

The impact of AI on education

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Abstract

The goal of this report is to provide a comprehensive overview of the impact of artificial intelligence (AI) on education, exploring the benefits, challenges, and future implications of integrating AI technologies into learning and teaching processes. The report aims to cover various aspects, from personalized learning and accessibility to the evolving roles of teachers and the development of creativity and critical thinking skills in the AI era.

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1 Introduction

Artificial Intelligence (AI) is quickly becoming a big part of our daily lives, especially in education. For example, students, from young kids to those in universities like INSA Lyon, are using AI tools like ChatGPT to help with homework and even to pass some exams quickly with high marks.

AI in education is a double-edged sword. It can make learning better in many ways, but it could also cause problems if students rely too much on AI and don't learn the material themselves.

As someone who cares a lot about effective learning, I wanted to dig deeper into how AI is used in education. Since the word "AI" shows up a lot in this report—over 200 times—it makes sense to start by explaining what AI is. But defining AI is not simple.

First, we'll try to understand AI and then look at how it can really improve education. This includes making learning more personal, making educational tools available worldwide, and helping teachers with their tasks and grading.

But using AI in education also has its downsides. We need to think about issues like the risk of students losing their critical thinking skills, and the digital divide, which means that not everyone might have access to AI tools. This could make inequality worse.

Next, we'll talk about how the education system needs to change to fit into the AI era. This includes changing how we assess students to make sure we're testing their knowledge and not just their ability to use AI. We might also need to change the teacher's role in the classroom.

The use of AI in education is getting a lot of attention these days, making it a very relevant topic. We'll look at how AI can help education and how to integrate it thoughtfully and ethically so that it improves learning without harming the quality of education.

Let's explore these exciting and challenging changes together, and see how AI is changing the way we learn and teach.

2 The Building Blocks of AI in Education: Language, Speech, and Conversation

2.1 Defining Artificial Intelligence

2.1.1 Challenges of defining AI

Artificial Intelligence (AI) has become a buzzword in recent years, with its applications spanning across various domains, including education. However, defining AI is not a straightforward task due to several challenges. Firstly, there is a lack of a universally accepted definition of AI across different fields and contexts [22]. The concept of AI is complex and multifaceted, making it challenging to arrive at a precise, all-encompassing definition. Secondly, the rapidly evolving nature of AI technologies makes it difficult to establish a fixed definition [75] [14]. As AI capabilities expand, any definition may quickly become outdated. For instance, a simple linear regression would be considered as AI by some, while others would argue that it is just statistics. However, one could argue that all artificial intelligence techniques are essentially based on statistics. Even the latest revolutionary AIs such as ChatGPT work by "predicting the next word" based on patterns in large datasets. Lastly, various fields, such as computer science, philosophy, and law, approach AI from different perspectives and with different goals in mind, leading to a range of definitions that may not always align [71] [65].

2.1.2 Common definitions

Despite the challenges in defining AI, there are some common definitions that are widely used. For example, Wikipedia defines AI as "intelligence demonstrated by machines", as opposed to the natural intelligence displayed by animals including humans. Similarly, the Oxford English Dictionary defines AI as "The capacity of computers or other machines to exhibit or simulate intelligent behaviour." However, these definitions are themselves based on the concept of intelligence, which is also not a trivial task to define.

Interestingly, what is hard for humans is often easy for computers, and vice versa. For instance, it is hard for us to make complex computations quickly, but simple for computers. On the other hand, it is trivial for us to recognize animals, stop signs, talk, and drive, but these tasks are incredibly challenging for computers to perform accurately and consistently. In practice, what is considered as artificial intelligence is often what has been challenging or seen as impossible for computers in the past. As computers become more capable of performing tasks that were once thought to be the exclusive domain of human intelligence, the definition of AI continues to evolve and expand.

2.2 Fields of AI

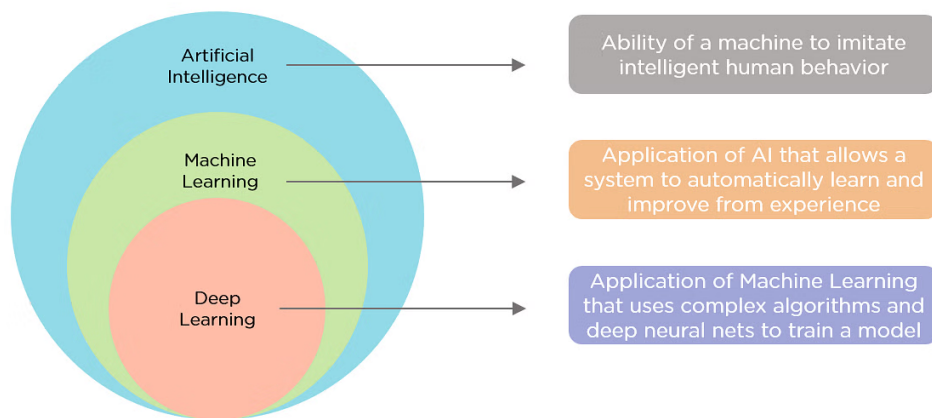


Figure 1: AI vs Machine Learning vs Deep Learning [72]

The Artificial Intelligence landscape is vast and encompasses a wide range of subfields and techniques. Nearly all the recent breakthroughs in AI can be attributed to the subfield called Machine

Learning.

2.2.1 Introduction of Machine learning (ML)

Machine Learning (ML) is a special type of AI programming that allows computers to learn from data, rather than being explicitly programmed with rules. To illustrate this concept, let's consider the task of distinguishing between pictures of cats and dogs. It would be incredibly difficult, if not impossible, to write down all the rules that would account for all the possible variations in size, color, shape, and behavior.

This is where Machine Learning comes in. Instead of trying to write down all these rules, we can provide the computer with a large collection of labeled pictures (i.e., pictures that have been identified as either a cat or a dog). The computer then uses statistical techniques to find patterns and relationships within these pictures. For example, it might learn that dogs usually have longer noses than cats, or that cats have pointy ears while dogs' ears are more rounded.

Once the computer has learned these patterns, it can then use them to correctly identify cats and dogs in new pictures that it hasn't seen before. In essence, Machine Learning is like giving the computer a set of examples to learn from, rather than a set of rules to follow. This makes it a powerful tool for solving complex problems that would be too difficult for traditional programming. And the best part is, the more data the computer has to learn from, the better it becomes at making accurate predictions.

Machine Learning has a wide range of applications across various domains, including image and speech recognition, natural language processing (NLP), recommendation systems, fraud detection, predictive maintenance, autonomous vehicles, healthcare, and many more.

2.2.2 Deep Learning

Nearly all the recent breakthroughs in Machine Learning can be attributed to the field of Deep Learning. Deep Learning uses layers of artificial "neurons" in a way that is similar to how the human brain learns. This approach is very flexible but requires a lot of data and computer power.

