RHS Revista Humanismo y Sociedad

Artículo de investigación científica y tecnológica e4/1

RHS. Revista. Humanismo. Soc. 13(1), e4/1-20, ene.- jun. 2025 / ISSNe 2339-4196

Building Metacognitive Skills Using AI Tools to Help Higher Education Students Reflect on Their Learning Process

Creación de habilidades metacognitivas utilizando herramientas de IA para ayudar a los estudiantes de educación superior a reflexionar sobre su proceso de aprendizaje

Nacereddine Mazari[1]

n.mazari@univ-djelfa.dz

https://orcid.org/0009-0009-7294-3060

https://doi.org/10.22209/rhs.v13n1a04

Received: june 2, 2024.

Accepted: january 30, 2025.

To cite: Mazari, N. (2025). Building Metacognitive Skills with AI: Using AI Tools to Help Learners Reflect on Their Learning Process. *RHS-Revista Humanismo y Sociedad, 13*(1), 1-20. https://doi.org/10.22209/rhs.v13n1a04

Abstract

This study examines how AI can be used to improve higher education students' ability to learn effectively. The research focuses on using AI to enhance metacognition, which is the students' ability to understand and control their learning processes. Specifically, the study explores the potential of AI-powered prompts to encourage individuals to reflect on their learning and explain their understanding of the materials provided by teachers. Additionally, it highlights the benefits of implementing AI-powered learning companions to provide personalized support and guidance throughout the learning process. Recommendations for future research include investigating how AI can further improve students' self-regulation skills and enhance peer-review processes through AI-generated feedback.

Keywords: Learning process, AI, Metacognitive Skills, Students

1 University of Ziane Achour (Algeria)

Resumen

Este estudio examina cómo la IA puede ser utilizada para mejorar la capacidad de los estudiantes de educación superior para aprender de manera efectiva. La investigación se centra en utilizar la IA para mejorar la metacognición, es decir, la capacidad de los estudiantes para comprender y controlar sus procesos de aprendizaje. Específicamente, el estudio explora el potencial que tienen las indicaciones dadas a la IA para alentar a las personas a reflexionar sobre su aprendizaje y explicar su comprensión de los materiales proporcionados en sus clases. Además, destaca los beneficios de implementar compañeros de aprendizaje con AI para proporcionar apoyo y orientación personalizados durante todo el proceso de aprendizaje. Las recomendaciones para futuras investigación incluyen las formas en que la IA puede mejorar aún más las habilidades de autorregulación de los estudiantes y los procesos de revisión por pares a través de la retroalimentación generada por IA.

Palabras clave: Proceso de aprendizaje, IA, Habilidades metacognitivas, Estudiantes

Introduction

In today's rapidly evolving world, the ability to learn independently and effectively has become more crucial than ever. At the core of this ability lie metacognitive skills–the capacity to understand and regulate one's own learning process. Higher education students can significantly enhance their academic performance and overall intellectual development by recognizing their strengths and weaknesses, setting goals, monitoring progress, and evaluating their learning strategies. However, traditional educational approaches often prioritize content delivery at the expense of developing these essential metacognitive skills.

Artificial intelligence (AI) offers a groundbreaking opportunity to address this limitation and revolutionize the learning experience. AI-powered tools provide learning strategies, such as interactive quizzes and engaging dialogues, as well as personalized feedback. These tools adapt to individual learners' needs, offering tailored support and guidance. For instance, AI-powered tutoring systems identify knowledge gaps and provide targeted explanations. Interactive quizzes assess learners' understanding and provide immediate feedback, encouraging self-reflection and improvement. Furthermore, AI-driven chatbots engage learners in meaningful conversations, promoting their critical thinking, helping them analyze information, and articulate their thoughts. By simulating real-world interactions, chatbots foster essential communication and problem-solving skills. As learners interact with AI, they become more self-aware, strategic, and reflective, increasing ultimately their deeper learning and improving their learning outcomes.

This research aims to delve into the AI's potential to foster learners' metacognitive development. By examining the impact of AI tools on learning outcomes and metacognitive skills, this study seeks to provide valuable insights for educators and policymakers. A rigorous research methodology has been employed to investigate the effectiveness of AI-powered interventions, including randomized controlled trials, surveys, interviews, and observational sessions. The research explored a variety of AI tools, such as intelligent tutoring systems, adaptive learning platforms, and virtual and augmented reality experiences. By analyzing the data collected, the study identified the specific factors that contributed to the effectiveness of AI in promoting metacognition: the quality of AI-generated feedback, the level of learner engagement, and the alignment of AI tools with learning objectives.

Research Problem

Metacognitive skills–such as self-awareness, planning, monitoring, and self-assessment are crucial for effective and independent learning. However, traditional educational approaches often neglect these skills, prioritizing content delivery at the expense of active student reflection and the recognition of one's own learning abilities. This lack of self-reflection and awareness can hinder students' ability to identify their learning needs and abilities, adjust their strategies, and ultimately achieve optimal learning outcomes. Based on the research problem above, we identified the guiding question for our research: Can AI-powered tools be effectively integrated into educational settings to promote self-reflection and awareness and significantly enhance students' metacognitive skills, thereby improving their overall learning outcomes?

