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Deploying chatbots to build students' critical thinking skills: Leveraging generative AI effectively and purposefully in higher education

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Abstract

Critical thinking skills are regarded as a higher order cognitive ability that can empower students to be more effective at acquiring and applying their hard-earned knowledge. With university education being the penultimate step before students join the working world, also coinciding with when they enter early adulthood, the higher education sector is often tasked with this important mission of inculcating in students critical thinking skills that will serve them well for lifelong learning. The concurrent ascendance of chatbots in a technologically-intensifying education landscape has raised questions about whether such conversational AI platforms can be deployed for general instruction, but also for building and enhancing students' critical thinking skills more specifically. This chapter will first unpack what constitutes critical thinking, before reviewing how chatbots have been and can be leveraged for cultivating university students' critical thinking abilities. It will discuss the opportunities and pitfalls presented by conversational AI from the perspectives of educators and students before concluding with key takeaways.

Introduction

Equipping students with critical thinking skills is a key educational outcome but this undertaking has attained even greater impetus in view of rising digitalization and the growing complexity of the information landscape. Indeed, digitalization has ushered in heightened connectivity, improved interactivity, and wider and deeper access to multimodal forms of knowledge. These have unlocked for learners of all ages access to rich, engaging and seemingly limitless opportunities for acquiring knowledge. Hardly an unalloyed blessing however, digitalization has also unleashed a firestorm of misinformation and disinformation, along with the compounding pressure of information overload on individuals. These have had adverse impact on students' learning and necessitated a sharpening of their competencies for critical discernment. Nevertheless, the emergence of innovations in Artificial Intelligence (AI), notably Generative AI, may present compelling opportunities for leveraging new AI tools to incorporate into pedagogical strategies for instilling in students critical thinking skills.

Nurturing students' critical thinking capacities

Critical thinking is a cornerstone of learning and education because it is deemed an essential skill that enhances individuals' ability to engage in lifelong learning, and to navigate the complexities of everyday life. However, it is by no means a straightforward competency to instill in individuals and indeed, necessitates a suite of pedagogical methods that builds individual skills through preferably, a stepwise approach.

Extensive research has been conducted on optimal pedagogical strategies for building critical thinking skills in students, many founded on the landmark Bloom's Taxonomy. Originally proposed by Benjamin S. Bloom in 1949, then Associate Director of the Board of Examinations of the University of Chicago, this taxonomy has since been revised and enhanced but has remained a guiding framework for pedagogical innovation. By categorizing different levels of cognitive thinking skills, Bloom's Taxonomy provides a structured approach to understanding how students can progress from basic knowledge acquisition to higher-order thinking skills, including critical thinking.

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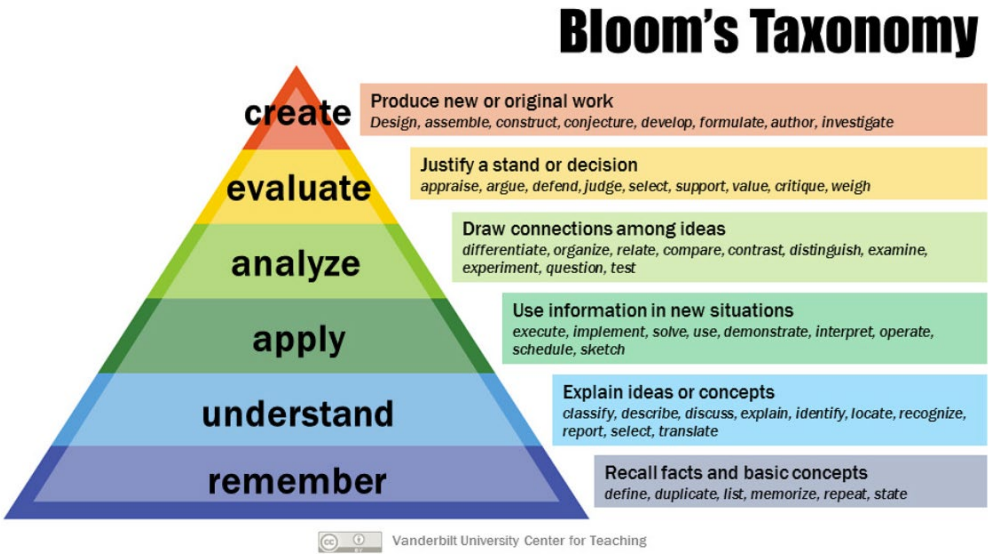
Teaching critical thinking in schools often involves various strategies and methods that align with the levels of Bloom's Taxonomy (Duron et al. 2006), namely:



Remembering (Knowledge): At the foundational level, students acquire basic facts and information to develop their factual knowledge. Critical thinking is fostered on a strong foundation in subject matter knowledge where teachers provide students with accurate and relevant information through lectures, readings, and multimedia resources. At this level, assessment typically involves memory-based rote tasks like quizzes and tests.