Thanks to Deep Learning, computers are now able to perform tasks that were previously thought to be too difficult for them, such as recognizing speech or understanding natural language. Deep Learning has revolutionized the field of AI and has opened up new possibilities for solving complex problems.

2.3 Key Technologies Explored in This Report

We will not focus on AIs able to distinguish between cats and dogs, or systems that predict the price of Bitcoin. Instead, we will focus on AI technologies that can "understand" and produce human language, and allow engaging conversations between computers and humans.

2.3.1 Natural Language Processing (NLP)

Natural Language Processing (NLP) is an interdisciplinary subfield of computer science and information retrieval concerned with giving computers the ability to understand, interpret, and manipulate human language. The goal is a computer capable of "understanding" the contents of documents, including the contextual nuances of the language within them.

Up until the 1980s, most NLP systems were based on complex sets of hand-written rules. In the late 1980s, there was a revolution in NLP with the introduction of machine learning algorithms for language processing, due to increasing computational power. In the 2010s, representation learning and deep neural network-style machine learning methods became widespread in NLP, due to their achieving state-of-the-art results in many natural language tasks.

2.3.2 Large Language Models (LLM)

Large Language Models (LLMs) represent a significant advancement in the field of natural language processing (NLP). These models are deep learning algorithms trained on extensive datasets to understand and generate human language. Among these models, ChatGPT, developed by OpenAI, stands out as the first LLM to achieve widespread public recognition and usage. Launched in November

2022, ChatGPT demonstrated the potential of LLMs to engage in coherent and contextually relevant conversations, making the technology accessible and practical for everyday users.

While ChatGPT became a household name, it was not the first LLM ever created. Earlier models, though technically advanced, did not gain the same level of popularity or usage due to various factors, including accessibility and practical application. The success of ChatGPT highlighted the capabilities of LLMs to a broader audience, catalyzing interest and development in this technology.

Today, a variety of LLMs exist, both open-source and closed-source. Open-source models, such as LLaMA developed by Meta and the "Mistral" models from the French company Mistral, are accessible to researchers, companies, and the broader community. These models encourage collaboration and innovation by allowing a wide range of users to experiment and build upon the existing technology. On the other hand, closed-source models like OpenAI's GPT-3 and GPT-4, Anthropic's Claude, and Google's Gemini are proprietary, often providing advanced capabilities and support for commercial applications.

LLMs are versatile tools capable of performing numerous NLP tasks without the need for task-specific training data. They excel in various applications, including chatbots and conversational AI (such as ChatGPT) that can engage in open-ended dialogue, text generation, summarization, translation, creative writing assistance, knowledge retrieval, and question answering from large knowledge bases. The impact of LLMs on these applications is profound, offering enhanced performance and new possibilities across many domains.

In summary, the development and success of ChatGPT marked a turning point for LLMs, demonstrating their potential to a wide audience and sparking further advancements in the field. As the technology continues to evolve, both open-source and closed-source LLMs play a crucial role in driving innovation and expanding the applications of artificial intelligence in understanding and generating human language.

2.3.3 Vision

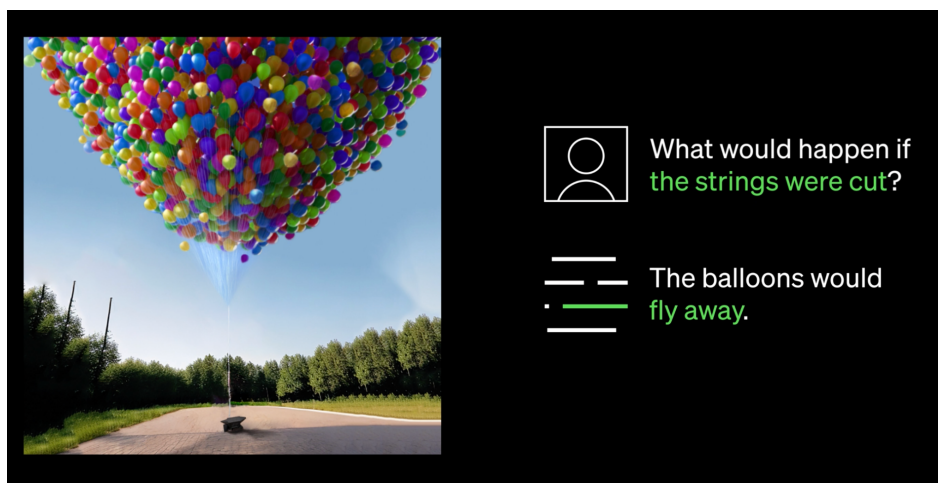


Figure 2: Example of a visual reasoning task using GPT-4 [45].

More and more LLMs come with vision capabilities, allowing them to handle not just text but also images and even videos. LLMs can perform general-purpose vision tasks such as answering questions about image content (Figure 2), recognizing objects, scenes, and visual concepts, generating detailed, contextual captions and descriptions for images, visual grounding and reasoning (e.g., locating objects mentioned in a query), providing visual explanations and differentiating between similar images/classes, and enabling open-ended visual task instructions via natural language.

Some examples of vision-capable models include GPT-4 (OpenAI), the Claude 3 family of models (Anthropic), Gemini (Google) and Grok 1.5 Vision (xAI).

2.3.4 Speech Recognition and Synthesis

Speech recognition involves converting spoken language into written text. Previous models were not well-suited for human conversation, requiring exaggerated voice clarity and only recognizing one language at a time. Whisper [50], an open-source speech recognition model by OpenAI, has significantly improved performance, understanding technical vocabulary, and recognizing multiple languages within a single conversation. These improvements make it particularly useful in educational settings, where diverse linguistic capabilities and technical jargon are common.

Speech synthesis has also advanced, with new models capable of simulating emotions and allowing interruptions, enabling more natural, human-like conversations. These advancements support more dynamic and interactive educational tools, enhancing the learning experience by making digital assistants more relatable and effective.

Combining speech recognition, NLP, and speech synthesis enables real-life conversations with AI, which are faster and more engaging than typing. Example applications include [53, Pi.ai], an empathetic conversational AI assistant that provides factual knowledge and emotional support through open-ended dialogues. Pi.ai learns from interactions and accesses real-time information to engage users in deep, meaningful conversations across a wide range of topics, making it a valuable tool for both educators and students.

When I first wrote this section, a significant limitation of interacting with voice-based large language models was the requirement to convert voice to text before processing it. This process removed emotional nuances like irony, humor, and background noises, and struggled with multiple speakers. Similarly, converting text back to voice for responses made it difficult for AI to express emotions or different tones of voice accurately.

However, this limitation was addressed by OpenAI on May 13th, 2024, with the release of the GPT-4o [48]. This new AI model has been trained to understand and generate human voice directly, without needing text as an intermediary. It can understand multiple speakers, background noises, interruptions, and convey emotions and different tones of voice. Moreover, it can "see" the person and their surroundings in real-time, adapting its behavior accordingly.