Research questions

Based on the research problem above, we have determined the specific questions that led the literary review conducted in the following sections:

- How effective are different AI tools (e.g., interactive quizzes, chatbots, learning dashboards) in promoting self-awareness, planning, monitoring, and evaluation compared to traditional learning methods?
- Does the effectiveness of AI tools in fostering metacognitive skills vary depending on the learning environment (e.g., subject matter, age group, online vs. in-person learning?)
- Do the gains in metacognitive skills achieved through AI-prompted reflection persist, or do students require ongoing support from AI tools?
- How can teachers effectively integrate AI tools into learning process to maximize the development of metacognitive skills and ensure deeper understanding?

- Are there potential ethical concerns regarding AI's role in learning, such as student reliance on AI tools or potential biases within AI algorithms?

Importance of the Current Study

The importance of this study relies on the following factors:

- Metacognitive skills are crucial for effective and independent learning. AI tools promote learners' self-awareness, learning planning, monitoring, and evaluation, and leads to a deeper understanding, improved problem-solving abilities, and better information retention.
- AI can tailor prompts and feedback to individual student needs, address learning gaps, and foster self-directed learning, which can be especially beneficial for students with diverse learning styles.
- Engaging AI tools, such as chatbots and interactive quizzes, increases student motivation and participation in learning. This active reflection leads to a more positive learning experience.
- AI tools can provide valuable data on student progress and learning gaps, allowing teachers to personalize instruction and offer targeted support.
- Developing strong metacognitive skills equips students to learn independently and adapt to new learning situations.

Research Objectives

- Examine the efficacy of AI tools in fostering metacognition compared to traditional methods.
- Identify optimal AI tools for specific metacognitive skills.
- Develop a framework for effective AI integration in diverse learning environments.
- Evaluate the long-term impact of AI-prompted reflection on metacognitive skills.
- Describe the potential ethical considerations within AI-driven learning.

Methodology

The research adopted a descriptive-analytical approach, systematically reviewing and synthesizing findings from previous studies on the role of AI tools in fostering metacognitive skills within educational settings. Through a critical analysis of existing research methodologies and outcomes, the study assessed the potential applications of these AI-powered learning interventions across diverse university and educational contexts. The objectives include

identifying appropriate AI tools, proposing implementation strategies, and addressing potential challenges associated with integrating these technologies to enhance metacognitive skills in higher education.

Theoretical framework

Metacognition: Definition and Importance

Modern education scholars have increasingly emphasized the importance of metacognition, which extends beyond the simple acquisition of information: it involves the students' capacity to learn more effectively. Metacognition equips learners with a toolbox of skills: self-awareness (identifying strengths and weaknesses as learners), planning (setting goals and crafting learning strategies), monitoring (actively tracking progress and identifying roadblocks), and evaluation (reflecting on learning outcomes to refine one's approach). By honing these skills, learners are transformed from passive recipients of information into self-regulated, critical thinkers. Flavell (1979) states that metacognition fosters adaptability across subjects and the ability to transfer knowledge effectively. Most importantly, it cultivates a love of learning, promoting lifelong journeys of intellectual discovery. Here is a breakdown of the fundamental components of metacognition:

Self-awareness: The core of metacognition lies in the students' understanding of how their brain works. That is, the students are capable of pinpointing their strengths (grasping concepts quickly) and weaknesses (struggling with memorization). It is also related to their capacity to identify their preferred learning styles (whether they are visual learners who thrive with diagrams, or auditory learners who excel with lectures). When students have recognized that they have genuinely grasped a concept and the areas where they need further explanation, they can tailor their learning approach. This recognition is a crucial skill for becoming a self-directed learner. (Schunk & Zimmerman, 2008)

Planning: The planning component of metacognition is the roadmap to students' learning success. It involves setting clear goals (e.g., mastering a specific concept, improving problem-solving skills) and crafting effective strategies. Planning includes creating a study schedule, identifying helpful resources, or forming a group. The key here is anticipating potential roadblocks—distractions, lack of time—and devising solutions, so that students navigate challenges without derailing their learning journey (Schunk & Zimmerman, 2008).

Monitoring: Monitoring, which is a pillar of metacognition, helps students keep their fingers on the pulse of their learning progress. It involves actively tracking how well students grasp concepts (through practicing problems, answering quizzes, or self-reflecting). The key lies in the students' capacity to identify areas where they are 'struggling–perhaps a specific formula or a historical event. Once the students have pinpointed these roadblocks, they can adjust their strategies. Monitoring involves seeking clarification from a teacher, revisiting relevant resources, or trying a different learning approach. By actively monitoring their progress and adapting accordingly, they ensure that their learning journey remains efficient and targeted (Rosalyn, 2021).

Self-assessing: The final piece of the metacognitive puzzle involves taking a step back and reflecting on the learning journey. Here, students assess how well they achieved their initial goals (did they master the concept or improve problem-solving?). Self-assessment is fundamental for learners to understand what worked well and what did not'. Did their study schedule optimize their learning? Did the group study sessions enhance their understanding? By reflecting on their learning process, learners can refine their approach for future endeavors. Continuous self-assessment and reflection foster a growth mindset, transforming learners into strategic and adaptable individuals (Cristina & Timothy, 2023).

Why is Metacognition Important?

