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The Role of AI in Fostering Computational Thinking and Self-Efficacy in Educational Settings: A Systematic Review

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Abstract:

Integrating artificial intelligence (AI) in education offers transformative opportunities and significant challenges. Ethical concerns, such as privacy and data misuse, and practical issues like system integration, funding, and teacher training must be addressed to harness AI's potential fully. Despite these challenges, AI promises advancements in personalised learning, intelligent tutoring, and automated assessments, which can enhance computational thinking and self-efficacy. Computational thinking and self-efficacy, crucial for effective problem-solving and confidence in a technology-driven world, are increasingly recognised as vital. This review synthesises the literature on how AI supports the development of computational thinking and self-efficacy across various educational levels. The PRISMA method addresses the following research questions: (1) What gaps exist in understanding AI's role in enhancing educational outcomes? (2) How does AI integration influence students' self-efficacy, particularly concerning computational thinking? (3) What challenges and limitations affect the effectiveness of AI-driven educational tools? The review investigates AI's role in boosting students' self-efficacy and identifies critical mechanisms through which AI supports computational thinking. Insights highlight AI's potential to transform education through personalised learning, adaptive feedback, and collaborative problem-solving. The findings provide practical implications for educators, policymakers, and researchers aiming to effectively integrate AI into educational settings to enhance computational thinking and self-efficacy, preparing students for future challenges in the digital age.

Keywords: *Artificial Intelligence, Computational Thinking, Educational Technology, Personalized Learning, Self-Efficacy*

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Introduction

Artificial Intelligence (AI) is swiftly revolutionising numerous industries (Chatterjee & Bhattacharjee, 2020; König & Wenzelburger, 2020; Ouyang et al., 2022; Reddy et al., 2018), including education (Matovu et al., 2023; Ou et al., 2024; Won et al., 2023; Zhai et al., 2021). Its integration into educational contexts offers significant potential to enrich learning experiences, improve educational outcomes, and empower students with critical skills such as problem-solving, collaboration, and digital literacy essential for the 21st century. One of the things that AI can influence significantly is improving students' computational thinking and self-efficacy.

Computational thinking, defined as solving problems by breaking them down into manageable parts, recognising patterns, abstracting general principles, and developing step-by-step algorithms using computer science concepts and methods, is increasingly a critical skill for the digital age (Wing, 2006). AI technologies, such as intelligent tutoring systems, personalised learning platforms, and data analytics tools, can facilitate the development of computational thinking by providing students with tailored learning experiences and immediate feedback (Amri et al., 2022; Budiyanto et al., 2020; Budiyanto et al., 2021; Ng et al., 2023). These technologies not only help students grasp complex concepts but also enable them to apply their knowledge to real-world problems, thereby fostering more profound understanding and retention (Holmes et al., 2019; Kirkwood & Price, 2013; Park et al., 2023; Zawacki-Richter et al., 2019).

Moreover, integrating AI in education enhances cognitive skills like computational thinking and significantly impacts students' self-efficacy. Self-efficacy, the belief in one's ability to achieve a goal or desired outcome, is essential for academic achievement and motivation (Bandura, 2006). The application of AI in education can increase a student's self-efficacy by using a unique and adaptable learning environment so that it can meet the needs of individual students (Jing et al., 2023; Moroianu et al., 2023). When students experience success in these environments, their confidence in their abilities to succeed in similar tasks increases, leading to improved academic outcomes (Das et al., 2023; Massaty et al., 2020).

The intersection of AI, computational thinking, and self-efficacy is an emerging area of interest in educational research. AI has the potential to provide personalised learning experiences, adaptive feedback, and engaging educational tools that can significantly enhance students' computational thinking skills (Huang & Qiao, 2024). At the same time, these AI-driven educational interventions can influence students' self-efficacy by giving them confidence and belief in their abilities to tackle complex problems (Chai et al., 2021).

However, incorporating AI into education comes with challenges. Addressing technical and ethical challenges is vital for effective AI implementation in education. Technical issues include system reliability and integration with existing infrastructure, which can disrupt learning. Ethically, concerns about data privacy and algorithmic bias are significant. Ensuring data protection and fairness in AI decision-making is crucial. Strong privacy measures, transparent practices, and bias mitigation strategies can help create effective and equitable educational AI systems Moreover, educators and students may need more time to adopt new technologies, necessitating comprehensive training and support to facilitate the transition (Dignum, 2021; Mhlongo et al., 2023).