This new model has been a game changer in the field of conversational AI, opening up new possibilities for human-computer interactions. For instance, it is used in the *Be My Eyes* [23] application to help blind people in their daily lives by describing what the camera sees in real-time and answering questions. The AI can, for example, warn the user of an incoming taxi, as demonstrated in [84].

These advancements are revolutionizing educational tools by providing more natural, interactive, and accessible learning experiences. The integration of sophisticated speech recognition and synthesis technologies in AI models enhances the potential for personalized and effective education, catering to diverse learning needs and environments.

2.3.5 Building on LLMs

Large Language Models can be integrated into a wide range of tasks beyond chatbots in web browsers. Their versatility allows them to act as teachers, experts, and other roles, automating and enhancing various workflows.

Examples of LLM integration include customer service, where LLMs can automate customer interactions by providing instant, accurate responses to inquiries, reducing wait times, and improving satisfaction. In healthcare, LLMs assist in diagnosing conditions by analyzing patient data and offering recommendations, thus enhancing decision-making and patient outcomes. In the field of education, personalized tutoring powered by LLMs can tailor learning experiences, helping students with homework and explaining complex concepts. LLMs also aid in content creation, generating marketing copy, blog posts, and scripts, streamlining the content creation process for writers and marketers.

Retrieval-Augmented Generation (RAG) enhances LLMs by combining them with external knowledge retrieval. This technique retrieves relevant information from knowledge bases and uses it to generate accurate and contextually relevant responses. Applications of RAG include customer support, where it provides detailed, accurate responses by accessing product manuals and FAQs. In research, RAG synthesizes information from scientific literature for researchers. In legal assistance, RAG analyzes case law and statutes for legal professionals. [26]

In summary, LLMs and RAG technology can revolutionize various fields by enhancing efficiency, accuracy, and knowledge coverage. As these technologies evolve, their applications will continue to

expand, offering innovative solutions across different domains.

3 The Growing Influence of AI in Education

3.1 Record-Breaking User Growth

ChatGPT achieved unprecedented user growth, becoming the fastest-growing consumer application in history [76]. It surpassed 1 million users within just 5 days of launch and skyrocketed to 100 million monthly active users by January 2023, only two months after its debut. For comparison, TikTok took 9 months and Instagram about 2.5 years to reach the 100 million user milestone [76].

As of August 2023, ChatGPT boasts over 180.5 million users, an 80.5% increase in just 8 months [38] [42] [52].

3.2 Global Reach and Demographics

ChatGPT has a global presence, with users spanning 161 countries. However, it remains banned in several nations, including China, Russia, Iran, and Venezuela [33]. The United States accounts for the largest share of users at 46.75%, followed by India at 5.47% [42]. In terms of demographics, 55.99% of ChatGPT users are male, while 44.01% are female. But most importantly, the majority of users (62.52%) are young, between the ages of 18 and 34 [42].

3.3 News coverage and public attention

The impact of AI on education has garnered significant media attention, with numerous articles discussing the potential benefits, risks, and implications for students and teachers [44] [78] [12]. Headlines have highlighted both the revolutionary potential of AI to transform learning and the challenges it poses for academic honesty and traditional educational practices. The topic has sparked widespread public debate about the appropriate role and regulation of AI tools in schools [78] [12].

3.4 Fear of Widespread Cheating and Plagiarism

One of the primary concerns surrounding ChatGPT's launch was its potential to facilitate cheating and plagiarism among students [2] [70] [58].

With its ability to generate high-quality, human-like text based on prompts, educators feared that students would use ChatGPT to complete assignments, essays, and exams without putting in the necessary effort or learning [2] [58] [11]. A recent survey revealed that nearly half of students were likely to use AI tools like ChatGPT, while 60% perceived reliance on such tools as cheating [2].

The ease of use and accessibility of ChatGPT heightened concerns about the prevalence of academic dishonesty across all levels of education [70][58].

Most cheating statistics are derived from surveys in which students are asked about their recent cheating behavior. However, to accurately interpret these statistics, it is crucial to understand what students consider to be cheating. A Pew Research Center survey of U.S. teens, conducted between September and October 2023, revealed an interesting discrepancy in students' perceptions of AI usage. While approximately 60% of students believe that using ChatGPT to write essays is unacceptable, around 70% consider it acceptable to use the tool for researching new topics (Figure 3). This finding suggests that students are more likely to view AI as an acceptable tool for exploration and learning rather than for completing actual assignments or assessments.

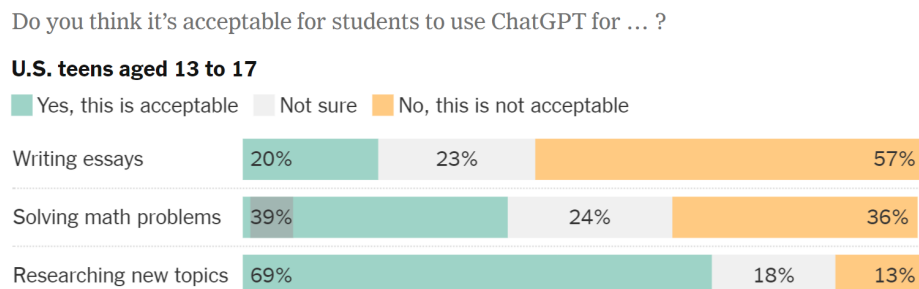


Figure 3: Pew Research Center survey on AI use in education [79]

3.5 Bans and Restrictions in Schools

In response to the potential for widespread cheating, several large public school districts, including New York City, Los Angeles, Seattle, and Baltimore, swiftly banned access to ChatGPT on school devices and networks. However, the effectiveness of such bans remains questionable, as students can still access ChatGPT on personal devices outside of school networks. The bans also sparked debates about the role of AI in education and the need for schools to adapt to emerging technologies [2] [58].

Recent research from Stanford University suggests these cheating fears may have been overblown, as overall cheating rates in high schools have not significantly increased despite the growing use of AI tools [79].

3.6 Emergence of AI Detection Tools

In response of the cheating concerns, various AI detection tools have been developed to help identify content that has been partially or wholly generated by AI. These tools are intended for use by educators, publishers, recruiters, and others who want to ensure the originality and authenticity of written content. Examples are [51, Originality.ai], [15, Copyleaks], [54, Quillbot], [29, GPTZero], or [10, Compilatio].

However, the effectiveness and reliability of these tools have been the subject of much debate [67] [13] [25].

3.6.1 How AI Detection Tools Work

AI detection tools rely on machine learning (ML) and natural language processing (NLP) techniques to analyze and classify text as either human-written or AI-generated. They are often built using language models similar to those used in the AI writing tools they aim to detect. These tools work by examining various linguistic patterns, sentence structures, and other characteristics of the text [68] [67] [13].