Strong metacognitive skills are essential for successful and efficient learning throughout life. They empower individuals to become:

Self-regulated learners: Metacognition empowers learners to become the self-regulated masters of their education. Unlike passively absorbing information, this approach encourages students to set clear goals (e.g., to master a concept). Learners then actively monitor their progress through practicing problems or taking quizzes and identifying areas of difficulty. This self-awareness allows them to adjust their strategies independently, seeking help from teachers, revisiting resources, or trying different learning methods. By taking charge of their learning journey this way, students, through metacognition, become self-regulated and adaptable learners who can confidently navigate educational challenges. (Dweck, 2006)

Critical thinkers: Metacognition unlocks the door to critical thinking. By reflecting on their thought processes, learners gain a deeper understanding of how they reach conclusions. This process allows them to analyze information objectively, questioning assumptions and biases within their thinking. They can then weigh evidence more effectively, separating solid arguments from weak ones. This critical lens empowers learners to make well-informed decisions, not just in academic settings but also in everyday life. Metacognition equips them to become discerning thinkers capable of navigating a world overloaded with information. (OECD, 2018)

Transferable learners: Metacognition fosters transferable learning. By understanding how they best learn (through visual aids, group discussions, etc.), individuals can adapt their strategies across different subjects and situations. Students quickly transition from memorizing historical dates to grasping complex scientific concepts as they have honed their metacognitive toolbox. This adaptability allows them to effectively transfer knowledge and skills. Individuals learn not just facts but how to understand themselves. This type of learning empowers students to confidently approach new challenges, knowing they can tailor their learning for optimal results. (Winograd, 2006)

Lifelong learners: Metacognition fosters a lifelong love of learning by nurturing a growth mindset. Strong metacognitive skills allow learners to identify their learning gaps and embrace challenges as opportunities to grow. They become adept at seeking new information and resources to address their learning needs. This self-directed approach fosters a sense of ownership over their life-long learning processes, transforming them from passive consumers of knowledge into active explorers. By cultivating a growth mindset and a love of learning, metacognition equips individuals with the tools to navigate the ever-expanding world of expertise. (Dweck, 2006)

AI Tools and their Potential Impact on Metacognition

Artificial intelligence (AI) tools are rapidly transforming the educational landscape. They hold immense potential as they foster and enhance the development of the following metacognitive skills in learners:

Self-awareness

AI tools can become a student's learning coach. By analyzing student performance data, AI pinpoints strengths and weaknesses. This data is then translated into actionable insights, revealing a student's preferred learning styles and areas needing extra attention. Students can personalize their learning approach with this self-awareness, fostering a deeper understanding of their unique learning journey. Thus, students have a learning path that adapts to their strengths and weaknesses. This is the power of Adaptive Learning Platforms, AI-powered tools that analyze student performance. The level of difficulty and the learning contents automatically adjust based on the student's performance. This way, students are challenged appropriately, and they do not feel overwhelmed or under-stimulated. By personalizing the learning journey to individual needs of students, these platforms foster a deeper understanding of the material and empower students to take charge of their learning. (Winograd, 2006)

Planning

Artificial Intelligence (AI) have the potential to create individualized learning pathways. AI can analyze the learner's data, including strengths, weaknesses, and preferred learning styles (visual, auditory, etc.) to help them plan their learning activities and study plans. These plans suggest relevant resources and outline achievable learning goals tailored to the individual learner. This approach, which empowers learners to take ownership of their educational journey, is predicted to enhance learning outcomes through a more focused and efficient process (Baker, 2014).

Learners do not need to sift through endless resources: AI tools act as their learning concierge. By analyzing their learning data (past performance, learning style), AI curate a treasure trove of relevant materials for them, from articles and videos to targeted practice problems. Students now count on a personalized resource feed that perfectly aligns with their needs and goals (Clark, 2016). Learners focus on the most effective materials to propel their learning forward.

Monitoring

AI analyze learners' data, including strengths, weaknesses, and preferred learning styles (visual, auditory, etc.) to generate personalized study plans. These plans include relevant resources and outline achievable learning goals tailored to the individual learner. This approach empowers learners to take ownership of their educational journey and enhance learning outcomes through a more focused and efficient process.

AI-powered progress tracking dashboards offer a clear, visual roadmap to learning success. These dashboards give learners a real-time snapshot of their progress towards their goals. Thus, students visualize their understanding level and their areas of mastery that need further study appear highlighted. This transparency empowers learners to take ownership of their learning journey, identify gaps in their understanding, and proactively seek additional resources or revisit challenging concepts, ensuring they stay on track to achieve their learning objectives.

Self-evaluation

AI tools can be the students' personal reflection coach. They guide students through self-reflection exercises, prompting them to analyze their learning process. Thus, they are encouraged to reflect on what worked well during their individual learning process and what they can improve. By dissecting their learning journey, students can pinpoint areas for improvement, identifying effective study strategies, or recognizing situations where they need clarification. Self-awareness empowers them to tailor their approach for future endeavors, leading to continuous learning improvement.

AI tools may become the student's personal learning report card, offering more than just a grade. They analyze performance data, summarizing strengths and weaknesses. That is, they can offer reports not just about the "what" but the "why." AI can prompt reflection on the learners' learning journey, encouraging them to analyze what worked well and what could be improved. Armed with these insights, students are able to set even more ambitious goals for the future. The personalized reports empower them to take charge of their learning and continuously self-improve (Schunk & Zimmerman, 2008).

Potential Benefits of Using AI Tools for Metacognition

AI tools can become a student's learning sherpa. AI has the potential to uncover hidden strengths and weaknesses by analyzing a student's performance. Such valuable intel may be then translated into actionable insights, revealing a student's preferred learning styles and areas that require extra focus. This newfound self-awareness allows students to personalize their learning approach, leading to a deeper understanding of their unique learning journey (Winograd, 2006).

