AI as a Cognitive Partner: A Systematic Review of the Influence of AI on Metacognition and Self-Reflection in Critical Thinking

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Abstract: Educational settings today include Artificial Intelligence (AI) systems that transform student interaction with critical thinking and metacognitive processes. The research assesses AI's positive and negative effects on developing cognitive abilities through systematic analysis and review. Contemporary learning tools backed by artificial intelligence provide individualised feedback, automated tutoring, and adaptive testing that enhances students' problem-solving skills and cognitive awareness. Concerns regarding cognitive offloading, metacognitive sloth, and algorithmic bias challenge the possible impact of AI on independent thinking and learning autonomy. This study synthesises existing research to investigate how AI works as a cognitive partner that supports critical thinking ability and a potential barrier to long-term cognitive engagement in learning environments. Evidence shows that AI supports learning assistance and self-regulation development, but overdependence on it results in lower problem-solving skills and decreased metacognitive thinking. Data privacy issues, access fairness concerns, and AI decision-making biases make it necessary for educational institutions to control their incorporation of AI technologies carefully.

The review highlights necessary teaching practices for the ethical use of AI and advocates for equitable AI-human collaboration to produce compelling learning experiences. The report recommends that educators and policymakers implement measures to ensure that AI applications augment critical thinking capabilities rather than replace them. Long-term studies must assess the impact of AI on students' cognitive resilience and how they learn adaptive learning strategies. This review aims to construct AI-fortified educational designs by leveraging AI's potential and risks to enhance students' inquiry skills, self-reflection, and critical thinking capabilities.

Keywords: Artificial Intelligence, Critical Thinking, Metacognition, Self-Reflection, Cognitive Offloading, AI in Education, Systematic Literature Review.

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I. INTRODUCTION

Skill sets like capitalising or embedding critical thinking, self-reflection, and metacognition are abilities that students need in today's fast-paced, information-laden world. New ideas come from critical thinking, and students can analyse information to get there. Metacognition is higher-order thinking, where students know and regulate their thinking; self-reflection allows students to consider what they have learned [1]. These skills are essential for academic achievements and lifelong learning.

AI in education helps personalised learning experiences by providing instant feedback and improving efficiency in routine tasks [2]. AI tools like tutoring systems and adaptive tests make learning more personal and enhance the educational experience. However, it's essential not to depend too much on AI. Students who rely heavily on these tools may struggle to think independently and develop skills like metacognition, which is the ability to reflect on one's thinking. They might also experience cognitive offloading, where they stop engaging in critical thinking about a subject [3]. Additionally, we must address ethical issues like algorithm bias and ensure everyone can access these tools to create effective learning environments.

This literature review will show how AI affects the development of critical thinking, self-reflection, and metacognition. It will explore the advantages and challenges of using AI in teaching and offer suggestions for teachers and policymakers on using AI to enhance, rather than hinder, cognitive skills.

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A. Problem Statement

Educational stakeholders are concerned about the impact of AI on students' critical and analytical skills. While it is known that AI can be harnessed to facilitate personalised learning, there is serious concern as to how widespread dependency will impact or hamper their critical thinking skills [4]. Since AI can provide solutions quickly, students may not engage as much in actively solving things or thinking hard about what they learn [5].

There are several serious issues with the application of AI in education, specifically cognitive offloading. Students could rely excessively on AI to perform critical thinking tasks, such as interpreting information or defining complex problems. Such reliance can reduce their cognitive effort and negatively affect their skill acquisition [6]. Another issue is metacognitive laziness [7]. When students are provided with automated feedback and directions from AI systems, it could make it more difficult to comprehend their learning and study approaches. Consequently, their metacognitive knowledge and self-regulation will be affected [8]. Moreover, algorithmic fairness and bias remain key issues because AI algorithms are developed using data that could be biased, thus producing biased outcomes for specific student groups.

There is a need to address prejudices so all students receive quality education [9]. Businesses now prioritise ethical matters such as data privacy and properly acknowledging authors. We must also address the potential abuse of AI-created content to ensure academic integrity [10] [11].

Understanding how AI tools impact critical thinking, metacognition, and self-reflection is limited. This review aims to address that gap. It will gather existing research, examine how AI affects these skills, and offer recommendations for educators and policymakers. By specifying risks and benefits, this review seeks to inform the creation of strategies that leverage AI's potential while fostering critical cognitive skills in students.