They compare the input text to large datasets of known AI-generated and human-written content to determine the likelihood that the text was created by an AI. Some common techniques used by AI detection tools include [68] [13]:

- Perplexity: Measuring how well a language model predicts the next word in a sequence
- Burstiness: Analyzing variations in sentence structure and length
- Semantic techniques: Topic modeling, sentiment analysis, and consistency assessment

3.6.2 Challenges and Limitations

Despite the development of various AI detection tools, their effectiveness and reliability remain questionable.

Several studies have shown that these tools often struggle to accurately classify text, particularly as AI text generators become more advanced [67] [13] [25].

Some key challenges and limitations include:

- High rates of false positives and false negatives [67] [25] [5]
- Difficulty keeping pace with rapidly evolving AI technologies [68] [13]
- Inconsistent performance across different AI models and generators [25]
- Reduced effectiveness when faced with obfuscation techniques like manual editing or machine paraphrasing [24]

Additionally, the results provided by AI detection tools can be difficult for average users to interpret, with some tools providing complex statistical information or highlighting text without clear explanations [24].

3.6.3 An arm race

As AI detection tools become more prevalent, users and students are employing various strategies to evade these tools when using AI-generated content for schoolwork or other purposes. This has led to an ongoing battle, often referred to as an "arms race," between AI generators and detectors.

Some of the techniques used to bypass AI detection include manual editing and paraphrasing, where users take the AI-generated text and manually rephrase sentences, change word choices, and introduce minor grammatical errors to make the writing seem more human-like and less perfect [59] [63].

Another approach is the multilingual method, where users have AI tools like ChatGPT generate the text in a different language, then translate it back to English themselves, which can help obscure AI patterns [61].

Users also instruct AI models to mimic specific writing styles, such as a "struggling B-level student" or a "lazy student rushing to proofread a paper," complete with intentional errors and imperfections expected from those archetypes [62] [63].

Some even resort to using "AI-detection-bypass" tools, which are AI-powered tools specifically designed to rephrase AI-generated text in ways that are harder for detectors to identify. Examples of such tools include Hix AI, Nova, Conch AI, Undetectable AI, and Stealthwriter [59] [62] [60].

Some users even exploit technical loopholes, such as replacing certain letters in their text with visually similar Unicode characters, which can trick AI detectors [57].

Others believe that text from more sophisticated models like GPT-4 is harder for current detectors to identify compared to GPT-3.5 or other models [61].

However, many users also express doubts about the effectiveness and longevity of these methods. Students are compiling evidence of false positives from detectors (e.g., flagging historical texts as AI-generated) to undermine their reliability and persuade schools not to trust the tools [63] [57].

3.6.4 Implications and Future Directions

The development of AI detection tools has significant implications for academia and beyond. Educators are grappling with how to adapt courses and assessments to the AI era while maintaining academic integrity [67] [5]. Publishers and content creators are also exploring ways to ensure the originality of their content [67]. However, the current limitations of AI detection tools suggest that they should be used with caution and not relied upon as the sole means of identifying AI-generated content [24] [25] [5]. Experts emphasize the importance of combining automated detection with human review and other methods to ensure the accuracy and fairness of the results [24] [25]. As AI text generators continue to advance, it is clear that AI detection tools will need to evolve in tandem to remain effective [68] [13] [25]. This ongoing arms race between AI generators and detectors is likely to shape the future of academic integrity and content authenticity in significant ways. Educators, institutions, and policymakers will need to stay informed about the latest developments in AI technology and adapt their practices accordingly to ensure the integrity of the educational process in the face of these rapidly evolving tools.

3.7 Government initiatives and policies

3.7.1 Investing in AI Infrastructure and Partnerships

Governments around the world are increasingly recognizing the potential of AI to transform education and are investing in initiatives to support AI research, development, and deployment in academic institutions. In the United States, the National Science Foundation (NSF) is leading efforts to create a national network of AI research centers by facilitating partnerships between government agencies and academic institutions [32]. These collaborations aim to increase access to AI resources for academia and support national AI goals. The UK government has also announced a £2 million investment in new classroom technology, including AI tools, to reduce teachers' workloads and enhance education [46] [27]. This funding will be used by Oak National Academy to develop and expand AI-powered teacher support tools, such as lesson planners and quiz builders [28] [27]. In 2018, the French government launched a national strategy for artificial intelligence (AI) called "AI for Humanity." This strategy aims to position France as a global leader in AI research, development, and innovation [41] [40]. The strategy is divided into two phases:

1. Phase 1 (2018-2022): Focused on strengthening France’s research capabilities in AI, with an investment of €1.5 billion [41] [40] [39].
2. Phase 2 (2021-2025): Aims to diffuse AI technologies throughout the economy and support the development of trustworthy, frugal, and generative AI. This phase has a budget of €1.5 billion as part of the France 2030 plan [41] [40].

The French government has supported the creation and development of a network of interdisciplinary AI institutes, the establishment of chairs of excellence, and doctoral programs [40] [39]. It has also deployed the Jean Zay supercomputer to support AI research [40].

3.7.2 Developing Frameworks and Guidelines

Governments and international organizations are developing frameworks and guidelines to ensure the safe, ethical, and effective use of AI in education. For example, the Australian Government Department of Education has released the inaugural Australian Framework for Generative Artificial Intelligence in Schools, to be implemented from Term 1 2024 [35]. The framework prioritizes privacy, security, safety, teaching and learning outcomes, human and social wellbeing, transparency, fairness, and accountability [35]. UNESCO has also developed policy guidance for leveraging AI in education, emphasizing the need to harness the benefits of AI while mitigating risks [80]. The guidance covers various aspects, including promoting inclusive and equitable use of AI, developing ethical guidelines, fostering local AI innovations, and building an evidence base through pilot testing and evaluation [80]. As part of its broader national strategy for artificial intelligence (AI), the French government has recognized the importance of integrating AI into the education system. The strategy aims to position France as a global leader in AI research, development, and innovation, with education playing a crucial role [41] [40]. In March 2024, the Commission on Artificial Intelligence submitted a report to the President of the Republic containing 25 recommendations to help France capitalize on the AI technological revolution [85] [17] [37]. These recommendations were based on extensive consultations and aim to guide public authorities in making decisions to position France at the forefront of AI, including in the field of education.

4 Benefits of AI in Education

4.1 Existing Benefits of Digital Tools

Even without AI, the digital world offers numerous opportunities to enhance learning experiences. Throughout this section, we will explore three excellent examples: Brilliant, an online learning platform; Remnote, a note-taking app; and Duolingo, a language learning app.

[7, Brilliant] is an interactive online learning platform that offers guided courses and problem-solving challenges in math, science, and computer science to develop critical thinking and creative problem-solving skills.