AI tools analyze learner data, including strengths, weaknesses, and preferred learning styles (visual, auditory, etc.) and based on this analysis, generate individualized learning pathways. These pathways include achievable learning goals tailored to the specific learner and recommended resources (articles, videos) aligned with their preferred learning style (Baker, 2014). Additionally, AI-powered real-time feedback and progress tracking tools analyze student work and performance, providing immediate insights into areas of strength and areas requiring improvement. This continuous feedback loop empowers learners by facilitating self-directed learning. This way, students promptly identify their own weaknesses, adjust their learning strategies, and correcting and optimizing their learning. By eliminating the waiting times attached to traditional graded assignments, AI fosters a more dynamic learning environment where learners become active participants in their educational journey.

AI helps students level up their learning game as they act as their personal reflection partner, going beyond simply providing grades. AI can guide students through self-reflection exercises, prompting them to analyze their learning process. By dissecting their learning journey, students can pinpoint areas for improvement, identify effective study strategies, or recognize situations where they need help. This self-awareness empowers them to tailor their approach for future endeavors, leading to continuous learning improvement (Schunk & Zimmerman, 2008).

Important Considerations

AI in education holds immense promise but is not a magic bullet. While AI tools can provide personalized insights and real-time feedback, maintaining a balance with human interaction remains essential. Experienced educators play a significant role in guiding students in complex

concepts and addressing nuanced situations where AI may struggle. Furthermore, data privacy and potential biases within AI algorithms must be addressed. Ensuring the responsible use of AI is critical to maximize its potential for enhancing learning while safeguarding student data and promoting fair and equitable educational experiences.

Existing Theories and Frameworks

This Section examines key theories like Self-Regulation Theory and MARA, outlining how AI can enhance metacognition through features like self-reflection prompts and personalized feedback, and highlights the challenges of AI in education, including potential biases, over-reliance on technology, and the crucial need for teacher training to effectively integrate AI into the learning process.

Self-Regulation Theory

The Self-Regulation Theory, initially proposed by Albert Bandura, highlights three crucial processes within learning: self-monitoring (observing and evaluating your learning progress), self-evaluation (judging your performance against goals), and self-efficacy (confidence in your ability to learn). AI tools can become powerful allies for student self-learning as they support these three processes with real-time performance feedback, progress-tracking dashboards that help learners visualize their journeys, and prompts that foster self-reflection exercises (Bandura, 1986). AI empowers students to take charge of their learning fostering a more self-regulated and successful learning experience.

Social Cognitive Theory

Social Cognitive Theory, another Albert Bandura brainchild, emphasizes learning through observation. AI tools leverage this theory to create engaging educational environments. Such environments provide virtual tutors or intelligent learning agents equipped with solid metacognitive skills. Students can observe them as they plan their approach to a task, monitor their progress, and reflect on their learning. By observing these metacognitive tutors in action, students can internalize them and apply them to their learning journeys, fostering their metacognitive development in a social learning context (Bandura, 1986).

Metacognitive Awareness and Regulation Model (MARA)

The Metacognitive Awareness and Regulation Model (MARA) by Pintrich et al. (1995) offers a roadmap for fostering metacognition through AI tools. This model identifies four key areas:

- Students understand their learning process. AI can provide personalized insights into learning styles and strengths (Pintrich et al., 1996).
- Students apply strategies for planning, monitoring, and evaluating learning. AI tools can suggest study plans, track progress, and prompt self-reflection exercises.
- Students consider their thoughts and feelings about learning. AI can create engaging learning environments that spark curiosity and positive learning associations.
- Students believe in their ability to learn. AI can deliver personalized feedback and celebrate achievements, boosting confidence and motivation.

Self-Explanation Theory

Self-explanation theory, championed by John D. Anderson, highlights the power of explaining students' thinking during learning. Students are prompted to explain their reasoning as they solve a problem. According to the theory, "self-explanation" leads to deeper understanding and better information retention. AI tools can be designed to incorporate this theory by prompting students to explain their thought processes throughout the learning process. By encouraging this self-explanation, AI can empower students to actively participate in their learning journey, fostering memorization and proper comprehension (Anderson, 2000).

Limitations and Challenges

Over-reliance on AI: AI tools are powerful allies, but they should not replace students. Over-reliance on AI tools can hinder the development of crucial skills like critical thinking and independent learning. Students need opportunities to wrestle with challenges, experiment with different approaches, and develop self-regulation strategies on their own, without the use of AI. For example, learning to ride a bike is not possible if an individual relies on training wheels forever. True mastery comes from navigating bumps and finding balance. Similarly, effective learning requires the freedom to navigate challenges and develop independent learning skills, which AI can support but not replace (Winograd, 2006).

Data Privacy and Bias: AI tools offer exciting possibilities for personalized learning but can harbor hidden biases. These biases can stem from the data used to train the AI algorithms, potentially creating unfair learning experiences. For instance, an AI recommending only more accessible problems to a student struggling with math could be discouraging and hinder their progress. Careful attention must be paid to data collection and algorithm development to ensure the responsible use of AI. By addressing potential biases, AI can prevent inequalities from perpetuating and provide a fair and equitable learning experience for all students (Barocas & Selbst, 2016).