B. Research Questions

This systematic review seeks to explain the various influences of AI on critical thinking, metacognition, and selfreflection based on the following research questions. The rationale and context behind each question are provided below:

How does Combining AI Tools Influence Students' Critical Thinking Abilities Within Learning Environments?

Critical thinking is necessary to analyse, compare, and integrate information [12]. There are more education applications of AI tools, e.g., tutoring systems based on AI and writing assistants. It is vital to comprehend how these technologies affect students' critical thinking capabilities to maximise their learning applications. This question addresses the issue of whether excessive usage of AI reduces students' participation in active problem-solving and profound cognitive processing. How do Students' Metacognitive Awareness and Self-Regulation Change with AI-Powered Personalised Learning Environments?

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Metacognition is consciousness and control of one's thought processes [13]. AI personalised learning (PL) tailors learning experiences through AI technologies. It is warranted to investigate whether such environments improve or distract students from their capabilities to track their knowledge, modify their learning strategies, and cultivate self-regulatory capacities. The threat of "metacognitive laziness" requires an intensive exploration of the impact of AI on these pivotal thought processes.

What are the Moral Implications and Issues of AI in Education, Specifically Regarding Algorithmic Bias, Data Privacy, and Equal Access?

Ethical concerns are a top priority in applying AI in education [14] [15]. Algorithmic prejudice may cause uneven results for particular student groups. Meanwhile, data privacy and manipulating AI-generated content are issues regarding academic integrity [16]. Resolving these ethical issues ensures that AI bolsters inclusive and efficient learning settings.

How can Teachers use AI Tools to Encourage Critical Thinking, Self-Reflection, and Awareness of their Thinking?

Educators need to identify the most effective strategies that have the potential to deliver maximum benefit to the learner without the associated risks of AI [17]. This question explores pedagogical approaches that support the development of essential cognitive skills alongside AI tools. Educators can create learning environments that foster technological competence and intellectual independence by understanding how to balance AI assistance with active mental engagement.

These research questions aim to comprehensively understand the complex relationship between AI and cognitive development in educational settings. By synthesising existing research and addressing these key questions, this systematic review seeks to inform evidencebased recommendations for educators, policymakers, and AI developers [18].

C. Objectives

This systematic review synthesises recent studies on the impact of AI on critical thinking, metacognition, and self-reflection in learning. The objectives are:

- Assess AI's Effects on Critical Thinking: Determine how AI technologies impact students' capacities to examine information and make educated decisions, as well as AI's potential strengths and weaknesses in critical thinking.
- **Investigate Influence on Metacognitive Awareness:** Determine the best learning settings for promoting metacognitive self-regulation, measuring if they assist learners in monitoring their knowledge and modifying learning strategies.

- **Identify Ethical Issues**: Examine the ethical dilemmas of AI implementation in education, such as algorithmic prejudice, data privacy, and equal access to learning.
- **Best Practices for Teaching**: Specify how teachers may best utilise AI to encourage critical thinking and self-knowledge by establishing a balanced process between AI implementation and active learning.
- **Synopsis of Current Research**: Review available research on AI and cognitive ability to determine patterns, lacunae, and contradictions for further study.
- **Policymaker and Educator Support**: Recommend maximising AI in schools and maximising its advantages while minimising risks to students' thinking capacities.

II. LITERATURE REVIEW

The literature review integrates language, literacy, and writing research from a cognitive viewpoint. It discusses selfefficacy, with particular emphasis on studies with elementary-grade students. It also defines learning disabilities (LDs) and related disorders, explains what writing is like for struggling learners, and provides an overview of writing accommodations.

A. Language, Literacy, and Writing

Zua describes how literacy is key to individual development and active social engagement [19]. Functional writing abilities can assist learners in academic success and life achievement. Frequent writing assists in translating ideas into words and is spoken through handwriting, typing, or speech-to-text. Reading and writing are essential for academic and life achievement, as stated in the OHRC (2022) Right to Read Inquiry Report [1].

Writing entails producing, structuring, and editing ideas for different audiences and publishing [20]. It involves sociocultural and cognitive aspects such as self-regulation, motivation, transcription, and working memory. Major models of writing are control - goal setting, motivation, planning [21], processes such as translating thoughts, suggesting, and assessing [22], the task context such as collaborators, task materials, technology [23], and other resources such as working memory and attention [24].