Understanding (Comprehension): At this stage, students progress from memorization to comprehending concepts, principles, and relationships between different pieces and bodies of information. To hone students' skills and process for understanding, teachers encourage students to explain concepts in their own words, summarize information, and create diagrams or concept maps. Discussions and group activities facilitate deeper understanding.

Applying (Application): Critical thinking involves using acquired knowledge and understanding to solve problems or address real-world situations. To give students the experience of applying knowledge, teachers assign tasks and projects involving practical scenarios. Case studies, simulations, and hands-on tasks are typical classroom activities to help students foster problem-solving skills.

Analyzing (Analysis): Critical thinking also includes the ability to break down complex information into its constituent parts, identify patterns, and draw connections. To sharpen students' analytical skills, students are given tasks that require them to compare and contrast information, identify causal relationships, and evaluate the validity of arguments. Critical reading and research assignments also allow students to undertake a deeper level of analysis.

Evaluating (Evaluation): In the face of today's information onslaught, students must learn to critically assess the quality and relevance of information, arguments, and solutions. Teachers can encourage students to assess the credibility of sources, examine multiple perspectives, and make judgments based on evidence. Debates, peer reviews, and reflective essays promote evaluative thinking.

Creating (Synthesis): At the pinnacle of the taxonomy lies creation and synthesis where critical thinking involves generating new ideas, solutions, or perspectives based on existing knowledge and analysis. Students are challenged to design innovative solutions to complex problems, create original

works, or propose new theories. Projects, research papers, and creative assignments inculcate creative and critical thinking.

To effectively teach critical thinking in schools, educators should scaffold instruction by gradually moving students through the levels of Bloom's Taxonomy. This progression enables students to develop strong foundational knowledge and gradually layer on analytical and evaluative skills that are essential for critical thinking. Additionally, fostering a classroom environment that encourages questioning, collaboration, and open discussion is crucial for nurturing critical thinking abilities in students. See Facione et al. (2020) for an overview of empirical research on efforts to improve critical thinking in educational and employment settings.

Natural Language Processing chatbots: Applications and limitations

Chatbots can play an increasingly useful role in education and specifically, in the development of students' critical thinking skills. However, it is important to first understand how they work, how they can be applied, but also their limitations so that they can be used effectively and judiciously, but also appropriately and purposefully.

Fundamentally, chatbots are computer programs designed to mimic how humans communicate with each other. The computational algorithms decoding natural human language at the core of a chatbot are modeled after the biological networks of the human brain. In the face of millions of years of evolution, the human species forged sophisticated adaptations, of which human language is one of the most marvelous. The ability to perform mental computations needed for natural language is distinctively human and deceptively complex despite the eloquence and speed at which most humans perform it daily. The human mind is a powerful computational machine that can build up and consequently break down the utterances used to communicate meaning from the mundane to the extraordinary. For people to understand a language, we need our brains to recognize patterns of sounds (phonetics), words (morphology), syntax (grammar), meaning (semantics), context, and many other mechanisms.

Chatbots employ a variety of algorithms to break down the information within sentences into individual words called tokens. It then analyzes the grammatical structures to parse the relationship of the tokens with each other. Parts of the sentence are recognized as the user's intent, signaling what the user wants to do, while other parts will be identified as entities, such as locations, objects, or subjects. For more sophisticated systems, additional information about the context of previous interactions is added at this point.

There are two broad categories in which a chatbot can reply to a human: those based on rules and those powered by artificial intelligence (AI). Rule-based approaches use simple rules to match human intents to predefined responses. These chatbots present users with questions and prompts, guiding them through a sequence of actions using 'if-then' logic to arrive at the appropriate answer. AI-based approaches use a variety of machine-learning algorithms, neural networks and, lately, generative transformer models.

