- Gaining transparent permission and seeking authorization from the authors of the documents for training the model with their content.
- Informing the users about copyright policies and raising awareness [140].

### B. UNPREDICTABLE CONTROL

Specific GAI models, such as GANs, are known to be unstable, making it challenging to control their behavior. They often fail to produce the expected outcomes, and

**TABLE 5.** Various limitations of using GAI in education, their definitions, and countermeasures.

Limitations	Definitions	Countermeasures
Copyright	Training, GAI models on large datasets of educational content may violate the government's copyright policies, as the model may directly provide the output from some existing materials and content. It also raises plagiarism issues and crosses the borderline of ethical concerns	<ul style="list-style-type: none"> <li>The model should specify the inheritance of the content generated.</li> <li>Interpretable AI and Explainable AI techniques should be promoted, which could prevent the model from breaking ethical boundaries.</li> </ul>
Hard to Control	Some AI models, such as GANs, are unstable, and it isn't easy to control their behavior and the output they will produce. They produce some unexpected outputs, and their derivations are difficult to detect.	<ul style="list-style-type: none"> <li>Explainable AI methods should be promoted</li> </ul>
Privacy, Security & Ethical Concerns,	GAI models could create synthetic but compelling media, which can blur the line between factual and fabricated data. It could be used to produce fake data and identities, harming the students and their data. These techniques could even be used in the exams to promote impersonation. These technologies can replicate copyright material, raise intellectual property concerns, fake authorities, etc.	<ul style="list-style-type: none"> <li>Laws such as GDPR should be made and rigorously implemented.</li> <li>Transparent policies should be made regarding collecting, storing, and using student data.</li> <li>Regular data audits should be conducted.</li> </ul>
Training & Maintenance	Training and Maintaining large GAI models is too much work to be done at the small educational institutions like schools	<ul style="list-style-type: none"> <li>Pre-trained models should be maintained, which could be easily fine-tuned.</li> <li>Advanced research on pruning, compression, and distillation of models should be enhanced.</li> <li>Small-sized models should be made and provided to the institutions, and large models should be used only for certain purposes like personalization.</li> </ul>
Bias, Fairness & Ethics	Bias present in the dataset are easily reflected in the models, resulting in biased outputs.	<ul style="list-style-type: none"> <li>A more diverse dataset should be chosen, and the dataset should be regularly updated</li> <li>Regular monitoring and performance checks of the dataset should be conducted.</li> <li>Fairness measures and bias correction techniques should be adopted.</li> <li>Transparency should be promoted, enabling the prediction of the output.</li> <li>Students and Teachers should be trained to recognize the biases and learn methods to address them.</li> </ul>
Distinguishing Model vs Students' Answers	With advancements in GAI, it isn't easy to predict whether the output is student-generated or via a machine	Applications like GPTZero should be promoted, which can detect the answers generated by the model.

understanding the reasons behind these deviations can be complex and difficult to detect. This unpredictability poses a significant challenge in ensuring consistent and desired results when working with these models. It is essential not to allow the model to run uncontrollably because the models

would be used by children, who can get severe impressions at a tender age if the model produces something not befitting to be told to the students. This limitation could be raised in applications like Early Education because children are more susceptible to getting wrong impressions. At such a

tender age, they don't have the intelligence to distinguish right from wrong, worsening the condition. Similar issues could be raised when GAI behaves uncontrollably at all levels of education, including education at universities, because it could create confusion among the students, disturbing them in their studies and personal lives. In the case of content verification, GAI could not behave uncontrollably because the basis of the application is the trust that the GAI models could figure out any discrepancies in the content and verify if the content is valid or not. In the case of text generation, image and video synthesis, simulations, and virtual reality, the GAI models should not be allowed to generate text, image, video, or simulations uncontrollably. Still, there should be control over the output generated. This issue can be addressed by promoting the concept of explainable AI, which is based on the idea that the model should be able to explain each and everything that it produces [141]. Using the concept of explainable AI, the model should be tested and verified several times so that it doesn't produce anything out of the syllabus, and specific guidelines could be laid for the users regarding using it.