This literature review explores AI's influence on computational thinking and self-efficacy in educational contexts. It begins by outlining the theoretical framework underpinning these constructs, followed by a discussion of the methodologies employed in current research. The review then examines the applications of AI in education, the relationship between computational thinking and self-efficacy, and the challenges and barriers to AI integration. Finally, it identifies research gaps and provides future research and practice recommendations. This research aims to address the following questions:

1. What are the current gaps in understanding the role of AI in enhancing educational outcomes, and how can these gaps be addressed to maximise AI's potential in education?
2. How does integrating AI in education influence students' self-efficacy, particularly in computational thinking, and what factors contribute to this impact?
3. What are the challenges and limitations of implementing AI-driven educational tools?

Research Method

This systematic literature review adheres to the guidelines established by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method (Page et al., 2021). The review process involved a comprehensive search across multiple academic databases, including SpringerLink and ScienceDirect, using keywords such as "artificial intelligence," "machine learning," "intelligent systems," "computational thinking," and "self-efficacy." Boolean operators "AND," "OR," and "NOT" were employed to refine the search results, ensuring a thorough exploration of relevant literature. The inclusion criteria focused on peer-reviewed articles, conference papers, and systematic reviews published between 2020 and 2024 in English and directly addressed the impact of AI on computational thinking and self-efficacy in educational settings. Exclusion criteria involved non-peer-reviewed sources, outdated or redundant research, and studies focusing on AI applications outside educational contexts.

Article Selection

In this literature review article, we used three different keywords as references to search for the titles and analyse the abstracts of research articles. We searched for articles in the ScienceDirect and SpringerLink databases using three predetermined keywords: "artificial intelligence", "machine learning", and "intelligent systems", along with the keywords "computational thinking" and "self-efficacy".

Article Filtering and Inclusion

Initially, 48 articles matching the specified keywords were identified. To ensure relevance, specific inclusion and exclusion criteria were applied. Articles were included if they focused on the application of AI, machine learning, or intelligent systems in educational settings, addressed topics related to computational thinking or self-efficacy in education, and were empirical studies or theoretical papers strongly emphasising practical applications in education.

Conversely, articles were excluded if they did not correlate with learning or teaching, were review articles rather than original research, or needed a clear focus on educational outcomes or contexts. After applying these criteria, 12 articles were excluded for not correlating with learning or teaching; five were excluded because they were review articles, and one was excluded because it was not empirical. This filtering process resulted in 30 articles that met the specified criteria, as illustrated in Figure 1.

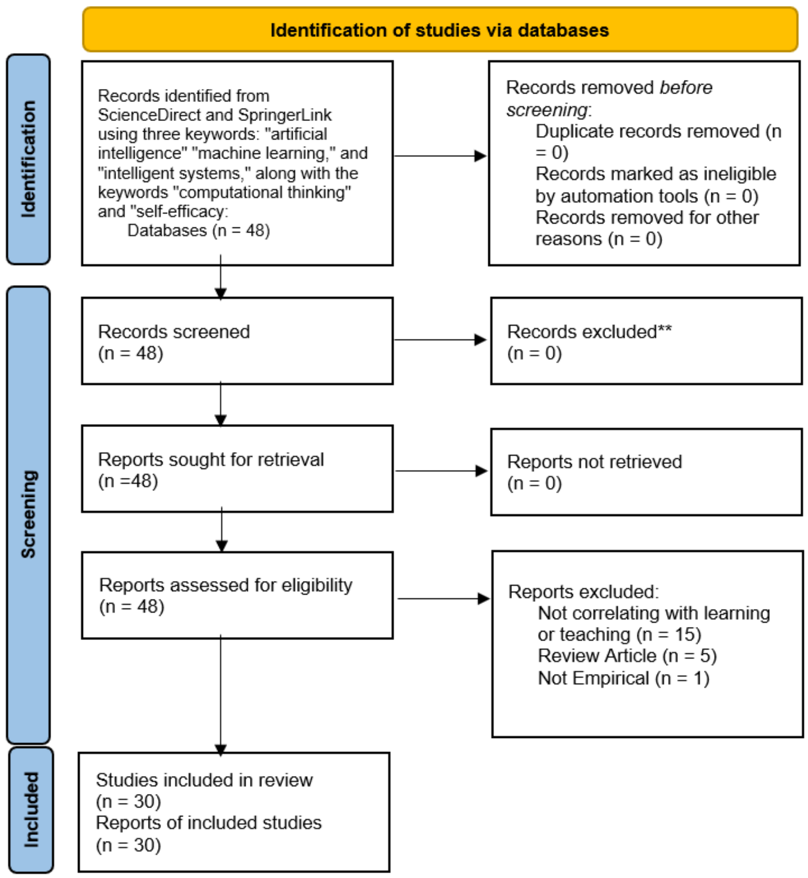

Figure 1. ScienceDirect and SpringerLink database searching steps.