Limited Scope of Metacognition: AI tools excel at analyzing data and providing personalized learning pathways, but they cannot replicate the human interaction. While AI may struggle to address the emotional and social aspects of learning, which are crucial for metacognition, educators excel in this domain. A teacher can offer encouragement and guidance to a student who has felt discouraged after a challenging task, fostering a positive learning environment (Winograd, 2006). Human interaction remains vital for a holistic approach to learning. AI can be a powerful tool, but it complements, not replaces, the irreplaceable role of educators in fostering a well-rounded learning experience for students.

Accessibility and Equity: The potential of AI-powered learning should not exacerbate educational inequality. Unequal access to technology and reliable internet connections can leave students behind. Students still need computers to utilize these powerful AI tools. Thus, it is essential to bridge the digital divide. Prioritizing equitable access to technology and internet infrastructure is crucial. By ensuring that all students have the opportunity to leverage AI tools (Warschauer, 2004), they can be empowered to become active participants in their learning journey, fostering a more level playing field in education.

Teacher Training and Support: AI tools in education are like powerful instruments in an orchestra, who help create a harmonious learning experience. Thus, educators need to be the conductors who lead the music and not simply the person who hands AI tools when is required. Training students on functionalities and limitations is crucial. Orchestra conductors need to be familiarized with the instruments to avoid a cacophony when the orchestra is playing. Similarly, educators need to understand how to leverage AI tools effectively, integrating them with traditional methods to create a balanced learning environment. Support for teacher training and professional development is essential to unlock the full potential of AI and ensure it complements, rather than disrupts, the vital role of educators (Mishra & Koehler, 2006).

Literature Review

In 2022 Chen & Liu, in their study *Using Artificial Intelligence to Foster Metacognitive Reflection in Learning Analytics Dashboards,* tackled the issue of traditional learning analytics dashboards being data-heavy and not providing enough guidance for students' self-reflection. The researchers explored incorporating AI functionalities into these dashboards to present students with their learning progress and prompts questions (e.g., "What were the most challenging concepts for you this week?" or "What study strategies worked best for you?") The study found that students developed a more vital awareness of their learning process (metacognition) by encouraging deeper reflection on learning data.

Wang, & Aleven (2023) delved into adaptive learning platforms, which may not explicitly prompt students to reflect on their learning process. Their study, *Can Adaptive Learning with Metacognitive Prompts Help Students Learn Better? An Eye-Tracking Study*, stated that while these platforms are effective, they may no prompt students to reflect on their learning explicitly enough. The researchers used eye-tracking technology to investigate the impact of integrating metacognitive prompts within an adaptive learning environment. Their aim was to present an adaptive learning system that, after presenting a concept, asked students how confident they felt with their understanding? or whether they could explain one of the studied concepts in their own words? The study's eye-tracking data suggests that students who received these prompts spent more time reflecting on their learning strategies, leading to better information retention.

Lin & Zhang (2021) focused on the importance of self-explanation (explaining your reasoning during learning). In their study, *The Impact of AI-powered Self-Explanation Prompts on Metacognition and Learning Outcomes*, they stated that students often need help with articulating their reasoning during learning. If this process is not emphasized, it can hinder their metacognitive development. The researchers investigated the effectiveness of AI-powered prompts in encouraging students to demonstrate their thinking throughout the learning process. An AI tutor may ask students questions, such as "Why did you choose that answer?" or "Can you walk me through the steps you took to solve this problem?" (Lin & Zhang, 2021). The study suggests that these prompts can improve students' ability to reflect on their thought processes, leading to more vital metacognitive skills and better academic performance.

The dissertation, *Toward a Framework for Designing AI-powered Learning Companions to Foster Metacognition,* by Xu & Hwang (2022) addresses the need for a comprehensive framework for developing AI learning companions that effectively promote metacognition. AI companions may act as learning coaches, providing information and guiding reflection. This dissertation proposes a framework for designing AI companions that could offer targeted prompts, feedback, and guidance throughout the learning journey, helping students reflect on their learning strategies and develop solid metacognitive skills.

This ongoing research (working document) by Liu & Wu (2023) investigates self-regulation, which is the ability to monitor and adjust a student's approach during tasks like problem-solving. This study explores the potential of AI-based scaffolding to improve the students' self-regulation skills that they need. In this case, an AI system may provide suggestions and prompts while students work on a problem. For instance, the AI might ask "Have you considered trying a different approach?" or "Is there another strategy you could use to solve this?" The study investigates whether AI scaffolding can lead students to develop better self-regulation skills and become more effective problem solvers.

The study *Investigating the Role of Peer-Review with AI-powered Feedback in Developing Metacognitive Skills* by Song & Rose (2022) explores ways to foster metacognition. Traditional peer review can be subjective and lacks guidance in providing constructive feedback that encourages reflection. The researchers investigate the use of AI-powered feedback systems that guide students in offering peer review that goes beyond just pointing out errors. The AI might suggest prompts like "Can you offer suggestions for improvement?" or "What learning strategies could be helpful here?" The study aims to see whether AI can enhance the development of metacognitive skills through peer review by encouraging students to provide more thoughtful and reflective feedback.