### C. PSEUDO IMAGINATION

GANs represent an ML algorithm category that demands substantial training data to learn and generate meaningful outputs. GANs rely heavily on varied and extensive datasets for training to produce realistic and diverse results. However, obtaining such datasets can be challenging for various reasons, thereby hindering the efficiency of these models.

Furthermore, while GANs can generate entirely new content, they lack the inherent creativity and understanding that humans possess. They excel at amalgamating existing knowledge to create new content, providing a form of pseudo-imagination rather than generating genuinely novel and authentic material. Consequently, their content often synthesizes existing information rather than entirely fresh and innovative [142].

This limitation is significant in many areas, such as Early Education, education at other levels, Medical education, etc., because people get bored by repetitive presentations of the same topic. Hence, providing new content is very important. However, it poses a much more serious problem when GAI presents personalization. Everyone is a different human being, and we can't estimate someone's behavior by obtaining a linear or polynomial combination of multiple other human beings. To provide top-class personalization, GAI should be able to generate novel and authentic data. Similar is content creation. If the content generated is not novel, it will not hold any value in the long term, and the academicians would prefer to shift to a new way of generating good quality, novel content.

### D. PRIVACY, SECURITY AND ETHICAL CONCERNS

The malicious application of GAI, especially deepfakes, raises substantial concerns. Deepfakes, created using

techniques like GANs, produce synthetic but compelling media, blurring the line between factual and fabricated content. These technologies can be exploited to develop deceptive political videos, fake celebrity appearances, or explicit materials featuring unsuspecting individuals, which could harm the students. Deepfakes can infringe on the student's privacy by fabricating content, which could damage the users' reputations and violate personal privacy. They can contribute to the misinformation, which can help disturb peace and public trust in authentic information sources. They can also produce exact facial images, fingerprints, and voice recordings, which could initiate theft in the identity society. They may also generate sensitive information, which can lead to privacy breaches. These models can also fake documents like passports and identity cards of the individuals, which can lead to impersonation problems, even in the exams. They can also manipulate training data, leading to malicious content generation and security compromises. Some ethical and legal implications include replicating copyrighted material, raising intellectual property concerns, and falsely authorizing someone to act on someone else's behalf. One of the problems with that is the existing rules and regulations are also unable to cope with the ethical challenges that the model poses. With the advancement of GAI, deepfakes become even more challenging to detect, and traditional methods struggle to distinguish between accurate and generated data.

The issue of privacy, security, and ethical concern is valid for almost all the applications listed above. If data is being leaked or privacy principles are being breached, then it is doubtful that the users would like to use the model for their academic works. The Leakage of sensitive information regarding students is hazardous, and if some unauthorized people manipulate that data, it can lead to wrong information being propagated in society. The leakage of simulations or medical data can result in great losses to companies and the student's efforts to make a project successful. This will also lead to the violation of individuals' intellectual property rights.

Some of the countermeasures that could be taken include developing and implementing robust and secure data policies that meet the standard of government policies like GDPR, HIPAA, etc. Transparent policies should be created regarding collecting, storing, and using student data. Blockchain technology could also be used to prevent data from breaches and unauthorized and unethical uses. Government and private authorities should conduct regular data audits, which would help enhance the privacy and security of data. Secondly, the government should devise a response plan, which could be used in the case of mishappenings. Governments should also raise public awareness against deepfake threats. The implications should be openly taught in the classroom, and the students should be adequately educated so they do not misuse it when they grow up.

A recent case study is presented to present the seriousness of the issue. As per a report by Business Today on March 21, 2024 [143], Italian Prime Minister is taking bold steps against

using artificial intelligence via deepfake technology. She has raised a demand of 100,000 euros from the accused, who have generated a fake pornographic video of her via deepfake technology. The reason for mentioning this case study is that if such things can happen to the Prime Minister of one of the most powerful countries of the world, then these things could be quickly done to innocent children, and the imposters could ruin their whole lives. Hence, the governments should take significant steps to protect the privacy of the students and the educational institutions.