Data Coding and Analysis

This study focuses on the use of AI in education and can be categorised into four domains: learning, teaching, assessment, and administration (Chiu et al., 2023). However, the primary impact of AI on computational thinking and self-efficacy is seen in the learning and teaching domain. Researchers typically assess students' computational thinking skills and self-efficacy following their experience with AI in learning. This category was determined to address the third research question, and an inductive approach (Scott & Howell, 2008) was used to answer it.

To address the three research questions, the author independently conducted coding. Initially, coding was performed for the first ten articles related to AI across four predetermined domains to assess the impact of AI on education. A systematic approach was used, and coding was conducted manually without the use of specialised software. To ensure consistency and reliability, the author employed a codebook developed from the literature, refined through an iterative process. Consistency checks were performed by re-coding a subset of articles to verify the reliability of the codes. After establishing a consistent coding scheme, the following ten articles were analysed to explore how AI affects computational thinking. Finally, an analysis was conducted on articles focusing on AI's impact on self-efficacy. The findings of these analyses will be presented in three tables. The findings of these analyses will be presented in three tables. The coding process followed the literature review approach outlined by Chu et al. (Chu et al., 2022). This framework involves categorising data based on themes that emerge from the literature, making it well-suited for identifying the impacts of AI in education. The approach was selected due to its structured method for extracting relevant information across different domains, which aligns with the goals of this study. For detailed coding data, refer to the following sections:

1. Research outline: includes information from the year of research, the author, and a summary of the background that has been analysed
2. Characteristics of the research: includes information about the learning environment, duration of the study, research domain, student evaluation, and selected learning strategies
3. The role of using AI in the topic being discussed (education, computational thinking, self-efficacy): includes information on the role of AI in the research questions being discussed

Result and Discussion

AI significantly impacts education by enhancing learning experiences, fostering computational thinking, and boosting self-efficacy among learners. This section delves into specific findings, highlighting how AI's implementation in educational settings influences these key areas and discusses the unique aspects of its impact based on the analysed articles. Recent advancements in AI technologies provide educators with tools to create adaptive learning environments that cater to individual student needs, promoting personalised learning pathways and facilitating complex problem-solving skills (Luckin et al., 2016). Additionally, AI-driven educational platforms facilitate computational thinking by engaging students in hands-on problem-solving activities. For example, platforms like Scratch use visual programming to help students break down problems and develop solutions. At the same time, AI-powered systems like ALEKS offer personalised tasks that adapt to the learner's progress, enhancing their ability to think algorithmically and solve complex problems (Lin et al., 2021), essential skills in the digital age (Wing, 2017).

Moreover, integrating AI in educational settings has been shown to influence self-efficacy positively (Kim & Kim, 2024; Yang et al., 2024), as intelligent tutoring systems and virtual assistants offer real-time feedback and support, enhancing learners' confidence and motivation. These developments underscore the transformative potential of AI in shaping the future of education. An information diagram illustrating the relationship between key components of this research is depicted in Figure 2. This figure visually represents how various elements, such as AI tools, self-efficacy, and computational thinking, interact and influence each other within the educational context. By mapping these relationships, Figure 2 helps to clarify the connections between AI integration, learner outcomes, and the mechanisms through which AI enhances educational experiences. It provides a conceptual framework for understanding how AI impacts cognitive development and confidence in learners, supporting the overall discussion of AI's role in education.