Large Language Models (LLMs), for example, OpenAI's GPT and Google's BERT, are trained on trillions of conversational examples to recognize patterns in human language. The underlying transformer architecture that powers an LLM weighs the parsed tokens according to how much 'attention' they should receive when the algorithm is formulating a response. Because LLMs can process all the words in a sentence simultaneously, this parallel and iterative processing of previous data makes the pattern recognition process fast and efficient.

The complexity of human language explains why AI wanting to simulate it is necessarily complicated. To address the absence of a biological evolutionary timeline, technological innovation compensates with data aggregation and information processing capabilities. Advances in recent decades have allowed chatbots to trawl the entire digital knowledge base of the open Internet, with approximately half a trillion words of text considered nearly simultaneously in hundreds of billions of parameters.

While biological and artificial intelligence are inherently different, there are conceptual similarities between chatbots and the human brain's language processing. For example, advanced machine learning models are structurally organized into nodes of processing units like neurons and recognize linguistic patterns akin to how people learn new languages over time. Bots and humans can use clues from context to "understand" language, especially when determining the meanings of ambiguous terms.

However, differences are aplenty. Most notably, while sounding knowledgeable with a plausible answer to a question, a chatbot does not comprehend nor care about the factuality of its statement (unlike humans who are more so inclined). The type of errors in syntax and semantics that chatbots make are different from typical human language development. Chatbots confabulate because it sounds acceptable, while children do it because it sounds magically believable.

In recent years, chatbots have found applications in the field of education. Next, we briefly review the latest developments in conversational AI for education.

Key developments in conversational AI for ed tech

Chatbots have become integral to the educational technology ecosystem, complementing other digital learning tools. Chatbots do not require specialized equipment as they operate on web-based platforms, making them versatile and accessible across multiple devices (Kuhail et al., 2023). These conversational tools, especially the latest iterations with generative AI capabilities, offer more natural educational content delivery and personalized assistance that could improve learning experiences. Learners primarily use chatbots to review previously studied information and catch up on missed class materials. For example, nonprofit educational organization Khan Academy is piloting Khanmigo, a new experimental artificial intelligence (AI) guide which is designed to mimic one-on-one tutoring for individual students through customized support, including to prompt critical thinking and recommend relevant resources.

More holistically, educational chatbots contribute to refining both the learning process and teaching methodologies that could enhance learning outcomes. Additionally, natural language conversations can help address school administration issues, assisting students with tasks such as course enrolment, exam schedules, and grade inquiries and reducing workload for school administrative departments (Adamapoulo & Moussiades, 2020). Again, Khanmigo is another excellent example, supporting teachers with administrative tasks so that their time can be better channeled towards pedagogical tasks.

Educational chatbots augment various learning practices rather than substantially altering the role of teachers. Rather than being a revolutionary change in the process of learning, they represent process improvements for both learners and teachers alike (Rudolph et al., 2023). In particular, the domains where chatbots have been used the most include language learning, self-guided activities, feedback, and metacognitive thinking (Wollny, 2021). Chatbots contribute to learning by aiding knowledge acquisition, simplifying students' everyday lives, and fostering personal development.

One of the most salient premises of integrating chatbots into educational platforms and services is their ability to aggregate various forms of information for rapid and accessible retrieval, thus

encouraging personalized learning and instant support while allowing multiple users simultaneous access to the same information (Okonkwo et al., 2021). Chatbots act as teaching and peer agents, recommend educational content, engage students in relevant discussions, conduct formative assessments, set learning goals, and provide instantaneous help by including term definitions and FAQs (Kuhail et al., 2023).

Challenges and opportunities in leveraging chatbots for education

Comfort levels with digital learning platforms have certainly risen over the years, and educational technology has been given a further shot in the arm over the course of the Covid-19 pandemic. Recent relentless waves of AI innovation have also influenced the developmental trajectory of educational technology. Notably, the emergence of generative AI tools such as ChatGPT, Bard, Dall.E and Midjourney allow for the generation of highly customized content that can be used to power personalized learning. Such tools, which can dynamically generate an endless fount of textual and audiovisual content, have made chatbots even more responsive and engaging. With the entry of this slew of teaching tools, teachers at all levels of the educational journey now have the opportunity but also the challenge of incorporating generative AI into their teaching and assessment. They must also bear in mind the overarching need to equip their students with the competencies for effectively using yet critiquing such tools.