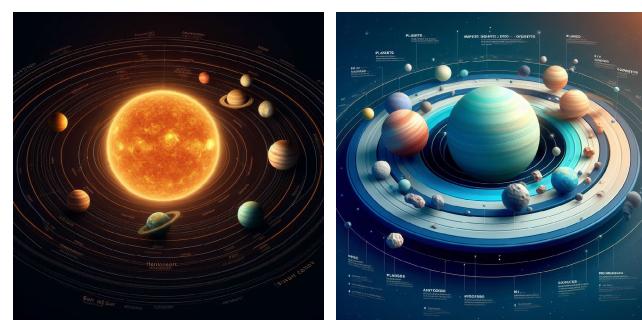
In May 2023, Samsung took a decisive step in response to a privacy and security breach involving ChatGPT and other GAI models. The incident unfolded when engineers leaked Samsung's internal source code to ChatGPT, a revelation reported by Bloomberg. Samsung's major worry was that the leaked data might find its way onto servers operated by tech giants like Google, Microsoft, and OpenAI. Once stored there, the challenge lies in deleting and gaining access to this information. This incident led to a domino effect in the industry, prompting companies, including Amazon, JP Morgan, Bank of America, and Citi Group, to issue similar warnings to their employees. The case of Samsung underscores the pervasive privacy and security risks entailed in the use of GAI models within corporate environments [144].

The case study highlights the privacy and security concerns faced by corporations like Samsung and sheds light on the potential risks for students and educational institutions. Unlike large tech corporations, academic institutions often lack the resources and infrastructure to handle such breaches effectively. This situation underscores the necessity for severe consideration and preventive measures before implementing GAI on a widespread scale in educational settings.

### E. QUALITY AND CONSISTENCY

Maintaining consistent quality in generated content remains a formidable challenge in GAI. AI models' output may lack realism, contain artifacts, or lack coherence, creating hurdles in achieving uniform, high-quality results. To illustrate this challenge, our team conducted a straightforward Bing AI experiment. We tasked Bing AI with generating images of the Solar System twice. The obtained results differed noticeably, as depicted in the following figure 6. One of the figures looked like a realistic image, but another didn't even represent a solar system. Even basic information like the color of the sun was unacceptable (the color of the sun is blue instead of yellow). Hence, before directly exposing students to GAI, a proper check has to be conducted that it may not pose some wrong information, which may infringe a wrong conception in the minds of the students, as is evident in this case, where the students may develop a conception that the sun is blue.

In a study conducted by Yu et al. [57] on the coding skills of GPTs, it was found that even GPT-4 predicts its erroneously generated code as correct. The code generation accuracy for GPT-4 is 77%, and that of GPT-3.5 is 65%, and the probability



(a) First image obtained from Bing AI      (b) Second image obtained from Bing AI

**FIGURE 6. Images generated by bing AI of the solar system, in two different prompts.**

of predicting an incorrect code as correct is 55% and 84%, respectively.

### F. MAINTAINENCE AND TRAINING

Training and maintaining large AI models pose significant challenges for schools and small educational institutions with limited resources. The limitation would directly affect early education and education at other levels also, as traditionally, education at school is cheap and easily affordable by many people. With the introduction of GAI, if education becomes costly, it would decrease the literacy rate in society and have negative impacts. Secondly, if GAI education were not cheap, students would hesitate to opt for skill development courses powered by GAI because they would be costly and might not guarantee a competitive job. Several solutions have been proposed to address this issue.

- To maintain pre-trained models, which can be easily fine-tuned, cloud service should be provided to the institutions.
- Models could be used only for high-quality tasks such as providing students with personalized and targeted learning experiences.
- Active research in the pruning, compression, and distillation of the models should be promoted to reduce the model size, the data, and the computational resources required.

### G. GENERATIVE AI BIAS: UNVEILING FAIRNESS AND ETHICS

GAI tends to reflect the biases present in the dataset, potentially leading to biased outcomes. Consequently, meticulous curation of preferences and ensuring ethical use of GAI is crucial. A tangible example of this bias is in Tesla cars, where the dataset was skewed toward white-skinned individuals. This bias manifested in the car design, making Tesla vehicles more prone to accidents involving dark-skinned individuals than white individuals, as indicated by a study [145]. Regular monitoring and testing across diverse groups can help identify and rectify biases early on. This underscores human

intervention's necessity to eliminate biases, ensuring the model's robustness and acceptance among diverse audiences.