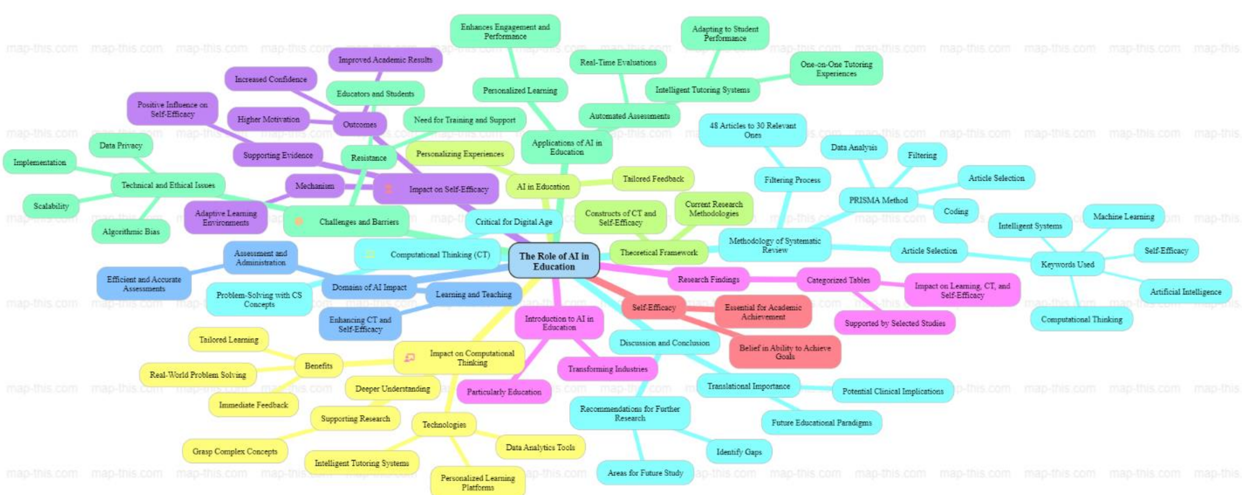

Figure 2. Diagram Illustrating Relationship Between Components.

Artificial Intelligence in Education Context

Artificial Intelligence (AI) integration in education has garnered significant attention in recent years due to its potential to transform traditional learning paradigms. AI technologies offer innovative solutions for personalised learning, intelligent tutoring, and data-driven insights, which enhance educational outcomes and address diverse learning needs. This section explores recent advancements in AI applications within educational settings.

Personalized learning through AI-driven educational technologies is a major focus of recent research. AI algorithms can analyze individual student data to customize learning experiences, catering to different paces and preferences (Luckin et al., 2016). This adaptability allows for differentiated instruction that aligns with students' unique learning styles and needs (Holmes et al., 2019). For example, using AI in adaptive learning platforms has improved student engagement and academic performance by providing tailored feedback and resources (Chen et al., 2020).

Building on this, AI-driven personalised learning extends into more sophisticated applications, such as Intelligent Tutoring Systems (ITS). Intelligent Tutoring Systems represent a significant advancement in AI applications for education. These systems provide personalised tutoring by leveraging AI to analyse student interactions and deliver customised instructional content (Vanlehn, 2011). ITS have effectively mimicked the benefits of one-on-one tutoring, offering adaptive feedback and assistance based on individual performance and learning progress (Kulik & Fletcher, 2015). Recent developments in ITS have expanded their capabilities to include natural language processing and machine learning techniques, further enhancing their effectiveness in educational settings (Alkhatlan & Kalita, 2019).

also play a crucial role in automating assessment and providing real-time feedback. For instance, tools like Turnitin's AI-driven plagiarism detection offer real-time checks to ensure academic integrity. These examples highlight how AI enhances the efficiency and effectiveness of assessments, offering timely insights that support continuous learning and improvement. Automated grading systems and AI-driven analytics efficiently evaluate student performance, reducing the administrative load on educators and enabling immediate responses to student submissions (Ke & Ng, 2019). Studies have shown that automated feedback can significantly enhance learning by providing timely, relevant, and constructive responses (Moorhouse et al., 2023). Moreover, AI's ability to analyse complex data sets allows for more nuanced assessments that can capture diverse aspects of student learning and development (Rudolph et al., 2023). Integrating AI across various educational technologies personalises learning experiences and streamlines instructional processes and evaluation, paving the way for more effective and efficient educational practices.

Artificial Intelligence and Computational Thinking

Integrating AI into educational practices presents significant opportunities for enhancing CT skills. CT, defined as the ability to solve problems algorithmically and think critically about processes, is essential in the digital age. AI technologies provide innovative tools and methodologies that can support and improve CT skills through personalised learning, intelligent tutoring, and practical applications. This review examines the role of AI in fostering CT skills, drawing insights from recent research to highlight effective strategies and educational implications. Our analysis of the selected ten articles reveals diverse perspectives on the relationship between AI and CT. The summary integrating all provided articles related to this topic can be seen in Table 1.