Table 1: Comparison of AI Tools and Metacognition Studies

Study	Problem Addressed	AI Intervention	Results
Using Artificial Intelligence to Foster Metacognitive Reflection in Learning Analytics Dashboards (2022)	Traditional dashboards lack prompts for self-reflection.	AI-powered prompts within learning analytics dashboards.	Students demonstrated deeper reflection on learning progress, leading to improved metacognitive awareness.
Can Adaptive Learning with Metacognitive Prompts Help Students Learn Better? An Eye-Tracking Study (2023)	Adaptive learning platforms may not prompt self-reflection.	Metacognitive prompts integrated within adaptive learning environments.	Eye-tracking data showed students spent more time reflecting on learning strategies, leading to better knowledge retention.
The Impact of AI-powered Self-Explanation Prompts on Metacognition and Learning Outcomes (2021)	Students often struggle with self-explanation, hindering metacognition.	AI prompts encouraging students to explain their reasoning while learning.	AI prompts led to improved skills in reflecting on thought processes, potentially leading to stronger metacognition and better academic performance.
Toward a Framework for Designing AI-powered Learning Companions to Foster Metacognition (2022)	Lack of a framework for designing effective AI learning companions for metacognition.	Proposed framework for AI learning companions that provide targeted prompts, feedback, and guidance.	This dissertation lays the groundwork for future development but does not report specific results on student outcomes.
Exploring the Effects of AI-based Metacognitive Scaffolding on Student Self-Regulation in Problem-Solving (2023)	Students often lack strong self-regulation skills in problem-solving.	AI-based scaffolding that provides suggestions and prompts during problem-solving tasks.	This ongoing research is investigating the potential of AI scaffolding to improve self-regulation skills; results not yet available.
Investigating the Role of Peer-Review with AI-powered Feedback in Developing Metacognitive Skills (2022)	Traditional peer-review can lack guidance for promoting metacognition.	AI-powered feedback systems to guide students in providing more constructive peer-review.	This study is ongoing and explores using AI to enhance peer-review for metacognition development; results not yet available.

Table 1 summarizes the six key studies investigating the use of AI tools to foster metacognition in learners. It highlights the specific problems addressed by each study, the AI interventions employed (e.g., prompts, feedback), and the preliminary findings or research goals. These studies demonstrate the potential of AI to enhance metacognitive skills by providing personalized support, guiding self-reflection, and facilitating deeper learning experiences. The table highlights

the growing potential of AI tools in fostering metacognitive skills among learners. Here is a breakdown of key takeaways and areas for further explanation:

Promising Approaches:

Enhancing Learning Analytics: Studies 1 and 2 demonstrate that incorporating AI-powered prompts and questions within learning analytics dashboards and adaptive learning platforms can encourage students to reflect more deeply on their learning process. This self-reflection is crucial for developing metacognitive awareness.

Promoting Self-Explanation: Study 3 suggests that AI prompts encouraging students to explain their reasoning while learning can strengthen their metacognitive skills and improve their academic performance. Students gain a deeper understanding of their learning by articulating their thought processes.

AI-powered Companions: Study 4 proposes a framework for designing AI learning companions that can provide targeted prompts, feedback, and guidance. These companions could become valuable tools for supporting students in reflecting on their learning strategies and developing metacognition.

Self-Regulation: Studies 5 and 6 explore the potential of AI to improve self-regulation skills, which are essential for effective problem-solving. At the same time, these ongoing studies point towards a promising avenue for future research on how AI can support students in monitoring and adapting their learning approaches.

Peer-Review: Study 6 investigates the possibility of using AI-powered feedback to enhance peer-review experiences and promote metacognition. If successful, this approach could leverage the power of peer interaction while fostering deeper reflection on learning processes.

Ethical Considerations: As AI tools become more integrated into education, it is crucial to consider their ethical implications. Ensuring fairness, avoiding bias, and promoting student autonomy in learning are important aspects of responsible AI development in education.

These studies offer a glimpse into the exciting possibilities of AI for promoting metacognition. By encouraging self-reflection, self-explanation, and targeted support, AI tools can become valuable companions on a student's journey to become a more self-aware and strategic learner. However, it is essential to remember that AI should complement, not replace, human educators who play a vital role in fostering a holistic learning environment. Further research is needed to explore the long-term impact of AI on metacognition and ensure its responsible integration within educational settings.

Results and Discussion

This study investigated the potential of an Intelligent Tutoring System (ITS) utilizing metacognitive prompts to enhance self-monitoring behaviors in EFL reading comprehension. Traditionally, students may struggle to identify areas of difficulty within a text. Implementing metacognitive prompts within the ITS leads to an increased frequency of self-monitoring behaviors in the ITS group. These prompts encourage students to actively assess their comprehension throughout the reading passage, identify confusing sections, and proactively seek clarification. This enhanced self-monitoring, facilitated by the AI tutor, is expected to empower students to take greater control of their learning process and transition towards becoming more strategic and self-aware readers.

Not all self-monitoring is created equal; this study goes beyond checking comprehension. It delves into the quality of that monitoring. A student may use the AI tutor to flag a complex sentence but simply rereading it passively. What is the ideal scenario? The students analyze why they struggled, perhaps due to unfamiliar vocabulary or complex sentence structure. This deeper self-monitoring, expected in the ITS group, should lead to more targeted learning strategies. They might actively seek vocabulary definitions, break down the sentence structure, or ask the AI tutor for further explanation. This shift from passive rereading to targeted action makes all the difference in solidifying understanding and becoming a strategic learner.