Today's world is globalized, where many ethnicities and groups sit and work together. Having a biased GAI model would reduce its acceptance among the students, and it can also lead to a biased rationale of students from the very beginning of their lives, leading to a biased society. Hence, bias must be removed from the GAI models.

The following measures could be taken to remove bias from the model.

- To mitigate biases in GAI, selecting a diverse dataset is essential. The model should undergo training and fine-tuning on this dataset to ensure it is not skewed toward any particular group. This approach promotes fairness and inclusivity in the generated outcomes.
- Regular monitoring and performance checks are imperative to detect and rectify biases in GAI models. These ongoing evaluations ensure fairness and prevent the reinforcement of any unintended biases in the generated content.
- Adopting fairness measures and bias correction techniques, including pre-processing and post-processing methods, is crucial. Tools such as AI Fairness 360, IBM Watson OpenScale, and Google's What-If Tool can be utilized to identify and address biases effectively in GAI models. These tools enhance the fairness and equity of the generated content.
- Innovative transparency mechanisms should be developed to enable users to comprehend the model's outputs and the underlying data and assumptions used in the generation process. This transparency fosters trust and understanding, which is crucial for the ethical deployment of GAI models.
- Training programs should be implemented for teachers and students to recognize biases and learn appropriate methods to address them effectively. This education promotes awareness and equips individuals with the skills to handle discrimination in GAI applications.
- Continuous updates to the database with diverse and unbiased datasets are essential. This ongoing effort ensures that the GAI model remains current, representative, and free from biases, enhancing its outputs' quality and fairness.

#### **H. LIMITED GENERALIZATION**

GAI models frequently face difficulty generalizing beyond their training data. While they can produce samples resembling the training data, creating diverse and entirely novel outputs remains challenging. Generating content beyond the confines of the training data poses a significant hurdle in this technology.

#### **I. COMPREHENSIBILITY AND EXPLAINABILITY**

GAI models are intricate and expansive, making them difficult to interpret. Grasping and explaining specific outputs generated by these models is a complex task. Consequently,

enhancing the explainability and interpretability of GAI models has become a focal point for future research. Numerous research groups are delving into these areas to unravel the complexities associated with these models. One of the chief ML technologies that could be used in education is explainable AI (XAI). XAI means six principles: interpretability, transparency, fairness, trust, robustness, and privacy. Making the GAI models explainable helps the researchers and the users track down where the model went wrong, and it will also help train the users regarding how to use the models. By doing so, the impact of such inaccuracies on the student's learning can be minimized, as a proper guideline could also be devised, suggesting how to use the GAI model and what should not be done. It will also help create awareness among the students and the learners, helping them to do their tasks effectively. XAI is being used in industry for educational purposes. Some of the examples and important case studies of it are

- FUMA a framework that is used for modeling and supporting students in learning for various exploratory, open-ended learning environments, such as interactive simulations, educational games, etc.
- RiPPLE It is a course-level platform that instructors can incorporate into their teaching.
- AcaWriter It has been developed to primarily target university-level writing through both integration into specific courses like law and accounting, wider rollout to all students and supporting academic material to implement the tool in their context, and a high-level research version both as a standalone and integrated into an online course for learning how to write the abstract.
- TeamWork Analytics It was developed to support educators and undergraduate nursing students enrolled in clinical units.

#### **J. COMPUTATIONAL RESOURCES**

GAI models demand substantial computational power, relying on advanced hardware and extensive training data. Their development and deployment consume significant time and resources, limiting their accessibility. This means devising such models requires a lot of funds and expertise. Due to this, GAI models could not be built or used at small scales, making it difficult for schools and small educational institutions to afford these models and use them regularly in classes.

Reuters reported that OpenAI, since 2020, has utilized a massive supercomputer constructed by Microsoft, equipped with 10,000 Nvidia graphics processing units (GPUs) [146]. Among these, ChatGPT uses the NVIDIA A100 HPC accelerator, a high-performance tensor core GPU costing \$12,500, featuring 80 GB of HBM2 memory with up to 2 TBps memory bandwidth [147]. An analysis by Bernstein analyst Stacy Rasgon indicates that each ChatGPT query costs approximately 4 cents. If ChatGPT queries reached a tenth of Google's search volume, it would require around \$48.1 billion worth of GPUs and about \$16 billion worth of chips annually to remain operational.