Table 1. AI and CT articles summary table

Content	Summary
Educational Level	Primary: n = 1, Secondary: n = 3, High School: n = 2, College: n = 3, Mixed (Various Educational Levels): n = 1
Duration of the Studies	≤ One Day: n = 1, ≤ One Month: n = 2, ≤ One Semester: n = 4, ≤ One Year: n = 3
Learning Environments	Traditional Classrooms: n = 2, Online Learning Platforms: n = 3, Hybrid (Classroom and Online): n = 3 STEAM-focused Schools: n = 2
Application Domains	Personalized Learning: n = 3, Intelligent Tutoring Systems: n = 2, Voice Assistant Creation: n = 1, STEAM Education: n = 2, AI Literacy: n = 1, Multiple Evaluation Approaches: n = 1
Data Analysis	Quantitative: n = 4, Qualitative: n = 2, Mixed-Methods: n = 4
Evaluations of Learners' Performance	AI-driven Analytics: n = 3, Pre- and Post-Tests: n = 4, Surveys and Interviews: n = 2, Peer Reviews: n = 1
Learning Strategies	Adaptive Learning: n = 2, Project-Based Learning: n = 2, Guided Instruction: n = 2, Self-Directed Learning: n = 1, Collaborative Learning: n = 2, Interdisciplinary Learning: n = 1

We use the "Concept Tool" from ATLAS.ti, which identifies relevant concepts based on noun phrases. This tool transforms abstract thoughts into visual representations of scientific knowledge, aiding in organising knowledge, identifying research gaps, and uncovering relationships between concepts. We can examine the results within their context and determine what code we need to generate. During this review, we can analyse all the data segments for that concept within ten articles related to the noun phrase. The concept map of the selected articles is shown in Figure 3.

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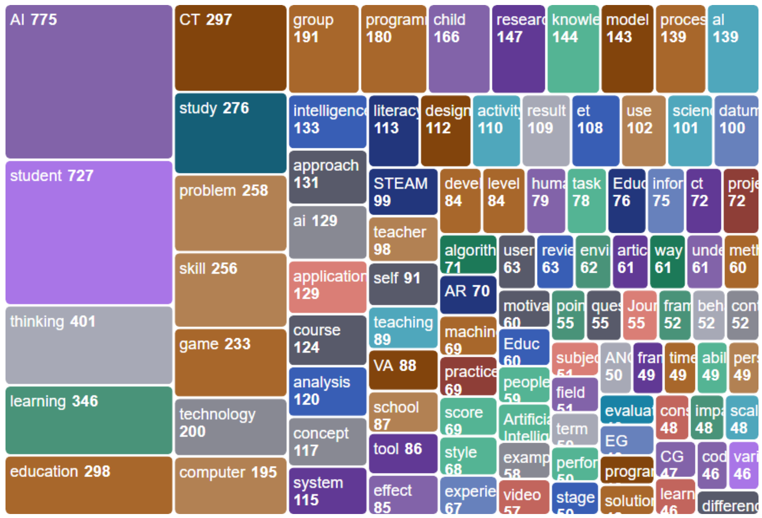

Figure 3. AI and CT concept map.

AI-Enhanced Learning Environments

Adaptive learning platforms use AI to tailor educational content to individual learning needs, enhancing CT skill development through personalised problem-solving challenges (Gadanidis, 2017). These platforms provide real-time feedback, encouraging iterative thinking and refining problem-solving strategies. Students engaging with these systems show improved abilities in decomposing problems and developing algorithmic solutions.

Intelligent Tutoring Systems (ITS) use AI to provide personalised tutoring that scaffolds CT skill development by offering hints and feedback tailored to each student's current understanding (Gadanidis, 2017). These systems adapt to the student's learning style and pace, effectively reinforcing CT skills. ITS significantly improves students' pattern recognition, logical reasoning, and systematic problem-solving abilities.

In addition, different learning approaches to creating voice assistants—such as project-based learning, guided instruction, and self-directed learning—also impact CT skill development (Hsu et al., 2023). Project-based and self-directed learning promotes higher engagement and advanced CT skills by allowing students to explore and create autonomously. Guided instruction supports foundational CT skills through structured guidance and direct feedback.

AI in Curriculum Integration and CT Development

Integrating AI modules like image processing, speech recognition, natural language processing, and machine translation into STEAM (Science, Technology, Engineering, Arts, and Mathematics) curricula enhances computational thinking (CT) skills by offering students practical, interdisciplinary learning experiences. These AI technologies allow students to engage with complex problems across various fields, fostering creativity, problem-solving, and critical thinking, essential for success in the digital age (Huang & Qiao, 2024). By incorporating AI into STEAM education, students gain hands-on experience with cutting-edge tools, promoting critical thinking, problem-solving, and algorithmic abilities, all of which prepare them for future technological advancements.