[18, Duolingo] is a free language-learning platform that offers fun, bite-sized lessons in over 40 languages, as well as courses in math and music, through its mobile app and website.

[64, Remnote] is a revolutionary note-taking software designed to help users remember what they learn. While it may appear similar to classic note-taking apps, with features like writing, inserting images, links, colors, and multiple pages, Remnote's true power lies in its unique approach to learning and retention.

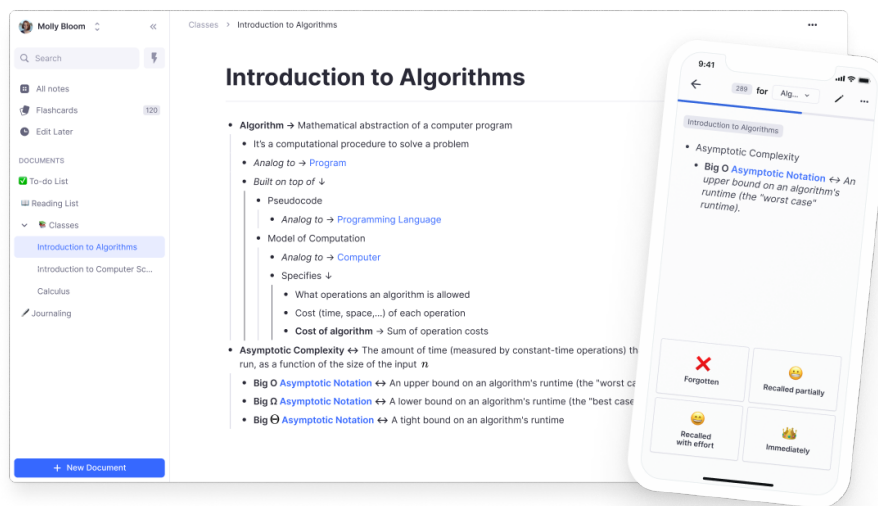


Figure 4: Remnote advertizing [64]

4.1.1 Optimized Learning Experience

Remnote leverages two powerful learning techniques: active recall and spaced repetition.

Active Recall

Reading through notes and trying to remember the content is an inefficient way to learn. While reading may give a false sense of knowing, being able to recall information from memory without referring to the text is a different skill altogether. Having someone test you on the subject would be far more effective, as it would highlight areas you don't know and allow you to focus on them, thus optimizing your learning process. This is known as the testing effect [81].

Flashcards are one of the best learning techniques that leverage active recall. By writing a hint on the front side and the answer on the back, you can test yourself effectively. Many websites offer services to create and practice flashcards, such as Anki.

However, creating flashcards is often a separate step after taking handwritten or digital notes, resulting in two sources of information and wasted time. Remnote takes a different approach: your notes *are* the flashcards. You create flashcards *while* taking notes, streamlining the process. The resulting flashcards are not just an unsorted list of unrelated cards disconnected from your notes; they are an integral part of your learning material.

Spaced Repetition

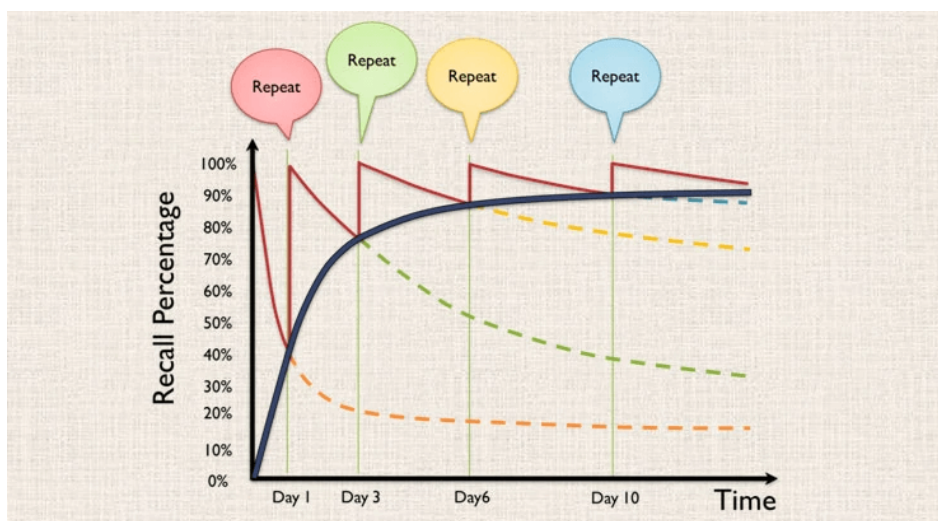


Figure 5: Spaced repetition graph [31]

Students who cram just before an exam may remember some material during the test but often forget most of it quickly afterward. While practicing a subject once a day over a long period can lead to long-term retention, it is not always practical or necessary. For example, a doctor doesn't need to review their textbooks daily to remember the symptoms of hepatitis. However, when they were in school, they likely forgot the information soon after learning it for the first time, but by practicing again a day later, then a week later, and so on, they were able to retain the knowledge.

The optimal frequency for long-term retention involves practicing frequently at the beginning, then gradually increasing the intervals between practice sessions. This is the science of "spaced repetition", a crucial concept for improving learning efficiency.

Spaced repetition is based on the "spacing effect," which suggests that spreading out learning sessions over time leads to more effective learning compared to cramming. The process involves:

1. Initial learning: Thoroughly studying new information to ensure a solid understanding.
2. First review: Reinforcing understanding and memory shortly after the initial learning session.
3. Gradually increasing intervals: As information is successfully recalled during each review, the time interval between reviews is gradually increased (e.g., one day, three days, one week, etc.).
4. Adapting to individual needs: Optimal spacing of reviews varies depending on the complexity of the information and individual learning pace. Shorter intervals may be necessary for challenging concepts.
5. Long-term retention: Consistently reviewing information at spaced intervals strengthens neural connections, making it easier to recall in the future.

Spaced repetition is often implemented using flashcards and software, as it is impractical with traditional books or sheets.

In Remnote, every note becomes a flashcard. During study sessions, which can be as short as one minute, users are tested on their flashcards. For each flashcard, they rate their level of retention ("forgot," "remembered with effort," "remembered," or "remembered easily"). This allows Remnote to precisely track the user's retention level for each piece of information, focusing on areas of difficulty while hiding well-known material. This targeted approach would be impossible with handwritten notes or simple digital notes, where users would have to sift through all their notes to identify challenging areas.

4.1.2 User Engagement

Remnote makes practicing incredibly easy. Once notes are taken, flashcards are automatically generated, and can be practiced everywhere. Whether on a laptop, but also on mobile. This is simply amazing. In less than 5 seconds, you can unlock your phone, see the Remnote app, open it and automatically be tested on your flashcards. The friction to learn is reduced to nothing, which allows me to start learning whenever I have 5 minutes free, for instance during public transportation.