B. AI's Impact on Cognitive Development in Education

Roman and Acosta's results indicate that AI can primarily enhance texts' cohesion, accuracy, and clarity as a support tool [25]. The success of these improvements relies on the situation they are used in and how humans engage with them.

In his study, Zhang selected ChatGPT to examine how teachers could use writing class lessons to engage students in their learning [26]. His research examined the role of AI tools in empowering students to feel more in charge and assisting English language students with more than one language in writing class. His research introduced learner agency and power shifts in teaching English Language Learning. The study also inquired how students responded to using AI in their writings. Zhang's findings revealed that students expressed a positive attitude and were open to further experimenting with the tool for faster generating ideas and creative writing around those ideas. Nonetheless, excessive use of AI threatens self-regulation and critical thinking.

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Specific challenges prevent the broader adoption of AI. Issues of biased algorithms and threats to privacy are drawing user attention and require an urgent address. Ghai and Mueller examined biases in algorithms and found they impacted the outcomes, which reflected the direct or implied biases [27]. Bansal and Zahedi concluded that privacy and trust were significant concerns with AI users, and resolving these concerns was key to expanding AI's ethical use [28].

C. Metacognition and Self-Regulated Learning (SRL)

Zhao and Ye presented metacognition and selfregulated learning in their framework analysis as key success factors for learners [29]. They assist learners in developing an awareness of their thought processes and their ability to deal with their knowledge. SRL can also be considered a threestep cyclical process for positive outcomes. The first step is to define the objectives based on motivational beliefs and then build a clear execution plan. The next step involves implementing controlled actions and monitoring outcomes. The final step is self-reflection and mistake assessment to explore ways of improvement.

The Junior Metacognitive Awareness Inventory-B (Jr. MAI-B) helps students understand their thinking and learning. Students get 15 questions to answer by scoring 1 to 5 for each. The total score ranges between 15 and 75 [30]. Lack of triggers for ideas and holding concentration for extended periods are primary reasons preventing students' critical thinking development. Teaching faculty must encourage students to discuss and debate ideas and approaches to free writing and show how self-regulated evaluation will help them improve their creative writing skills.

D. The Role of Feedback and Collaboration in AI-Enhanced Learning

Both engagement and feedback are crucial for effective learning with AI, offering various advantages and drawbacks.

AI feedback tools give instant feedback on grammar, style, and content errors. While this is helpful, it does not provide adequate explanation, logic, or context to the student on how they can prevent future mistakes [31]. Collaborative writing with AI offers useful features like chat, comments, and edits in tools like InkSync. However, Cress and Kimmerle have highlighted issues regarding parallel writing, which also raise questions on attribution to the source and author of the original content [32].

Computerised physician order entry (CPOE) systems and similar static analysis tools help spot and prevent mistakes by providing real-time warnings. They constantly check information while applying auditing checks in various situations. For example, hospitals successfully deploy CPOE for error detection and medication errors [33]. On the positive side, Triberti et al. discovered that gamification in customised Volume 10, Issue 3, March – 2025

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learning content increased learner engagement and enhanced curiosity to explore content further [34].

III. METHODOLOGY

This systematic review adheres to the guidelines laid out in the PRISMA Statement [35]. The review process and results are meant to be reported by systematic reviewers. The method comprises steps to ensure the review is complete and trustworthy.

A. Data Collection and Analysis

- Data Collection: The relevant records were found in several databases, such as Google Scholar, MEDLINE, Web of Science, PsycINFO, and Scopus.
- Screening: All records were screened for eligibility after editing the duplicate content and implementing the appropriate language restrictions.
- Qualitative Data Analysis: Adhered to traditional content analysis processes, such as discourse-based corpus development, inductive category determination, coding, and indicator determination and maintained validity criteria (stability, reproducibility, accuracy) using source triangulation, utilising data from self-report measures and survey items. The coding process was replicated and systematised to ensure transparency, structure, and a systematic approach.
- Quantitative Protocols: Two coders worked on the coding scheme following Alhashim et al. and had intercoder reliability sessions on 20% of the sample [36].

B. Criteria for Inclusion and Exclusion

Clarity on inclusion and exclusion parameters is necessary for selecting relevant studies in our review, focusing on high-quality research relevant to our questions. The inclusion criteria specify that we consider only empirical studies based on observations published in trusted journals. We seek studies demonstrating how AI fosters critical thinking through personalised learning and assessments from K-12 to undergraduate levels and AI's role in teaching writing, speaking, and reading.