The impact of cognitive styles on CT skill acquisition in visual AI courses reveals that field-independent students excel in algorithmic thinking and problem decomposition. In contrast, field-dependent students benefit from structured tasks and external cues (Wang et al., 2022). However, Wang's current discussion does not critically analyse how different teaching strategies might be adapted to these cognitive styles. To address this gap, a more in-depth exploration is needed of how AI-driven educational tools can be tailored to cater to these varying cognitive styles, potentially enhancing the learning experience for all students.

The dual relationship between AI and CT emphasises mutual enhancement, where CT skills provide a foundation for understanding AI technologies, and AI offers practical applications for CT (Abelson & Breazeal, 2022). Interdisciplinary learning and collaborative projects in AI contexts promote the development of CT skills by applying CT principles to real-world AI problems.

Assessing CT Skills with AI Tools

A multiple evaluation approach for assessing CT skills. The study used multiple evaluation approaches to assess CT skills, focusing on four key areas: computational concepts, metacognitive practices, learning behaviours, and game mechanics. Computational concepts, like loops and conditionals, were evaluated by how students applied them, with better application leading to advanced outcomes. Metacognitive practices, such as planning and self-evaluation, were assessed through problem-solving strategies, where strong skills improved debugging and iteration. Learning behaviours, including collaboration and perseverance, were measured by student interactions, showing that positive behaviours enhanced understanding and project success. Lastly, game mechanics were evaluated by how well students implemented rules and objectives, highlighting their practical and creative use of CT skills. This comprehensive approach provided a thorough understanding of students' CT skills by examining both technical and cognitive aspects of their learning (Allsop, 2019). This approach captures various dimensions of CT, offering a holistic view of students' CT processes and outcomes and enhancing engagement and learning effectiveness. AI literacy is influenced by factors such as the digital divide, CT skills, and cognitive absorption (Celik, 2023). Effective AI literacy education requires addressing access disparities, integrating CT education, and fostering engaging learning environments to enhance cognitive absorption and retention of AI concepts.

Practical Applications and Educational Implications

CS applications, such as simulations and modelling tools, offer invaluable hands-on experiences for exploring scientific concepts and conducting virtual experiments. These tools support experiential learning and enable students to apply CT skills to real-world scenarios, enhancing their understanding and practical application of theoretical knowledge. Additionally, AI-driven personalised learning systems play a pivotal role in CT skill development by delivering tailored feedback, adaptive challenges, and customised learning paths (García-Martínez et al., 2023). By adjusting educational content to meet individual student needs and learning trajectories, these systems foster iterative problem-solving and algorithmic thinking, further enriching students' CT capabilities in diverse educational settings.

Artificial Intelligence and Self-Efficacy

Self-efficacy, an individual's belief in their ability to achieve specific goals, is a critical factor influencing performance and learning outcomes (Bandura, 2006). The rise of AI technologies introduces new dimensions of how self-efficacy can be developed and enhanced. This review synthesises findings from ten studies to understand the impact of AI on self-efficacy and identify critical areas for future research. The articles discussed different viewpoints on the relationship between AI and Self-efficacy. The combined summary of all the provided articles is presented in Table 2.

Table 2. AI and SE articles summary table

Content	Summary
Educational Level	Higher Education: n = 3, Professional: n = 2, General/Multiple Levels: n = 5
Duration of the Studies	≤ One Week: n = 2, ≤ One Month: n = 4, ≥ One Month: n = 4
Learning Environments	Educational Institutions: n = 3, Professional Development: n = 3, Online Platforms: n = 2, General/Other: n = 2
Application Domains	Personalized Learning: n = 4, Career Development: n = 2, Leadership Training: n = 1, Decision-Making: n = 2, Cybersecurity: n = 1
Data Analysis	Quantitative: n = 5, Qualitative: n = 3, Mixed Methods: n = 2
Evaluations of Learners' Performance	AI-Driven Feedback: n = 4, Performance Analytics: n = 3, Scenario Analysis: n = 2, Automated Evaluation: n = 1
Learning Strategies	Adaptive Learning: n = 4, Personalized Feedback: n = 3, Scenario-Based Learning: n = 2, Gamified Learning: n = 1

The Sankey diagram was utilised to visually illustrate the relationships between critical elements selected for analysis in this study: motivation, efficacy, AI, and belief. By showing the flow and strength of connections between these variables, the diagram depicts how the frequency and prominence of these keywords in the article reveal their relevance to the topic. The width of the arrows in the diagram indicates the magnitude of the relationships between these elements, as reflected in the article. This visualisation highlights how frequently and significantly each keyword is associated with the others, providing insight into the article's relevance to the topic. The diagram for the selected articles is displayed in Figure 4.