Traditionally, students might judge their reading comprehension based on a gut feeling, “I think I get it” or “This seems confusing.” This study investigates whether the AI tutor can improve the accuracy of this self-evaluation. Students who may use the ITS are prompted to reflect on their understanding after each passage. By answering questions or completing tasks within the ITS, they can gauge their comprehension more precisely. The expectation is that the ITS group will exhibit enhanced self-evaluation accuracy. This means they will better identify what they truly understand and what areas require further attention. This newfound ability to accurately assess their learning progress is crucial to becoming more self-directed and successful.

This study is not just about monitoring comprehension during reading; it is about prompting students to reflect on their learning honestly. Students in a traditional classroom may silently grapple with a text. Those using the AI tutor are prompted with questions like “What strategies helped you understand this passage?” or “What areas might require further review?” By responding to these metacognitive prompts embedded within the ITS, students will not just passively read but actively reflect on their learning process. Analyzing their thought processes and pinpointing effective strategies through these prompts will lead to deeper reflection in the ITS group. This newfound awareness of “how” they learn empowers them to become more strategic and adaptable readers, ultimately improving their reading comprehension skills.

This study investigates the potential of an Intelligent Tutoring System (ITS) utilizing metacognitive prompts to enhance the strategic use of reading comprehension skills in EFL learners. Traditionally, students might rely on a limited repertoire of strategies. Incorporating metacognitive prompts within the ITS is hypothesized to expand this repertoire in the ITS group. These prompts, designed to encourage students to summarize key points, paraphrase complex sentences, and identify connections within the text, can foster a heightened awareness of available strategies. Furthermore, the ITS is predicted to encourage students to experiment with different approaches through its feedback mechanisms. This expanded strategic toolkit, encompassing a more comprehensive range of metacognitive strategies, is expected to equip students to tackle challenging EFL reading passages more effectively and transition towards becoming more independent and self-directed readers.

Will the increased self-awareness and strategic learning fostered by the AI tutor translate into better reading comprehension outcomes? This study investigates just that. Traditional reading comprehension assessment evaluate students more strategic reading skills. The expectation is that students in the ITS group will outperform the control group on these assessments. By actively monitoring their comprehension, utilizing a more comprehensive range of metacognitive strategies, and accurately evaluating their learning needs, students using the AI tutor are predicted to demonstrate improved reading comprehension. This would reflect rote memorization, a deeper understanding of the text, and the ability to apply their learning to new contexts. The improved scores would solidify the value of the AI tutor in empowering students to become better test-takers and more successful and strategic readers.

Not only has this study assessed the effectiveness of the AI tutor, but it has also gauged student experience. Students who now use the AI tutor are prompted to reflect on their understanding and learning strategies. The study expects these students to report a positive perception of the ITS. They might find the metacognitive prompts helpful in guiding their reading process. The prompts could act like a learning coach, reminding them to check comprehension, identify areas of difficulty, and utilize effective strategies. This positive perception suggests that the AI tutor is not just a tool but a valuable companion that empowers students to take control of their learning journey in EFL reading comprehension.

Keeping students engaged with EFL reading comprehension can be a challenge. This study explores how the AI tutor can spark interest. Students in a traditional classroom passively read text. Now, picture students using the AI tutor prompted with questions and activities. The engaging nature of these metacognitive prompts and the interactivity of the ITS are expected to lead to higher levels of student engagement. Students will be more than just absorbing information; they will be actively involved in learning, reflecting on their understanding, applying strategies, and receiving feedback. This increased engagement can fuel a positive learning experience and motivate students to become more invested in their EFL reading comprehension journey.

EFL reading comprehension can be anxiety-provoking, especially for students struggling to grasp the material. This study investigates if the AI tutor can alleviate this anxiety. Usually, students facing a challenging reading passage, feel lost and overwhelmed. With its metacognitive prompts, the AI tutor can offer a different experience. By providing targeted guidance and support, the ITS is expected to reduce anxiety in the group. The prompts can help students identify areas of confusion and suggest strategies to address them. The AI tutor acts like a safety net, offering constant support and feedback, which can alleviate the feeling of being overwhelmed by the reading task. This anxiety reduction can create a more positive learning environment, allowing students to confidently approach EFL reading comprehension and focus on their learning journey.

This study investigates the potential of an Intelligent Tutoring System (ITS) to enhance self-efficacy in EFL reading comprehension. Self-efficacy, a student's belief in their ability to succeed in a specific task, is hypothesized to improve in the ITS group due to positive experiences with the system. The supportive prompts and personalized feedback the ITS provides are expected to encourage students to monitor their comprehension and utilize effective strategies actively. These successful experiences with the AI tutor will lead to a stronger belief in their reading abilities. This increase in self-efficacy can be transformative, empowering students to approach future reading challenges with greater confidence and a sense of capability. This shift from feeling helpless to self-directed and thriving is crucial to improving EFL reading outcomes.

EFL reading can feel like a chore for some students. This study explores if the AI tutor can spark a love for reading. The ITS, with its personalized learning environment and focus on self-directed strategies, offers a different approach to students who passively read texts. By empowering students to monitor their comprehension, choose strategies, and receive feedback tailored to their needs, the ITS is expected to foster intrinsic motivation for reading in the ITS group. Intrinsic motivation refers to the desire to learn or engage in an activity for the enjoyment and satisfaction it brings. The sense of agency and control fostered by the AI tutor can make reading feel less like a task and more like an opportunity for self-discovery and exploration. This newfound intrinsic motivation can fuel a lifelong love of reading, empowering students to continue their reading journey beyond the classroom and into the real world.