## K. DATA REQUIREMENTS

GAI models need high-quality training data to grasp meaningful patterns and produce realistic content. Acquiring and organizing extensive and diverse datasets can be exceptionally challenging, especially in fields where data availability is limited [148].

## L. DISTINGUISH MODEL VS. STUDENT RESPONSES

With advancements in GAI, distinguishing between human-written and machine-generated text has become increasingly challenging. Addressing this concern, New York City's Department of Education banned ChatGPT from school devices and networks [149]. A tool named GPTZero has been developed to detect AI-generated text. It utilizes perplexity as a measure, indicating generalization capabilities and seeing AI involvement in text creation. Techniques such as watermarking, proposed by [150], involve inserting specific words uncommon in human conversation, aiding in distinguishing AI-generated content.

## M. TRIGGER EMOTIONS THROUGH GAI

In a recent study outlined by [39], specific prompts were utilized to evoke curiosity among students, showcasing the potential of enhancing learning experiences. However, this innovation also raises significant concerns. If this technology were compromised, malicious individuals could exploit it to manipulate students' emotions negatively. Such misuse can potentially cause misinformation and harm, underlining the critical need for ethical considerations in implementing emotion-inducing AI in educational settings.

Children and students inherently require emotional support. If malicious entities manipulate emotions, it can profoundly impact students, diverting them down destructive paths. Hence, when it comes to students, it is crucial to scrutinize and regulate AI's emotion-inducing features, finding ways to prevent such potential harm [151].

## N. VERITY OF CONTENT

The verity of the content produced by GAI is a crucial concern. Although GAI can produce huge amounts of educational content, their accuracy and reliability are not always guaranteed. For example, the content generated by GAI may not always reflect the nuances and complexities of the real world, which may lead to false conclusions and interpretations. The quality of content generated may also vary, along with the existing concerns of content ownership, privacy, and security.

Some of the potential measures to solve the problem are

- GAI tools should be integrated with human oversight and validation, ensuring the quality and credibility of the generated educational content.
- Strong frameworks should be established to safeguard the stakeholders and ensure the responsibility of GAI in education.

- Quality assurance machines should be developed which will help assure the integrity and the value of the educational content generated by GAI.
- Educators should be properly trained regarding how to use the content generated by GAI in their educational content.
- Awareness should be created among the educators and the students regarding the limitations of GAI in this field, to help them not to fall prey to this limitation of GAI.

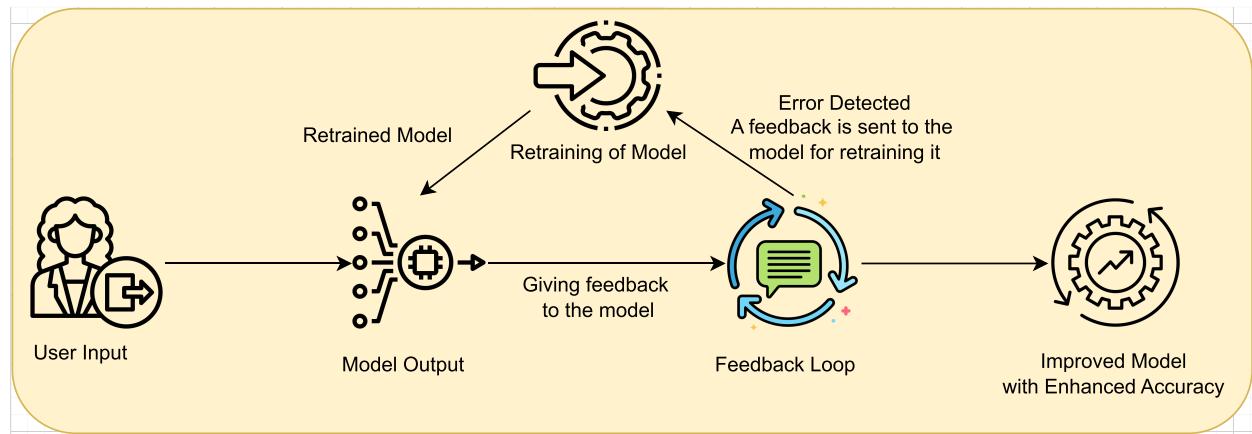
## O. FEEDBACK MECHANISM IN GENERATIVE AI