We exclude non-empirical studies, theoretical discussions, and non-peer-reviewed reports. Studies not in English or lacking detailed methodology are also disregarded. It ensures our findings are robust and evidence-based, relevant to AI in education and language learning.

C. Data Extraction and Synthesis

It describes the procedures for extracting and synthesising data from the chosen studies. It is necessary to determine current research's most important trends, patterns, and contradictions.

➢ Data Extraction

A review synthesises 60 to 90-minute studies to identify significant themes and coding characteristics according to their applicability to research questions, primarily effectiveness and limitations. Data collection is conducted online before and after interventions, utilising methodologies https://doi.org/10.38124/ijisrt/25mar1427

> Data Synthesis

This review uses thematic analysis to examine qualitative data on AI in education by familiarising and identifying themes. Categories such as AI helping to improve speaking skills and AI's limitations come from the codes. Our study seeks patterns to clarify findings and show trends in personalised learning. The systematic analysis overviews ongoing research, strengths, and weaknesses.

IV. DESCRIPTION OF STUDIES INCLUDED

Our exhaustive review process examined various AI tools and the methodologies adopted in education. The study analysed 85 relevant cases and examined 18 peer-reviewed articles published between 2009 and 2024. The reviews mainly looked at randomised controlled trials and long-term studies. The participants included 31 primary school teachers, including participants from K-12 schools, higher education, and vocational training programs.

A. Key Insights

We examined how AI affects students' thinking and self-reflection and discovered that AI is an effective tool when used in moderation for triggering ideas that promote critical thinking among students. However, we also concluded that excessive dependence on AI can lead to false confidence among students due to the fast output generation. Slow-learning students were more dependent on AI and consequently did not improve their critical thinking and selfevaluation skills. Therefore, including checks and balances within the AI frameworks used in the learning process is imperative.

AI has other benefits, especially in language learning, where students are stimulated to engage in verbal, text, and video formats. Similarly, science students discovered AI to stimulate curiosity and improve engagement. Instant feedback helps students think and evaluate their responses, allowing them to progress to the next level of learning.

B. Advantages and drawbacks of using AI to enhance Critical Thinking

> Benefits

AI minimises research, analysis time, costs, and the resultant stress. AI hastens literature review for improved critical assessment and reviews big data sets to test existing theories. AI also facilitates experimental design through the prediction of results and assists in complicated statistical analysis, which enables researchers to focus on interpreting data.

➤ Limitations

AI systems form echo chambers that restrict various opinions and tend to be impersonal, making academic research challenging. AI is limited because it cannot read and comprehend human emotions and feelings. Its overuse, Volume 10, Issue 3, March – 2025

therefore, hinders students from gaining crucial critical thinking skills. Stakeholders should realise that AI algorithms can fail to reflect personal preferences when choosing scholarly papers, hindering crucial analysis.

AI can enhance thinking and learning abilities such as self-reflection and critical thinking. However, we should consider its limitations and disadvantages by incorporating them cautiously and employing reflective teaching practices.

V. DISCUSSION

A. AI as a Cognitive Partner

We will discuss AI's potential to augment human intellect support learning and explore the balance between AI assistance and the development of independent thinking.

The Potential of AI to Enhance Human Cognition and Facilitate Learning:

AI improves learning skills by facilitating critical thinking using Natural Language Processing (NLP) tools for literature reviews [37] [38]. AI personalises education by interacting with learners, providing immediate feedback, and facilitating customised learning experiences to improve performance. AI facilitates self-reflection among learners in online settings and provides the tools necessary for goal setting and monitoring. Researchers can effectively use intelligent virtual assistants (IVAs) to analyse extensive data for main findings.

The Balance Between AI Support and the Creation of Independent Thought:

A balanced approach is necessary for critical thinking because depending too much on AI can cause passive learning rather than active thinking. AI has its limits, such as problems with personalisation and a limited understanding, so human assistance is essential. Discussions between teachers and students foster empathy and emotional intelligence, qualities AI cannot imitate. Students should weigh the pros and cons of using AI and learn to think about their ideas. To compete in the job market, they must improve their language skills to engage with AI and analyse critically effectively.