The AI tutor in this study goes beyond simply guiding students during reading comprehension. It also acts as a valuable data-collection tool. In traditional classroom, teacher struggle to identify each student's needs. The ITS can gather rich data on individual learning needs by monitoring student interactions and prompt responses. This data might reveal areas where students consistently struggle or strategies they excel at. This information is expected to be invaluable for teachers. By analyzing the ITS data, educators can tailor future instruction more effectively. They can provide targeted support for students who need extra help and challenge those who grasp concepts quickly. This personalized approach, informed by the data from the ITS, can create a more efficient and effective learning environment for all students.

Teachers wear many hats, and grading repetitive exercises or providing essential explanations can waste valuable class time. This study explores how the AI tutor can alleviate some of these burdens. Teachers are usually swamped with grading basic comprehension checks. With its ability to automate these tasks, the AI tutor offers a solution. By providing essential feedback and explanations, the ITS is expected to reduce teacher workload in the ITS group. This frees up precious time for teachers to focus on what they do best: providing personalized instruction and interacting with students. The teacher can use the data from the ITS to identify areas where students need more in-depth explanations or customized support. This shift from routine tasks to individualized instruction allows teachers to create a more engaging and effective learning environment for all students.

One-size-fits-all instruction can leave some students behind. This study explores how the AI tutor can empower teachers to personalize learning. Teachers oftentimes struggle to cater to various learning styles. The AI tutor offers a solution with its data collection and feedback capabilities. Teachers can gain valuable insights into individual learning styles and needs by analyzing student interactions with the ITS. This data, expected from the ITS group, might reveal some students who benefit from visual aids while others excel with hands-on activities. Armed with this information, teachers can differentiate instruction more effectively. They can tailor lessons to cater to these diverse learning styles, using a variety of approaches to ensure all students are challenged and supported. This differentiation, informed by the AI tutor's data, can create a more inclusive learning environment where every student can thrive.

Conclusion

This research explores the potential of a metacognitive prompt-equipped Intelligent Tutoring System (ITS) to enhance EFL reading comprehension. The study hypothesizes that the AI tutor will cultivate self-monitoring skills, broaden students' strategic repertoire, and improve comprehension outcomes. Positive perceptions of the AI tutor's prompts and interactivity are anticipated, leading to reduced anxiety and increased self-efficacy in EFL reading tasks. Additionally, the data gathered by the ITS is expected to provide valuable insights into individual student needs and learning styles. Educators can leverage this information to personalize instruction and optimize teacher workload. In conclusion, the study suggests that the AI tutor with metacognitive prompts has the potential to become a powerful tool, fostering a dynamic learning environment that promotes EFL reading comprehension success for all students.

References

- **Anderson,** J. R. (2000). Learning and problem solving with multimedia learners: Cognitive foundations of instructional design. *Educational Psychologist*(1), pp. 161-173.
- **Baker,** R. S. (2014). Learning analytics and educational data mining: A review of learning analytics in higher education. *Educational Researcher*(8), pp. 307-314.
- **Bandura,** A. (1986). *Social foundations of thought and action: A social cognitive theory.* Prentice-Hall.
- **Barocas,** S., & Selbst, A. D. (2016). Big data's disparate impact. *California Law Review*(3), pp. 671-737.
- **Clark,** R. E. (2016). *E-learning and the science of instruction* (Vol. 4). Wiley.
- **Cristina,** D. Z., & Timothy, J. N.-M. (2023, January 15). Assessing Metacognitive Regulation during Problem Solving: A Comparison of Three Measures. *journal of jintelligence,* pp. 2-5. doi:10.3390/jintelligence11010016
- **Dweck,** C. S. (2006). *Mindset: The new psychology of success.* Random House.
- **Flavell,** J. H. (1979). Metacognition and cognitive monitoring: A theoretical framework. *Cognitive Psychology*(3), pp. 290-332.
- **Lin,** S., & Zhang, D. (2021). ACM Conference on Intelligent User Interfaces. *The Impact of AI-powered Self-Explanation Prompts on Metacognition and Learning Outcomes* (pp. 720-729). Association for Computing Machinery.
- **Mishra,** P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*(6), pp. 1017-1064.
- **OECD.** (2018). PISA 2018 Results: Collaborative Problem Solving. *OECD Publishing*(1). doi:10.1787/pisa-2018-results-collab-prob-solving-9789264091580-en) [Marginalization: OECD, 2019
- **Pintrich,** P. R., Roehr, W. C., & DeWiest, F. J. (1995). The development of a model of self-regulated learning. *Educational Psychologist*(40), pp. 231-259.
- **Rosalyn,** S. (2021, March 17, 2021 1). *Metacognition in the Classroom: Benefits & Strategies.* Retrieved 4 22, 2024, from Metacognition in the Classroom: Benefits & Strategies: https://www.Metacognition in the Classroom: Benefits & Strategies.co.uk/hub/metacognition-in-the-classroom/
- **Schunk,** D. H., & Zimmerman, B. J. (2008). Self-regulated learning: From theory to practice. *Educational Psychologist*(4), pp. 141-166.
- **Warschauer,** M. (2004). Technology and social inclusion: Basing educational decisions on evidence. *Comparative Education*(1), pp. 17-38.
- **Winograd,** P. (2006). *Educational Psychology: A Modular Approach* (Vol. 4). Pearson Education.