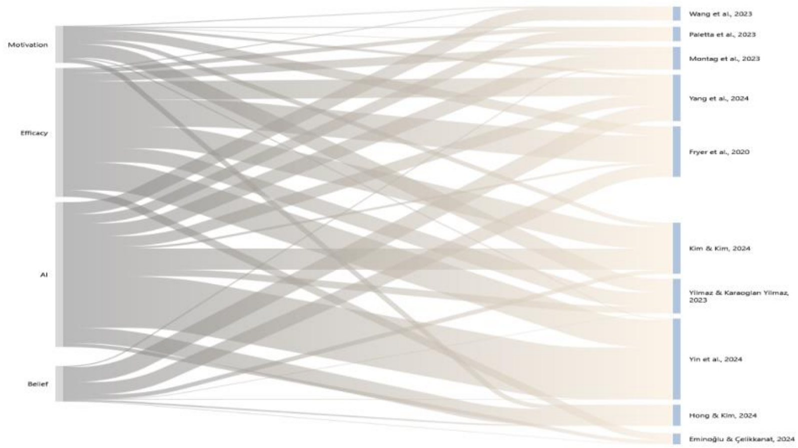

Figure 4. AI and self-efficacy relationship diagram.

AI and Self-efficacy in Education

This study explores the impact of AI-driven educational tools, such as adaptive learning platforms and personalised tutoring systems, on students' self-efficacy through playful elements like gamification and interactive activities. These AI tools cater to diverse learning styles by providing tailored content and challenges, such as adjusting such as adjusting difficulty levels based on individual performance or offering visual and auditory learning options. By offering immediate feedback and enhancing engagement, these tools boost students' confidence in their ability to tackle specific challenges, including problem-solving tasks and critical thinking exercises (Paletta et al., 2023). Additionally, AI integration in career education provides personalised guidance, skill assessments, and tailored learning pathways. By analysing individual strengths and weaknesses, AI tools clarify career goals and bolster students' self-efficacy in pursuing their chosen careers. This dual approach underscores AI's role in empowering academic and career development through personalised, interactive learning experiences (Hong & Kim, 2024).

AI in Professional Development

This study investigates the advantages of AI tools for both executive nurses and students across various educational settings. For executive nurses, specific AI systems such as Clinical Decision Support Systems (CDSS) and AI-powered performance dashboards deliver real-time feedback and performance evaluations. CDSS offers evidence-based recommendations that enhance critical decision-making in patient care, while performance dashboards provide insights into team dynamics and productivity. These tools allow nurses to refine their leadership and team management skills, thereby fostering increased confidence and self-efficacy in their professional roles. (Eminoğlu & Çelikkanat, 2024). Similarly, in higher education, AI tools like adaptive learning platforms and virtual tutors provide personalized academic support. These tools help students comprehend course material effectively and excel academically, nurturing feelings of competence and mastery that enhance their overall self-efficacy in their studies and future careers (Wang et al., 2023).

AI in Decision-Making

AI assistants influence user self-efficacy significantly, contingent upon their design and application context. Well-designed AI tools offer valuable insights and recommendations, bolstering users' confidence in their decision-making capabilities. Conversely, poorly designed AI may foster dependency or erode trust, undermining self-efficacy (Yin et al., 2024). Generative AI tools exemplify this dual potential by enhancing computational thinking through scenario planning and predictive analytics while boosting self-efficacy by empowering users to grasp potential outcomes and make informed decisions. This support reduces uncertainty and enhances users' confidence in making effective decisions (Yilmaz & Karaoglan Yilmaz, 2023).