The app forces you to write "atomic" flashcards. Instead of writing 1 flashcard on a whole paragraph

of a textbook, you will write 10 tiny flashcards that tests you on tiny bit of informations. That way, you can effectively rate your level of retention, so that Remnote can very precisely isolates what you struggle on. Additionally, since flashcards are tiny, they are more engaging and less discouraging.

The app is designed to be challenging but not too much, so that we aren't bored and but we don't abandon. It uses the same addictive techniques that other apps use, but for the good. For instance, there is a daily goal of flashcards to practice, and the number of consecutive days you achieved that goal is tracked and proudly displayed. That way, you feel motivated to continue achieving this goal to not reset the counter. Notifications are sent so that you can never say that you forgot. Similar techniques are used in Duolingo and many other apps.

Brilliant incorporates game design principles into their courses, featuring leaderboards, streaks, and interactive problem-solving with funny characters. This makes the learning experience more engaging and reduces anxiety associated with tackling unfamiliar concepts [55].

Brilliant and Duolingo allows users to learn at their own pace and provides simple explanations and real-time feedback to make learning efficient [55]. The platforms are accessible for all skill levels, from high school fundamentals to advanced topics [55].

Brilliant replaces traditional lecture videos with interactive lessons, daily challenges, and quizzes as part of the learning process [55]. This hands-on experience immerses users in the subject matter and encourages a problem-solving mindset [20].

4.1.3 Accessibility

Lots of online learning platforms and tools offer free versions. Many use a freemium strategy, which offer a free restricted version of the product, with premium subscriptions or purchases to unlock all the features. The good thing in these Duolingo proudly offer a free version which is financed by premium users [1]. This allow everyone in the whole world, and countries with less resources to access the service for free.

Remnote has a very capable free version, with unlimited flashcards.

Students can learn at their own pace and on their own schedule, making these platforms highly accessible and flexible.

4.2 Personalized Learning

AI-powered platforms can generate individualized learning paths for students based on their goals, interests, and prior knowledge [21]. This ensures that each student is presented with a curriculum that is most relevant and beneficial to their educational journey [77].

Speak's AI tutor designs a personalized curriculum for each user by getting to know them at a deep level. It understands the user's motivations and tailors every lesson to their unique needs [73].

Intelligent tutoring systems can engage in dialogue and provide interactive problem-solving support tailored to a student's needs, similar to one-on-one tutoring. Brilliant offers guided interactive problem solving that is powered by AI. The AI provides real-time feedback and simple explanations to make learning efficient and engaging [7].

4.3 Increased Accessibility to Knowledge and Education

4.3.1 Multilingual Support

The web interface of ChatGPT supports 50 languages [8]. However, the actual number of languages that the AI speaks is estimated to be more than a hundred. LLMs can learn a subject from one language source and be queried in another language. This feature is particularly beneficial for children of immigrants, who can receive help with their homework at home, even if their parents don't speak the language. This reduces the educational gap between children of immigrants and children of native speakers.

4.3.2 Worldwide and 24/7 Access

State-of-the-art AIs can be accessed with any browser (thus any machine) and a normal internet connection, providing worldwide access to LLMs' knowledge and capabilities. As AI models become smaller and more performant, we will soon see AIs running locally (without internet) everywhere.

It is already possible and easy to run small models on laptops. With models becoming smaller and smartphones optimized for AI, a lot of research is being invested in local AIs on mobiles [34]. We will soon see personalized and local AI assistants on our devices.

4.3.3 Free and Open-Source Options

Most AI providers don't require any payment method for free use. ChatGPT, Claude, Gemini, Meta, Mistral, Perplexity, Cohere, and even open-source platforms such as HuggingChat propose free access to their AI models, with hard-to-reach limits for normal use. On May 14, 2024, ChatGPT announced that their most advanced model, GPT-4o, will be available for free in the following weeks [48]. As of April 1, 2024, OpenAI announced that ChatGPT can be used immediately, without account creation.

The rise of open-source AIs and transparency will be a solution for privacy concerns, as users will have more control over their data and the AI's inner workings.

4.3.4 Ease of Use

Chatbots are among the easiest and most accessible software in the world. Instead of learning the tool, AIs have learned to understand humans, making the interaction more natural and intuitive.

4.3.5 Assistive Technologies

Additional technologies such as voice recognition and text-to-speech make LLMs accessible for people with disabilities, including the visually impaired, those with physical disabilities, and people with dyslexia who struggle with writing and reading. On a positive note, these technologies can reduce the use of screens and the strain on the eyes [66].

4.4 Student Engagement and Motivation

The personalization and adaptivity of learning itself improve engagement and motivation. Being late on what's taught or already knowing it is a factor of disengagement. With the adaptivity of learning, students get challenged just enough, so it is motivating but not overwhelming, reducing stress and enhancing confidence.

4.4.1 Minimal Distractions

Computers and smartphones were, of course, amazing tools for learning. But their obvious downside is that they are extremely distracting. On the other hand, chatbots - as of today, and base models - are not distracting. They won't change the subject during a discussion or issue notifications. However, we can program a personality that makes them not boring (that doesn't mean they'll become distracting). So they introduce a new technology, a new power, without new distractions, which is a good thing.

4.4.2 Immediate and Accessible Feedback

Immediate feedback is available 24/7. Knowing that we can get immediate and great feedback can reduce friction when it comes to getting to work. Duolingo uses AI to provide real-time feedback and support to learners [36]. [73, Speak] offers an AI tutor that can have open-ended conversations with learners on various topics while providing real-time feedback on pronunciation, grammar, vocabulary, and more.

4.4.3 AI as a Supportive Peer or Mentor

A non-judgmental presence makes asking for help easy and boosts students' confidence to keep trying [74]. An AI tutor can create learning plans, help students get started with small steps, and reduce procrastination. Speak's AI tutor keeps learners motivated and accountable to achieve their language learning goals by providing personalized support [73].

4.4.4 Interactive Conversations on Topics of Interest

In language learning, talking about a subject you like can be a great vector of motivation. AI tutors can engage in interactive conversations on a wide range of topics, making the learning experience more enjoyable and relevant to the student’s interests.

4.5 Administrative Efficiency and Teacher Support

AI can automate mundane tasks like scheduling, grading, and paperwork, saving teachers significant time that can be redirected to more impactful activities like lesson planning and working with students [16] [9]. The UK government’s investment in Oak National Academy’s AI-powered teacher support tools is a prime example of this [28] [27].

Some teachers are using AI tools like Perplexity to provide students with accurate, detailed information in real-time [30].

4.5.1 AI-Powered Content Creation

AI-powered content creation tools can generate unique, tailored materials that cater to various subjects and learning styles. For example, AI can automatically create interactive quizzes, educational games, diverse language exercises, and realistic science simulations. This enriches the curriculum and brings interactivity that was previously challenging to achieve [43]. This speeds up and improves the content creation, allowing teachers to focus on what’s more important.