As discussed above, it can be easily concluded that GAI poses many problems that hinder GAI's wide-scale acceptance in educational institutions. One of the ways to help GAI be more robust is through the use of feedback mechanisms or feedback loops. Feedback loops help the model learn from the outputs it has previously generated and the mistakes committed previously. Feedback loops identify the mistakes in the outputs generated by the model and then help the model prevent it from committing similar mistakes in the future. The corrected information is then fed into the model as input, which allows it to retrain and adapt to new data. This process continuously helps to improve the accuracy and performance of the model. Human feedback is also valuable in this loop. It is precious in model drifts when the model's accuracy degrades over time due to changes in the user's behavior, various updates in the content, and seasonal trends. Human evaluators can evaluate model predictions and provide valuable feedback, which will help rectify the discrepancies in the model.

Feedback loops help the model to learn from its mistakes and increase the reliability and accuracy of the outputs. By continuously improving the model's performance, the feedback loops reduce the need for the intervention of a human being, thus making the model more efficient and cost-effective. It also increases the model's adaptability by adapting to the ever-changing behavior of human beings. This is also important because children's behavior changes very rapidly.

If the feedback provided to the model is malicious, then it will significantly affect the accuracy and performance of the model, irrespective of whether the malicious feedback was intentional or unintentional. Malicious feedback can lead to bias in the model, which results in inaccurate and unfair predictions, leading to significant consequences in the educational sector, as discussed earlier in X-G. Malicious feedback can also erode trust in the model, as many users may become skeptical of its predictions. This can lead to losing confidence in the model, ultimately harming its adoption and usage.

Some ways to mitigate malicious feedback are implementing a detection mechanism to identify malicious feedback through some ML algorithm or manual detection or techniques like data validation, filtering, anomaly detection, etc. If some malicious feedback is detected, it should be immediately flagged for further review, and legal action could also be taken. Machine Unlearning algorithms could also



**FIGURE 7. Feedback loop mechanism.**

remove that malicious feedback from the model without disturbing any of the crucial model's information [152].

## XI. FUTURE RESEARCH WORKS

This section examines future research opportunities in GAI for education, exploring untapped potential and innovative avenues to enhance learning experiences.

### A. IMPROVE MODEL EFFICIENCY

Efforts should focus on creating generative models capable of generating high-quality data and content even with sparse or limited input. This advancement can significantly reduce computational costs and memory requirements. Research initiatives should prioritize the development of innovative training techniques, such as supervised and semi-supervised learning, enabling the creation of models with smaller datasets or fewer labeled samples.

### B. ENHANCE MODEL CAPABILITIES

Research efforts should concentrate on developing versatile GAI models capable of simultaneously producing various types of content, such as text, audio, and images. Enabling user interaction and influence over the generated output is essential to tailor content to specific needs and facilitate monetization.

Enhancing the quality and realism of generated content remains a challenge for researchers. Future studies could explore advanced models to improve audio, video, text, and image quality. It is vital to achieve precise control over the generated output and understand the model's evaluations, particularly in applications like autonomous vehicles.

Moreover, progress can be made by ensuring models generate content within defined user constraints. Integrating multiple modalities, including images, audio, and videos, into generative models broadens the scope of GAI, enhancing its versatility and accessibility.

Additionally, valuable research directions include investigating techniques for few-shot learning (making predictions

based on limited samples) and zero-shot understanding (generalizing from a category of pieces using pre-trained models) in GAI. Training models to generate content with minimal examples enhances flexibility and adaptability, making GAI more responsive to diverse contexts and requirements.

