

Enhancing student's critical thinking skills in education through generative AI

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Abstract

Education is one of the domains that suffered significant challenges throughout the years, having to adapt once more to respond to the requirements brought by the rapid evolution of artificial intelligence. This paper explores how critical thinking amongst students can be nourished through the usage of generative AI in educational software. It analyzes how generative AI can be properly implemented in tools used in teaching and learning, focusing on ways that guarantee the proper usage of this type of technology. A systematic literature review approach was used confirming that the selected studies met the specific criteria set in this paper. The criteria covers different components such as: publication date of the article (between 2020 and 2025), a specific set of keywords, methods that were used, language of the paper etc. A set of research questions was developed in order to highlight the important elements that can make the difference between the nourishment or the inhibition of the student's critical thinking. This literature review summarizes and explains the proper techniques that can be used to ensure that generative AI is used as a tool that supports thinking processes and not as a substitute for them. Through this approach, this paper can be seen as a starting point in the direction of studying the positive aspects of incorporating AI in education, listing new perspectives for future research in this direction. This analysis compares the positive and negative aspects of the usage of large language models in education, aiming to add value to current educational research by addressing the uncertainty of whether to or not to integrate AI in educational processes.

Keywords: artificial intelligence, large language models, educational technology.

1. Introduction

The fast paced evolution of artificial intelligence (AI) has led to a great change in the perception of how automation of tasks should be handled in our society. Over the years the topic of AI has grown in terms of popularity, reaching its peak with the discovery of transformers. This type of software has become the standard when it comes to the development of generative artificial intelligence software (GenAI). It is a neural network (NN) design that makes it easier for an AI model to understand and differentiate text in natural language. This discovery highlighted the potential of natural language processing (NLP) tools in everyday's working environments, making it possible for tools such as ChatGPT, Gemini AI and Claude Sonet to make their breakthrough to all types of users, focusing on everyone, not only on people who present a good knowledge in terms of technology.

Tools such as ChatGPT became prevalent quickly amongst students forcing the teaching personnel to adapt and change the way they teach. The usage of AI in educational contexts is still an underexplored field, especially when it comes to how this type of software impacts pupils critical thinking (CT) and their ethical academical reasoning.

The existing literature presents a fracture, focusing on either how to properly develop an LLM agent or showcasing where AI can be best integrated. Recently papers started to

point out the gaps in literature explaining the importance of developing AI literacy amongst students and teachers.

1.1. Scope and research questions

This paper aims to showcase in a systematic manner how student's critical thinking can be maintained and improved by implementing specific models or frameworks by pointing out crucial aspects showcased in the reviewed articles.

In order to properly understand, assess and discuss the possible impacts of GenAI amongst students we will shift our focus on answering the following research questions:

- How can we use simulations in order to put students in tough situations to enhance their critical thinking skill?
- Is it crucial to expose students to practical scenarios in order to nourish their critical thinking? Even traditional learning scenarios may lead to the same result?
- What are the best frameworks or models that can be used with AI to properly help pupils learn better?
- How limited is generative AI in educational technology when it comes to properly assessing a learning situation?

1.2. Methodology and acceptance criteria

The methodology used in this paper centers around a systematic approach to a literature review. All the materials used in this paper have undergone a selection process focused on a specific set of criteria that ensures that the materials studied are relevant to the content discussed in this research. The articles had to be part of an international scientific database such as IEEE Xplore, Web of Science, Scopus, Elsevier, SCIC Proceedings etc. and needed to be published after 2020.

The search process focused on the following inclusion criteria:

- Articles should have been published between 2020 and 2025 in order to properly assess the current development stage of LLMs
- Articles should have been written in English
- Papers should focus on how to integrate AI in order to get benefits from this type of integration and to respect ethical boundaries implied by ethical regulations specific to the region where the studies have been conducted
- Keywords specified contained one of the following terms: AI, education, intelligence, GenAI, content generation, critical thinking etc.