Duolingo has replaced some human writers and translators with AI technology to accelerate content creation. However, this has raised concerns about the quality of AI-generated lessons [6].

5 Challenges and Limitations of AI in Education

The integration of AI into education brings with it several challenges and limitations that need careful consideration. While AI offers numerous benefits, it also presents obstacles that educators, policymakers, and students must address to ensure effective and equitable learning experiences.

5.1 AI's Impact on Various Essential Skills

The reliance on AI chatbots for task completion can inadvertently undermine essential skills such as critical thinking, autonomy, communication, and creativity among students. The convenience of AI can make it tempting for students to seek easy solutions rather than engaging deeply with the material.

5.1.1 Critical Thinking

One significant concern is the potential decline in students' critical thinking abilities. As students turn to AI to generate responses and complete tasks, they might become less inclined to think critically and solve problems independently. For instance, using AI tools like ChatGPT to produce essays or homework answers can lead to a superficial understanding of the material and a lack of original insights. Furthermore, AI-generated content can sometimes include inaccuracies or "hallucinations." Students might lack the skills to discern these errors, especially if the misinformation is presented convincingly. This undermines their ability to critically evaluate information, an essential component of informed decision-making and rational thought.

5.1.2 Autonomy

AI can create a passive learning environment, where students are spoon-fed information and solutions. This hinders their ability to learn independently and take ownership of their education. Instead of formulating their own research questions based on curiosity and critical analysis, students might depend on AI to suggest topics or questions. This over-reliance on AI can reduce their motivation to explore topics in depth and develop self-directed learning strategies.

5.1.3 Communication Skills

The use of AI chatbots poses challenges to the development of students' writing and oral communication skills. If students rely on AI to generate essays, reports, or other assignments, they may neglect essential writing skills such as structuring arguments, expressing ideas clearly, and using language effectively. Additionally, the convenience of AI can impact oral communication skills, as students miss opportunities to articulate their thoughts, engage in discussions, and refine their presentation abilities.

5.1.4 Creativity and Original Thought

AI can limit student choice by recommending learning paths based solely on algorithms, potentially restricting exploration of other areas of interest or alternative learning styles. This can stifle creativity and original thought, as students may become constrained by AI's suggestions rather than pursuing their unique ideas and interests.

5.2 Reduction of Human Relationships

The overreliance on AI in education can lead to a reduction in human relationships, which are crucial for social and emotional development. Educators worry that the use of tools like ChatGPT could diminish students' ability to engage in original thought, conduct research, and construct arguments independently. This reliance on AI might also hinder students' social interaction and collaboration skills, as they may prioritize AI-generated answers over peer discussions and teamwork.

Students may become less inclined to participate in collaborative activities that require critical thinking, communication, and problem-solving skills. Reduced opportunities for meaningful group discussions and presentations can further impact their social and emotional development. Additionally, if students perceive AI as the primary decision-maker in their education, it can diminish their sense of

control and ownership over their learning, reducing their motivation to actively participate and engage in the learning process.

5.3 Inequalities in Access to AI Technologies

The accessibility of AI technologies in education raises significant concerns about equity and fairness. While many AI tools, such as ChatGPT, are available for free, the most powerful and advanced AI systems often require subscriptions, creating an uneven playing field among students. Premium chatbots like [4, Claude 3 Opus], [49, ChatGPT Plus], [3, Perplexity Pro], which cost around \$20 a month, offer advanced features that free versions do not, putting students who can afford these tools at a significant advantage.

This disparity is particularly evident in the context of exams and assignments. Traditional exam formats, when combined with the capabilities of premium AIs, can give unfair advantages to students with access to these advanced tools. Therefore, educators must reconsider and redesign assessment methods to ensure fairness in the AI era.

5.3.1 "Pay to Win"

The need to adapt exam formats arises from the powerful features of premium AIs that can aid significantly in completing assignments and exams. These features include:

- **Image Analysis:** Premium AIs can analyze images, providing students with detailed insights on graphs, scanned documents, and various other visuals. This capability allows students with premium access to scan their exam subjects and receive immediate, comprehensive answers, giving them a significant advantage over peers who must manually input information.
- **PDFs and Files Input:** Premium AI tools allow users to upload files directly, with the AI extracting and analyzing the text and images within these documents. This feature simplifies the process for students, allowing those with premium access to bypass the time-consuming task of manually entering text, thereby gaining an edge in efficiency and accuracy.
- **Web Searches:** Some premium AIs offer automatic web search capabilities, ensuring that students receive the most current and relevant information. This feature enhances the quality of research and answers but also creates a gap between students who have access to up-to-date information and those who do not.
- **Code Interpreter:** Available in ChatGPT Plus, the automatic code interpreter can write and execute code to solve complex problems. This is particularly beneficial for tasks involving data analysis, programming, and generating visuals, offering a clear advantage in subjects requiring such skills.
- **Custom Assistants (GPTs):** Introduced by OpenAI in November 2023, custom GPTs are specialized versions of ChatGPT that users can create for specific purposes without any coding. These custom assistants can be fed additional knowledge through PDFs and other files, and their behavior can be tailored through specific instructions, providing substantial advantages in unsupervised exams and assignments.

5.4 Environmental Impact

The environmental and cost aspects of large language models present notable challenges. These models consume substantial amounts of energy and resources during both their training and inference phases.

5.4.1 Energy Consumption

Training large models like GPT-3 and GPT-4 requires significant computational power, primarily sourced from data centers. These facilities are known for their high energy consumption and resultant carbon emissions. Data centers supporting AI models can emit substantial amounts of CO₂, contributing to their overall carbon footprint. Estimates suggest that models like ChatGPT emit around 8.4 tons of CO₂ annually, which is more than twice the emissions of an average individual.

5.4.2 Water Usage

The cooling processes for data centers also require large volumes of water. For example, training GPT-3 consumed approximately 700,000 liters of freshwater, an amount equivalent to producing hundreds of cars. This high water usage is necessary to manage the heat generated by extensive computational activities [19].

In addition to environmental concerns, the financial burden of developing and maintaining these models is considerable. Training GPT-3 alone cost around \$4.6 million [82], encompassing expenses related to computational power, data storage, and energy consumption. For GPT-4, the costs are significantly higher, with estimates reaching upwards of \$100 million [83] due to its increased size and complexity. These expenses are often passed on to users through premium subscriptions, which can limit accessibility and create disparities among users.

5.5 Privacy

The use of AI in education also raises privacy concerns, as student data may be collected and processed by AI systems. Ensuring the protection of student data and maintaining privacy standards is essential when implementing AI in educational settings.

5.6 Potential Impact on the Job Market

The adoption of AI in education may have consequences for the job market. For example, the demand for tutors might decrease as AI-powered platforms provide 24/7 support, feedback, and interactive learning experiences. Language learning is likely to be one of the most impacted areas, with AI offering features such as pronunciation feedback, engaging discussions, automatic assessment, and spaced repetition, often at no cost to the user.