> Metacognitive Implications

This analysis explores the effect of AI on students' learning and self-regulation of thinking. AI may facilitate deeper understanding, yet overdependence on it can trigger complacency and compromise self-regulation. Learners may be unable to metabolise mistakes and monitor their exchanges, overestimating the value of AI. Furthermore, regardless of the facilitative character of AI tools, failure to reflect may hinder the evaluation of their usefulness. AI can block SRL even for benefits such as personalised revision. Students must be guided to cooperate with AI to develop their metacognitive capacities responsibly.

Drawbacks of Overestimation and Requirements for Good Self-Assessment

AI can make students overestimate their performance due to biases in judging their abilities. It can be prevented by

carefully observing their interaction with AI. Users tend to feel too confident without verifying the reliability of AI. User confidence must coincide with AI uncertainty, which can be enhanced by graphically illustrating the uncertainty.

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Considering how students apply AI can assist them in making improved choices. Being conscious of their thinking can help in lessening confusion and enhance comprehension. Users need to learn how to use AI for maximum benefit. Hence, practising safe and efficient AI application methods is essential to prevent the associated risks.

B. Pedagogical Approaches

Education through AI should integrate the human touch with traditional learning. Educators need to induce empathy and AI ethics. Curricular integration of AI tools and education for teachers about AI instils critical thinking. Students, too, require AI literacy to learn through technology and for skills related to tasks such as prompt engineering.

Prompt Engineering and AI-Supported Editing to Instill Critical Thinking and Metacognition

Prompt Engineering applies AI to produce assignments facilitating students' metacognitive capabilities [39]. This practice will investigate pedagogical techniques for educational schemes, emphasising metacognition as a transferable skill students may learn from education.

> AI-enabled Editing

Editing with AI helps students improve their understanding by providing context and clarity. However, students must constantly verify that generated content is grammatically correct and aligns with the topic.

➢ Metacognitive Value

AI enables learners to improve reasoning and decisionmaking, allowing them to reflect on their cognitive strategies and enhance their analytical abilities. Therefore, teachers must blend AI tools with conventional approaches to maximise creativity and critical thinking.

C. Ethical Concerns about Using AI for Learning

Student data gathered by AI systems should be protected to avoid misuse and unauthorised access. AI systems that perpetuate existing biases based on demographics or learning styles should be shunned, as this can result in discriminatory treatment of specific students. Educators and students can better comprehend decision-making by explaining how AI systems operate. AI tests must be constructed to assess all students equally without jeopardising certain groups. Lastly, content developers and teaching institutions must take responsibility for the negative consequences of their AI systems.

VI. SUMMARY OF FINDINGS

We shall recap the main findings regarding AI's influence on critical thinking, metacognition, and self-reflection and optimise outcomes while limiting abuse.

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A. AI's Influence on Critical Thinking

Our study examines AI's impact on critical thinking, metacognition, and self-reflection in education, balancing its pros and cons through Natural Language Processing literature reviews. We focused on previous studies that analysed parameters that prompted learners to ask questions and think critically about the impact of their responses. The research identified the benefits of customised learning and how they delivered superior learning experiences through selfevaluation and analysis. Understanding AI's role and evaluating its outputs are crucial, as well as focusing on questioning established traditions and assessing evidence.

B. AI's Impact on Metacognition:

With the proper prompts, AI can help students think and evaluate approach options before commencing the actual writing. Metacognition helps learners prepare for subsequent actions or responses by comparing thought processes with AI's. Through self-reflection, learners identify challenges using AI tools and the best solutions. However, we found that generative AI tools like ChatGPT make slow learners too dependent on technology. As a result, they miss opportunities to develop critical thinking skills, which makes it harder for teachers to assess their progress. In the long term, it hinders their ability to make decisions when faced with complex options.

C. AI Catalyses Self-Reflection:

Traditional learning methods don't allow for much personalisation and can make it hard for students to engage, which limits their ability to reflect on their learning. Our study found clear benefits of adopting Large Language Models in teaching and learning. The higher levels of content engagement, which require student responses at every level, helped them develop evaluation skills by themselves. Studies demonstrated clear advantages through better academic performance on tests.

D. Striking Harmony: A Holistic Perspective

Any new technology requires a learning curve of user experience, and the adoption of AI in education is no different. Our studies identified both benefits and challenges in its adoption. They concluded that a balanced approach to technology with supervision was the way forward for positive student and teacher experiences.