The exclusion criteria ensured that the selected papers do not fall into one of the categories:

- Articles that consists of abstracts only
- Blogs or opinions posted on social media platforms
- Duplicate records or redundant information

The initial search identified an initial stack consisting of 40 potentially relevant articles, but only 12 articles met all aspects detailed in the inclusion criteria. The screening process was rigorous following a general systematic literature review (SLR) in a more reduced

manner illustrating a more exploratory synthesis approach. The selected articles represent a good basis because they illustrate different types of studies with different types of methodologies. That being said, the pool consists of 12 researches including narrative literature reviews, systematic literature reviews, design based research and empirical studies.

2. Background on GenAI-enhanced learning, critical thinking and STEM education

The usage of AI in education has become more prevalent, not only in universities and postgraduate education but also in primary and secondary education. However this also means that future teachers need to adapt on how to respond to certain topics in the classroom and how to handle pupils that are growing in a society where everything is powered by technology and where information is vast and unfiltered. Preservice teachers need to have a proper space where they can train on how to handle delicate situations and a mixed reality simulation might prove to be the best solution. A mixed reality simulation (MRS) platform powered by AI can serve as a sandbox where preservice teacher can train on how to handle difficult topics [1].

Difficult topics do not only rely on sensitive information meaning that sometimes a subject can be perceived as difficult based on how it is taught. We have a tendency to measure its difficulty based solely on how complex the learning process has to be done in order to be able to retain information on that specific topic. Even so, we tend to overlook the vocational areas where education is not the same and where theory should not be our only concern. We need a more practical approach and this can be achieved by implementing the STEM model and AI [2]. By doing so, pupils have the chance to experiment a more practical approach in their learning process which leads to the improvement of reasoning, decision making and collaboration. STEM might be a cohesive approach but it does not treat how AI is implemented alongside it. We need to take into account that vocational training should be focused on honing the practical skills of the students and we need to add AI into the schema by using appropriate approaches centered around practicality such as AI enabled open innovation paradigm [3].

One of the aspects of integrating AI in educational processes is directly linked to how to properly collect data from students. This action is not as easy as it seems because it has to respect ethical regulations. Despite the lack of examples of collecting data through AI in educational technologies we can take inspiration from the methods used in advertising via out of home advertising examples [4].

STEM methods can be applied in traditional teaching as well, methods that proved to be useful when it comes to teaching the Gen Z and Gen Alpha generations [5]. If we focus on the practical aspect we can try to understand how Object based STEM can help the engagement of the students improving their creativity, reasoning and problem thinking [6]. Empowering the STEM methods with AI comes with difficulties related to AI hallucinations and the language that the model was being trained on [7] [8].

The integration of AI in education is directly dependent on knowledge focused on how to properly use AI tools. AI literacy becomes a must that ensures that teachers and students use AI at its full potential rather than using some capabilities of AI powered platforms [9].

AI literacy comes in handy especially when we are talking about GenAI software because it forces the user to properly assess the situation that he needs help with. The main issue when it comes to this is that students are not always self sufficient and might not properly assess what they need help with, making it easier for them to use a specific framework like IDEE [10]. IDEE tries to make the assessment process of the situation easier by identifying the desired outcome, determining the automation level in regards to ethical consideration and lastly helping users to evaluate the generated content's effectiveness.

Another aspect that should be mentioned is that the AI generated content must comply with specific rules and regulations and students should not rely on GenAI to do all the work. This is important because teaching staff should understand the necessity of using AI detection software, especially in situations where the information presented by the students is suspicious and does not reflect an understanding of the topic in regards to their level of knowledge and thinking [11].

LLMs usage is directly dependent on the quality of the information that they can generate and sometimes students miss this key aspect when using tools such as ChatGPT. The quality of information usually reflect how much the AI did hallucinate and how recent the information that led to the generation of the content actually was, making it important to understand that GenAI models should have access to updated information. This can be achieved through the integration of RAGs in LLMs. RAG enhanced LLMs generate more accurate content, making it more engaging for people when it comes to accessing learning resources powered by GenAI agents [12].