Leveraging chatbots for education and teaching presents a spectrum of promises and pitfalls. On the one hand, chatbots offer exciting possibilities such as personalized learning experiences, adapting content to individual student needs, offering 24/7 availability for answering queries, and scaling to accommodate large numbers of students in various educational settings. Essentially, in a physical class, each student can now be individually aided by a dedicated AI-driven teaching assistant that tracks each student's performance and offers customized support specifically tailored to address each student's unique learning abilities and difficulties. AI chatbots can also provide instant feedback, help students access learning resources, and generate valuable data-driven insights to enhance the educational experience.

In terms of specific pedagogical strategies that exploit the capabilities of chatbots, various techniques can be employed to help students learn and retain new concepts. These include: enhancing students' grasp of challenging and abstract ideas by offering multiple examples; providing a wider range of clarifications and comparisons that help students dispel misconceptions; low stakes assessments that enable students to recall information and evaluate their comprehension; identification and evaluation of areas where students manifest knowledge deficits; and staggered practice sessions that reinforce and strengthen the learning process (Mollick and Mollick, 2023).

All these techniques although previously resource-intensive to develop, are now significantly and smoothly expedited by strategic and judicious use of AI chatbots. Importantly too, rather than teaching critical thinking skills in a piecemeal fashion, curricula and lesson plans must take an integrated approach that scaffolds students' learning with explicit instructions and thoughtfully-developed group collaborations involving chatbots, thus enabling students to discuss and probe issues while flexing their skills (Mejia & Sargent 2023).

However, there are notable challenges to consider in the use of chatbots. One significant challenge lies in the diminution of the human touch. Chatbots, while capable of dispensing information and guidance, lack the emotional intelligence and empathy that human educators can provide, especially in areas like counseling and mentorship. They may struggle to handle complex or nuanced questions

that demand deep subject matter expertise or critical thinking, potentially frustrating students. Using them in the context of instructor led learning is thus vital.

Furthermore, even though Large Language Models (LLMs) can be highly valuable in generating educational content to support student learning, it is imperative to emphasize the importance of instructor proficiency. Profound subject knowledge and teaching expertise are essential for evaluating the AI's output and determining whether and how to implement each approach effectively in a particular classroom context. As it stands, current chatbots have been found to hallucinate and still cannot engage in logical reasoning, in which case instructors play a vital role in showing students how to assess whether a chatbot's output is appropriate for their class and be alert to its inadequacies too.

Moreover, technological barriers can hinder effective chatbot use, as not all students have access to the necessary technology or internet connectivity. Privacy and data security concerns arise when collecting and storing student data through chatbots. Ensuring the security of personal and academic information becomes a priority. Chatbots also require ongoing maintenance and updates to stay accurate and relevant, and integration into existing educational systems can be complex and time-consuming.

Ethical considerations are inescapable, as decisions made by chatbots, such as grading assignments or providing feedback, may carry ethical implications that require careful evaluation. Additionally, there may be resistance to technology adoption among educators and students, with concerns about job displacement or a preference for traditional teaching methods.

In conclusion, while chatbots offer tremendous potential to enhance education through enhanced personalization and accessibility, addressing challenges such as maintaining a human touch, ensuring data security, overcoming technological barriers, and managing ethical considerations is crucial for realizing their full potential. A balanced approach that combines the strengths of chatbots with human educators is likely the most effective path forward in the evolving landscape of education.

Conclusion

Ultimately, chatbots do present a shot in the arm for educators and learners alike to foster critical thinking skills that can be widely applied and that will stand the test of time. While conversational technologies could enable personalized learning and extended accessibility beyond the classrooms, there are several implementation challenges to overcome. Even as the underlying algorithms rapidly adapt, the application of chatbots in education needs to be scrutinized, both from theoretical research and practical pedagogical standpoints. Instead of expecting a wholesale revolution with chatbots, we suggest a more incremental augmentation of existing teaching methodologies and learning experiences.

The need for logical reasoning and critical human oversight have not only remained constant but have instead intensified in the new era of LLMs and advanced AI-driven chatbots. Ethical considerations and guiding frameworks are necessary, particularly when chatbot outputs shape the decision-making capacities of young learners.

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