VII. RECOMMENDATIONS

We recommend AI literacy programs to empower students with the required skills to critically analyse AI outputs and foster the creation of AI tools that facilitate inquiry, debate, and critical analysis.

A. The Required Approach to AI Literacy Programs:

- Preparing Students: Encourage AI literacy programs to equip students with the knowledge to understand concepts in AI and critically analyse outputs.
- Socio-technical Knowledge: Users need to accept AI as a path to gaining social and technical knowledge with greater clarity on ethics.

- Metacognitive Reflection: Through demonstration, students must be shown the benefits of self-evaluation with the help of AI.
- Critical Thinking and Creativity: Developing critical thinking and creativity must become the prime target in every curriculum.
- Discerning Users: Developing students to interact reflectively and thoughtfully with AI technology prepares them to become discerning users who recognise the benefits and pitfalls of these resources.
- Ethical Considerations: Students must know AI concepts to appreciate AI's strengths and limitations so they will not rely too much on the technology.
- Curriculum Integration: The results present an opportunity to construct curricula using AI to help teachers craft differentiated instruction and facilitate students' self-regulated learning (SRL) ability.
- Development of Skills: Students must learn language skills to communicate effectively with AI and know what AI produces. It will make them compete effectively in future employment.
- Metacognitive Skills: Having metacognitive skills in every subject is necessary because it enables students to build the assessment skills they require to succeed.

B. Development of AI Tools:

- Inquiry, Debate, and Evaluation: Further development of interactive AI tools is needed to promote questioning, discussion, and critical thinking.
- Design and Implementation: AI tools are crucial as they should be developed to reduce rote learning and encourage better understanding, inquiry, debate, and critical evaluation.
- Wholistic Skillset: Incorporating idea evaluation into teaching gives students a holistic skill set for innovative problem-solving so they can function as effective curators of ideas.
- Critical Analysis: Through direct engagement of students in the editing of AI-provided content, this methodology ensures greater insight into the topic, improved editing skills, and critical thinking.
- Equitable and Inclusive: With AI increasingly integrated into education, testing and analysing techniques to minimise bias in AI systems can ensure these systems are more inclusive.
- Ethical Design: Researchers must design algorithms for AI systems that are explainable, understandable, and nondiscriminatory to provide all learners with equal and equitable learning opportunities.
- Human-Centred Design: EdTech stakeholders should work with teachers to design tools that are compliant with the Human-Centered Learning and Teaching Framework (HCLTF), ensuring that technology enhances educational outcomes without eclipsing the human aspects of teaching and learning.
- Cognitive Skills: Cognitive skills and values of inquiry are required to gauge the quality of critical thinking in a manner not readily replicable by AI.

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• Balanced Integration: Artificial Intelligence tools must be integrated carefully with curriculum goals so that the technology supports and does not substitute human interaction and critical thinking.

VIII. LIMITATIONS OF THE REVIEW

Acknowledging the limitations of a review is vital for providing context on the scope and generalizability of its findings. Identified limitations could stem from publication, reporting, and language biases.

The first can cause students to believe AI performs better than when the positive work is released. Reporting bias occurs when scientists present only favourable outcomes. Language bias is possible if scientists work primarily with English data. Specific databases and keywords may restrict the selected studies, and small sample populations will make it difficult to extrapolate findings. Problems in research can affect how trustworthy the results are. Focusing too much on people and the internet may overlook how correct language models are. Unique AI systems can be tested but often cannot be repeated precisely.

IX. FUTURE DIRECTIONS FOR RESEARCH

Future research should include longitudinal studies on effective teaching methods to assess how short-term performance impacts lasting knowledge and skill development. These studies could uncover shifts in learners' metacognitive awareness and teaching approaches as their understanding of AI improves. Exploring diverse groups of teachers across subjects will enhance findings. It is vital to investigate the link between students' creative confidence and their engagement with AI. Additionally, examining how initial AI findings apply across educational settings and ages is essential.

> Additional Research:

In the future, scholars should incorporate multiple tasks to deepen the understanding of how ChatGPT influences learners' motivation, self-regulated learning processes, and performance across various activities. Additionally, research can utilise virtual agents in more extensive classroom settings to monitor the longitudinal dynamics among learners' perceptions, learning gains, and metacognition. Ongoing analysis of syllabi within STEM disciplines is essential, and there should be a focus on developing and integrating targeted measurement protocols to explore the phenomenon of overreliance on Generative AI in learning environments in depth.

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