3. Discussions, implications and limitations

3.1. Can virtual environments impact critical thinking?

Simulations have been proved to be useful for teaching preservice teacher to handle difficult topics. By having access to a “sandbox” where they can simulate real interactions, teachers made it possible to encounter difficult questions or scenarios that they did not think of, forcing them to adapt and overcome difficulties. We can investigate how to properly invert this idea by providing more AI powered simulations that students can access to experiment and learn in a more practical way. One example of such scenario would be how to teach students to respond in emergency situations. Real life simulations do not usually properly mimic the real situations. It is difficult to do a real life simulation that mimics an emergency scenario, a situation where the student should be the one in charge. This can be changed by migrating the medium of where the simulation is happening. An virtual simulation in a medium powered by AI might be much more helpful because it can properly mimic a scenario without anyone being hurt. This can lead to a much better understanding of the importance of knowing the proper reactions in difficult emergencies. This can be enhanced even more by using a virtual reality tool that can allow to experiment the simulated event hands on. This proposal sounds good but it has to be studied taking into consideration different aspects. Simulations powered by AI are costly

because you need to have access to such software. Besides that, schools need to have a good infrastructure that can facilitate access to such teaching tools. Nonetheless, it would be wise to discuss all of the psychological aspects of having students learn in simulations. Are they actually beneficial for their mental wellbeing or in some cases these simulations might trigger some mental conditions such as anxiety or OCD?

3.2. Approaches for using GenAI effectively in education

Students should be encouraged to experiment with their knowledge a bit more. Teaching in today’s society should be adapted to respond to young people’s needs. Pupils do not learn the same they did 50 years ago because they have been exposed to big amounts of information since the day they were born by having access to technology. Retaining information without applying what has been studied can lead to a decrease in the engagement of the students in class. There are multiple ways to shift the teaching to a practical approach and one of the most effective and popular approaches is the STEM approach. All of the frameworks presented in different papers disseminate aspects that are part of the STEM approach, making it one of the most comprehensive ones. Applying STEMS aspects in teaching and learning focuses on improving critical thinking, problem solving skills, mathematical reasoning and improving the scientific inquiry. The STEM approach can be improved with the help of AI, especially of GenAI. LLMs software can help with proposing key scenarios that force students to think before they act, honing their problem solving skills and mathematical reasoning. Not only that, but a good AI agent can asses the situation and even present alternatives to the solution proposed by students, making the learning process more intersteting for the student making them curious and eager to learn by themselves.

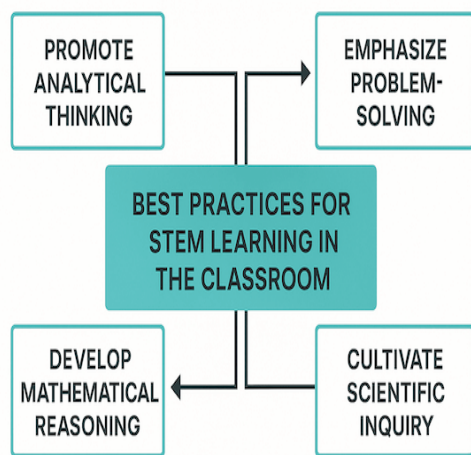


Fig. 1. Best practices for STEM learning approach.
Source: <https://www.structural-learning.com/post/stem-education>

Integration of AI in educational software is a controversial topic, especially for the teaching personnel that does not comply with the automation of every learning process. Some people are still reluctant to the integration of AI, or to the usage of such technologies for doing homework or creating teaching materials. This can be understood because

software can be faulty and GenAI is still improving. \nations still exists in the generated content, the fabrication of citation did not disappear and sometimes the LLM agent generates content that does not make any sense. All of these are correct observations, but we should not overlook the improvement that has been made to these tools in the last years and the problems presented above have been minimized. That being said, the teaching personnel should take into account that the integration of AI in their teaching methods and process might bring facilities in a facile manner, helping them personalize the teaching material to student's needs, reducing their workload making it easier for them to analyze the progress of each pupil.