6 Evolving Roles of Teachers and Assessment Methods

As artificial intelligence becomes more integrated into education, the roles of teachers and the methods of assessment need to evolve. Educators must navigate the challenges and opportunities presented by AI to ensure that student learning and performance are accurately and effectively evaluated.

6.1 Adapting Exams to the AI Era

In the context of homework and poorly supervised exams, teachers should anticipate that students will use AI tools. Forbidding the use of AI tools is a possible approach, but enforcing such a ban is challenging. As previously discussed, relying on AI detectors is not a reliable solution, making it naive to prohibit AI use at home or during poorly supervised exams.

Poorly supervised exams include scenarios such as online multiple-choice question exams taken on student machines or exams in auditoriums with minimal supervision. In these situations, using AI tools is easy and tempting through simple copy-pastes or screenshots. Students often stop studying the material once they know the exam will be online, instead preparing custom versions of AI tools like ChatGPT, which have access to lesson PDFs and can quickly answer questions. Even in exams where external tool usage is clearly forbidden, more than half of the students still use them. Students with access to premium AI tools have a significant advantage in questions requiring computations, reasoning, or access to lesson PDFs. This creates an environment where even ethically-minded students might feel compelled to use AI to compete fairly.

In some exams, AI tool usage is not forbidden, allowing students to achieve high grades effortlessly by simply dragging and dropping the exam subject into a ChatGPT window. This undermines the purpose of the exam and questions its utility. Therefore, there is an urgent need to design exams that truly evaluate student performance on the material and not their proficiency with AI tools.

6.1.1 Oral Exams

Oral exams can be an effective solution to genuinely evaluate student performance while also improving their communication skills. This format ensures that students demonstrate their understanding and ability to articulate their knowledge without relying on AI assistance.

6.1.2 Homework

Homework assignments should be designed with the capabilities of AI tools in mind. Educators need to create tasks that require critical thinking, creativity, and in-depth understanding, which cannot be easily replicated by AI.

6.1.3 Collaborative Learning Environments

Promoting collaborative learning environments can help mitigate the over-reliance on AI tools. Encouraging group projects and peer discussions fosters a learning culture where students engage with each other and develop essential interpersonal and teamwork skills.

6.2 AI as a Complementary Tool for Teachers

AI has the potential to complement and enhance the teaching process. It can assist in designing better course materials by integrating multiple media formats such as text, audio, and interactive content. This can make learning more engaging and accessible for students.

6.2.1 Interactive and Engaging Content

AI can create interactive and engaging content that captures students' attention and enhances their learning experience. By incorporating simulations, gamification, and multimedia resources, AI can transform traditional teaching methods and make learning more dynamic.

6.2.2 Helping Teachers Focus on the Most Important Tasks

By automating routine tasks such as grading and providing basic feedback, AI allows teachers to focus on more critical aspects of education, such as personalized instruction and mentoring. AI can also serve as a tutoring tool, offering additional support to students who need it and freeing up teachers' time for more impactful interactions.

6.3 Importance of Teacher Training and Professional Development

The integration of AI in education requires teachers to be adequately trained and continually develop their skills. The article [56] *Unlocking the Potential of AI in Education: Challenges and Opportunities* highlights several key points:

6.3.1 AI Literacy for Educators

The Department of Education's report *Artificial Intelligence and the Future of Teaching and Learning* [47] advocates for equipping teachers with a foundational understanding of AI, referred to as "AI literacy". This encompasses not only the technical aspects but also the pedagogical approaches to AI integration. Teachers need training to understand AI's capabilities and limitations, recognize potential biases, and maximize AI's benefits while safeguarding against risks.

6.3.2 Pre-service and In-service Training

Comprehensive training programs for both aspiring teachers (pre-service) and practicing educators (in-service) are essential. The paper *Unlocking the Potential of AI in Education* [56] stresses the need for these programs to equip educators with the skills and knowledge to incorporate AI-based pedagogy into their teaching practices.

6.3.3 Addressing Teacher Concerns

Teachers might have concerns regarding AI's impact on their roles and responsibilities. The *Artificial Intelligence and the Future of Teaching and Learning* article highlights the importance of involving educators in the design and development of AI-powered tools. This participatory approach allows teachers to voice their concerns and ensures AI integration aligns with their needs and priorities, supporting teachers in their work without adding undue burdens or replacing their core responsibilities.

6.3.4 Professional Development as a Continuous Process

Continuous professional development is crucial for educators to remain up-to-date on rapidly evolving AI technologies. The source *Integration of AI with Higher Education Innovation* [69] emphasizes the need for ongoing learning, enabling educators to adapt their pedagogical approaches to the changing landscape of AI in education.

7 Conclusion

The purpose of this report was to explore the transformative impact of artificial intelligence on education, examining both the opportunities and challenges presented by AI technologies. Throughout our exploration, we discussed the foundational concepts of AI, including its various subfields such as machine learning, natural language processing, and deep learning. We highlighted how these technologies enhance personalized learning, increase accessibility, and improve administrative efficiency. Additionally, we examined the challenges AI poses to critical thinking, autonomy, and communication skills, as well as the implications for privacy and equity in education.

AI has the potential to revolutionize education by providing personalized learning experiences, facilitating access to knowledge, and supporting teachers with advanced tools. These benefits can lead to more engaging, effective, and inclusive educational environments. For instance, AI-powered platforms can generate individualized learning paths, provide real-time feedback, and offer multilingual support, making education more accessible to diverse populations. Additionally, AI can automate routine tasks, allowing teachers to focus on more impactful activities like personalized instruction and mentoring.

However, the integration of AI also presents significant challenges, including potential impacts on essential skills development, equity in access to technology, environmental concerns, and privacy issues. The reliance on AI tools can undermine critical thinking, autonomy, and creativity among students, and the disparity in access to premium AI tools can exacerbate educational inequalities. Moreover, the environmental impact of AI, with its high energy and water consumption, cannot be overlooked.

As AI continues to evolve, it is crucial for educators, policymakers, and researchers to collaborate in developing ethical guidelines, equitable access, and sustainable practices. Continuous investment in teacher training and the development of robust assessment methods will be essential to maximize the benefits while mitigating the risks. Governments and institutions should also invest in AI infrastructure and partnerships, and develop frameworks and guidelines to ensure the safe, ethical, and effective use of AI in education.

It is imperative that we embrace the opportunities presented by AI while actively addressing its challenges. By fostering innovation, ensuring ethical practices, and promoting inclusive education, we can harness the full potential of AI to create a brighter future for learners worldwide. As we stand on the brink of a new era in education, the integration of AI offers unprecedented possibilities. The question remains: how will we shape this future to benefit all students and educators?

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