AI in Personal Development

This study developed a professional development program based on Bandura's social cognitive theory to enhance primary school teachers' self-efficacy in integrating AI-based technology, specifically the Questions app, into English-speaking instruction. Spanning eight months, the program included core activities like lesson planning, enactment, and reflection, complemented by supportive strategies such as monthly workshops, the Questions app, and community support. The Questions app, featuring speech-to-text and text-to-speech functions, facilitated the creation and evaluation of English-speaking tasks. Teachers' self-efficacy was assessed using the Ohio State Teacher Efficacy Scale (OSTES) before and after the program, revealing significant improvements in classroom management, student engagement, and instructional strategies. Despite these positive outcomes, the study faced limitations, including the absence of long-term follow-up and a small participant sample, which may affect the generalizability of the findings. Future research should explore the long-term impacts of such programs and their broader applicability in educational settings (Yang et al., 2024). Simultaneously, AI-based educational tools cater to students by providing adaptive learning experiences, motivational feedback, and personalised support. By assisting students in setting realistic goals, tracking progress, and bolstering confidence in their academic abilities, these tools foster a positive environment for learning and growth, ultimately boosting student self-fficacy and interest in their studie (Fryer et al., 2020).

Ethical and Dependency Issues

Trust in AI technology plays a crucial role in shaping users' self-efficacy in utilizing these systems. The study found a moderate link between the propensity to trust in (automated) technology and both accepting and fearing AI. This suggests that research on trust in automation—traditionally focused on areas like industrial control or human-robot interaction—can offer valuable insights into understanding trust in AI. However, the moderate associations also highlight that trust in technology and attitudes toward AI are distinct constructs, even though AI is a significant driver of further automation. Mediation analysis revealed that technology self-efficacy partially mediates the relationship between trust in (automated) technology and attitudes toward AI. This implies that greater technology competence can lead to higher trust and more positive attitudes toward AI, underscoring the importance of enhancing technology self-efficacy to build trust in AI. As users' trust in AI systems increases, they are more likely to feel confident in their ability to effectively use these technologies. Thus, prioritizing the development of trustworthy and transparent AI systems is essential for enhancing overall self-efficacy (Montag et al., 2023). Additionally, work overload has been shown to detrimentally impact self-efficacy in cybersecurity behaviors (Kim & Kim, 2024). AI tools offer a solution by providing essential support, automating routine tasks, and reducing cognitive load. This assistance enables users to manage their workloads more efficiently, thereby maintaining their self-efficacy in cybersecurity practices despite potential challenges from workload pressures.

Conclusion

AI in education presents ethical and practical challenges. Ethical issues include privacy concerns and data misuse, which can be addressed through strict data protection measures and transparency in AI processes. Practical challenges involve integrating AI into existing systems, which requires funding, teacher training, and system compatibility. Solutions include securing funding, developing educator training programs, and designing adaptable AI tools. Integrating AI in education offers transformative potential for personalised learning, intelligent tutoring, and automated assessment, fostering computational thinking (CT) skills and enhancing learners' self-efficacy. For instance, AI tools can support personalised learning by adapting content to individual needs. At the same time, intelligent tutoring systems provide real-time feedback, helping students build confidence in their problem-solving abilities. Research has shown that AI-driven educational tools improve self-efficacy by offering tailored feedback and support, which boosts students' confidence in their academic abilities.

Additionally, AI enhances CT skills by incorporating complex technologies into curricula, which engage students in interdisciplinary problem-solving. These insights underscore the importance of integrating AI into educational practices to develop CT skills and self-efficacy among learners. AI can augment CT by providing tools that analyse complex information, encourage reasoning, and support decision-making processes. Additionally, AI-driven personalised feedback and adaptive learning systems can boost learners' self-efficacy by providing tailored support and guidance, increasing their confidence and motivation to tackle challenging tasks.

The fact that only one article addresses the implementation of AI in computational thinking (CT) and its impact on self-efficacy underscores a critical gap in the current research. This limited exploration indicates a need for more comprehensive studies to examine how AI simultaneously influences CT development and self-efficacy. Future research should focus on conducting empirical studies that integrate these dimensions to understand better the interplay between AI-enhanced CT skills and learners' self-confidence. By addressing this gap, researchers can provide deeper insights into how AI can effectively improve educational outcomes and support learners in developing their CT abilities and self-efficacy. While the research results show a positive influence, no empirical data states whether CT and AI are related to each other when using AI in educational settings. As AI continues to evolve, it is set to transform education by making learning experiences more accessible, efficient, and effective. For instance, AI-powered adaptive learning platforms tailor educational content to individual student needs, ensuring learners receive personalised support that enhances their cognitive skills. Intelligent tutoring systems offer real-time feedback and guidance, which helps students build problem-solving abilities and boosts their confidence in tackling complex tasks. Additionally, AI tools can automate routine tasks, reduce cognitive load, and provide motivational feedback, all contributing to a more engaging and supportive learning environment. These advancements empower learners to develop their cognitive skills and self-efficacy, ultimately leading to more successful educational outcomes.

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