### C. BIAS AND FAIRNESS

Addressing issues related to bias and fairness is critical in GAI. Future research should focus on detecting biases in training data and developing unbiased models representing diverse populations. It is essential to ensure impartial outputs across demographic groups. Exploring methods to enhance the interpretability of these models is crucial. Models should be capable of explaining their generated content, increasing user acceptance, and aiding in identifying and correcting potential shortcomings. Improving the interpretability of GAI models is vital for their adoption, particularly in critical domains. Further research can concentrate on developing techniques to interpret the decision-making processes of these models.

### D. ETHICAL AND RESPONSIBLE AI

In the realm of GAI, it is essential for research to prioritize ethical considerations and responsible usage. This means delving into the implications of GAI technologies and actively addressing concerns related to privacy, ownership, and the reliable implementation of generative models. By studying these ethical dimensions, the research community can ensure that the development and deployment of GAI are conducted to be mindful of social and moral implications, promoting ethical advancements in the field.

### E. ADVERSARIAL ROBUSTNESS

Researching methods to bolster the robustness of GAI models against adversarial attacks is a crucial study area. It is imperative to develop techniques that enhance the resilience of generative models, ensuring their integrity and security even when faced with manipulative inputs. Moreover, it is

essential to guarantee that these models generate accurate and reliable outputs, even in the presence of malicious inputs.

To achieve this, GAI models must be fortified against various attacks, including data leakage and model inversion attacks. Strengthening the security measures surrounding these models is essential to maintain their effectiveness and trustworthiness, safeguarding them from potential vulnerabilities and ensuring their safe deployment in real-world applications.

#### **F. HUMAN AI COLLABORATION**

A burgeoning research area involves exploring effective methods to facilitate collaboration and interaction between humans and GAI models. Understanding how humans can collaborate with AI systems to co-create, refine, and enhance generated outputs has the potential to yield more productive and beneficial applications. This research direction fosters a deeper understanding of human-AI collaboration and paves the way for innovative approaches in leveraging GAI technology for various creative and problem-solving tasks.

#### **G. ENVIRONMENTAL AND SUSTAINABLE AI**

Promoting research efforts geared towards developing energy-efficient generative models is essential for fostering the growth of sustainable AI technologies. Research groups are encouraged to delve into the applications of generative models in environmental science. This includes generating synthetic environmental data designed explicitly for climate modeling and analysis. By focusing on these areas, the research community can significantly contribute to the advancement of AI technology and its positive impact on environmental research and sustainability efforts.

#### **H. EXPLORE NEW ARCHITECTURE AND PARADIGMS**

Combining neural networks with symbolic logic offers a promising avenue to create generative models capable of reasoning and generating structured, interpretable outputs [153]. This integration can instill logic and reasoning skills in students, enhancing their understanding and problem-solving abilities [154].

Additionally, the potential of quantum computing in generative modeling should be thoroughly explored [155]. Investigating the advantages of quantum parallelism can open new doors for generating intricate data distributions, offering innovative solutions to complex computational challenges [156]. By harnessing the power of quantum computing, generative models can potentially achieve significant advancements in their capabilities and efficiency [157].

#### **I. DIVERSITY AND CREATIVITY**

Research into techniques enabling precise control over generated samples is pivotal. These methods should empower users to influence specific output attributes, including style, mood, and content. Additionally, exploring the intersection between GAI and creativity is essential. Investigating how

AI systems can exhibit true creativity by generating novel and imaginative content across diverse domains holds the key to unlocking groundbreaking advancements in the field. This research direction can redefine the boundaries of artificial intelligence and human-machine collaboration in creative endeavors.

#### **XII. CONCLUSION**

GAI empowers machines with human-like capabilities, enabling them to generate new content on text, music, video, images, etc. In this study, several applications of GAI have been explored in the context of using it for educational purposes. Implementation of GAI will bring revolution in the field of education. It will help provide the students with an immersive education experience, motivating them to learn and excel in their studies. The applications of GAI are not just limited to the students but also to the teachers, who can use GAI for evaluation and several other purposes, which have been listed in the studies, which will help them focus more on the students and their growth. Along with applications, some of the limitations of GAI have also been listed in this study, including privacy threats, bias, etc. Since GAI is a progressive and emerging field, the team has also figured out some areas where GAI could be used and where future research is needed.

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