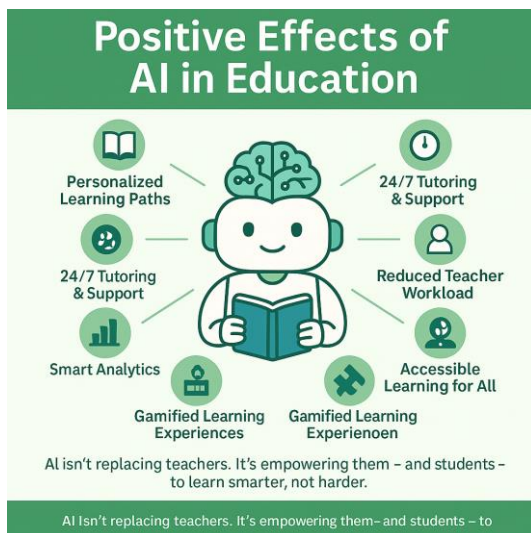


Fig. 2. Positive aspects of using AI in educational processes.

Source: <https://aifirstbiz.com/ai-in-education/>

3.3. The necessity of AI literacy

AI literacy is important for students and teachers. This ensures that the software is being used correctly, making it easier to solve the possible faulty scenarios that might be encountered. One problem that students, especially students in primary and secondary schools are facing is that they have difficulties in grasping where they need help or where they do not understand, making it difficult for them to generate content that can help them with their struggles. This can be solved by teaching them different approaches that they can use when creating prompts for ChatGPT, Gemini AI, Claude Sonet etc. A good example of approach that teaches them how to think a prompt and how to asses the importance of the information that has been generated is the IDEE approach. This methods consists of 4 steps that guides the student: the identification of the desired outcome (what does the student wants to achieve from that specific prompt), determining the proper level of automation (does the student needs the AI to solve a problem step by step or does he need guidance while he figures how to solve the problem by himself), ensuring ethical considerations (does the generated content comply with the regulations and requirements that the students has to respect) and the evaluation of the effectiveness of the generated content (does the student find the answer from the LLM agent helpful in any way).

3.4. AI is not a substitute for teachers

We have to understand that AI does not think as we understand how the thinking process works. How a human thinks is different from how a machine thinks, making it harder for a machine to understand a specific context and to assess a situation. Even if we give all the important information that counts a specific context to a GenAI agent we have to understand that it may not be able to assess what we did with our minds. This is improved from update to update and from model to model. The development of the transformer was a great accomplishment because it made a significant change, a visible one on how the generation of the content actually is. The integration of RAGs in order to have access to the most recent and relevant data in our LLM agent was also a great achievement that did rise the contextual awareness of AI models, but AI still lacks reasoning capabilities. This can impact the educational technologies in a bad way, especially when GenAI tools are being used to generate content for subjects that need problem solving and contextual assessment skills, disciplines such as mathematics and physics. In these scenarios, AI can lack the understanding of the problem, not because it is not trained to understand the given details, but because sometimes to solve a mathematical problem you do not only need access to information, you might also need creativity to come with new approaches, creativity that is solely dependent on mathematical rules, rules that are not stored in in-memory of the AI agent indefinitely because memory is a limited resource.

4. Personal contribution

My contribution in this study is reflected in the analysis of the usage of AI in educational technologies through various models and frameworks in order to enhance the critical thinking of students. This process covered the selection of the proper articles and the identification of gaps in existing literature which resulted in ideas formulated in the final section of this paper. The conclusion showcase in a more concise manner the answers to the research questions leaving a starting point for future research in the direction detailed throughout this study.

5. Final thoughts

This topic is still underexplored and many aspects and limitations that were briefly explained should be studied in the future to create a solid foundation when it comes to discussing the best ways to integrate AI in Education.

Critical thinking can be nourished through the integration of AI in educational technologies. However, critical thinking can be impacted negatively if the usage of AI is done in such a manner that does not force the student to think. One of the most effective ways to increase the critical thinking of students is to implement STEM approaches powered by AI in combination with ways that ensure that the students know how to assess and generate educational content with GenAI by using methods like IDEE prompt creation and usage approach.

The integration of AI in educational technologies should enhance collaboration between students, making the educational process interesting and much more engaging for them. This integration does not imply that teachers will not be needed in the future, on the contrary teachers will have a much more important role to play, being a key part in the

educational process, helping students to experiment and learn much more effectively with the help of AI.

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