

## A SYSTEMATIC REVIEW OF EDUCATORS' ENGAGEMENT WITH AI IN PROBLEM-BASED LEARNING

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**Abstract.** This systematic review examines the role of Artificial Intelligence (AI) in supporting Problem-Based Learning (PBL) within the Human-Computer Interaction (HCI) framework in education, with explicit alignment to Sustainable Development Goal 4 (Quality Education). The review aims to: (i) examine how educators interact with AI-driven PBL tools, (ii) evaluate the pedagogical impact of AI-enhanced PBL on teaching and learning outcomes, and (iii) identify key research gaps related to AI, HCI, and PBL adoption in educational contexts. Guided by the PRISMA 2020 framework, 50 peer-reviewed journal articles published between 2015 and 2024 were systematically selected from major academic databases. The selected studies were analyzed using thematic analysis supported by NVivo 14 to ensure transparency. The findings reveal three dominant themes. First, AI-driven PBL environments enhance educator and student collaboration by facilitating real-time feedback, intelligent scaffolding, and data-informed instructional decisions. Second, AI tools support adaptive and personalized learning experiences that improve learner engagement and problem-solving skills. However, these benefits are accompanied by persistent ethical concerns related to data privacy, algorithmic bias, and educator autonomy. Third, AI-based assessment practices within PBL contexts remain underdeveloped, indicating a lack of robust empirical evidence on automated feedback, formative assessment, and learning analytics integration. Based on the synthesis, this review proposes the AI-Enhanced Academic Interaction Model (AEAIM), integrating the Technology Acceptance Model, Constructivist Learning Theory, and Krashen's Input Hypothesis to explain educators' adoption and use of AI-enhanced PBL. The review contributes theoretically by advancing an integrative adoption framework and practically by highlighting design, ethical, and policy implications for sustainable AI integration in education.

**Keywords:** *artificial intelligence, problem-based learning, human-computer interaction, sustainable development goal 4, AI in education, AI ethics*

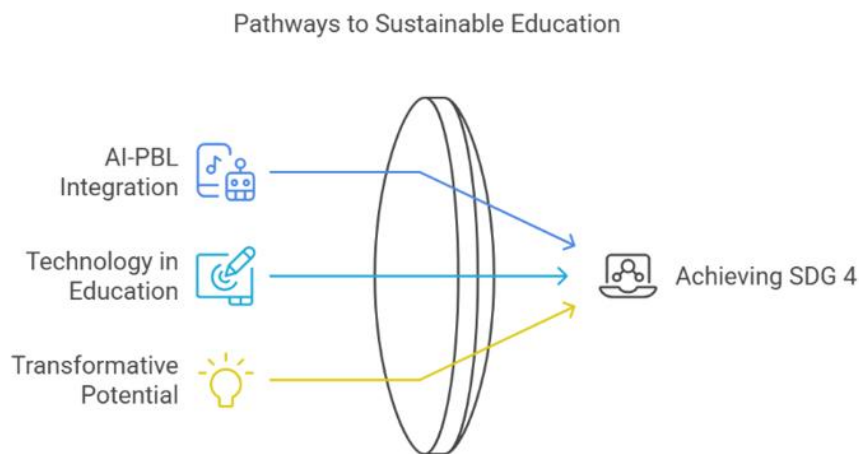
### Introduction

The intersection of Human-Computer Interaction (HCI) and Artificial Intelligence (AI) has significantly influenced modern education, particularly within Problem-Based Learning (PBL) environments. AI-driven technologies enhance interactivity, adaptability, and student-centered learning beyond automation. However, the usability, accessibility, and cognitive impact of AI tools on educators remain underexplored, posing challenges for the effective integration of AI into pedagogical frameworks. This gap is particularly significant in ensuring that HCI principles such as interaction design, cognitive load management, user-centered AI interfaces, and explainability are effectively incorporated into AI-driven educational tools. The interplay between HCI,

AI, and PBL is essential for advancing Sustainable Development Goal 4 (SDG 4): Quality Education, as it fosters equity, accessibility, and engagement in AI-enhanced learning environments.

### ***AI-PBL and its role in achieving SDG 4***

Global AI education policies are increasingly shaping the role of AI in PBL. UNESCO's AI emphasizes the need for AI usability guidelines tailored to educators' needs, ensuring that AI supports not replaces the pedagogical expertise. These policies serve as a foundation for guiding AI integration in higher education and minimizing its risks. However, while AI-driven PBL enhances accessibility, critics argue that its reliance on digital infrastructure may deepen the digital divide, particularly in resource-limited regions where AI adoption is constrained by inadequate funding and internet access. The integration of AI-driven Problem-Based Learning (AI-PBL) plays a transformative role in advancing Sustainable Development Goal 4 (SDG 4). AI-powered learning enhances accessibility, personalization, and digital inclusion, promoting equitable and quality education through tailored feedback and adaptive learning (Hariyanto et al., 2025). These contributions are particularly relevant in higher education, where AI-PBL models can support self-directed learning, critical thinking, and digital literacy. To provide a clearer representation of these connections, *Figure 1* illustrates the pathways through which AI-PBL contributes to SDG 4, highlighting key mechanisms such as adaptive learning, intelligent tutoring, and real-time feedback systems.



***Figure 1.*** Pathways to achieving SDG 4 through AI-PBL integration.

Research indicates that AI-driven adaptive learning platforms can dynamically tailor instruction to individual learners, leading to enhanced learning outcomes and personalized educational experiences (Tan et al., 2025). AI-based adaptive learning systems have demonstrated potential in reducing disparities in education by tailoring learning materials to individual student needs, ensuring that students from different socioeconomic backgrounds receive personalized and effective learning support. Furthermore, AI in PBL fosters digital inclusion, allowing students and educators to interact with intelligent learning environments that provide real-time feedback,

collaborative opportunities, and automated problem-solving assistance (Omeh and Ayanwale, 2025).

However, while AI-driven tools offer innovative learning solutions, their integration in PBL also presents challenges, including educators' ability to effectively interpret AI-generated recommendations, maintain pedagogical control, and navigate AI decision-support systems. Empirical studies suggest that only 45% of educators feel confident using AI-driven PBL platforms without additional training, highlighting a crucial gap in AI usability support such in TVET and STEM education (Amin et al., 2025). These challenges underscore the need for HCI-driven AI usability frameworks that ensure educators' autonomy and trust in AI-powered PBL environments.

### ***The role of HCI in AI-Powered learning***

HCI plays a crucial role in designing intelligent learning environments that facilitate seamless interaction between educators, students, and AI-driven systems. AI-powered adaptive learning platforms, intelligent tutoring systems (ITS), and real-time analytics dashboards are increasingly utilized to support personalized and data-driven instruction specially in STEM education in higher and lower learning institution (Amdan et al., 2024a). AI analyzes learning patterns and provides real-time recommendations, but its usability and explainability challenge educators. While existing research focuses heavily on AI's impact on student learning and engagement, fewer studies investigate how educators interact with, trust, and adopt AI tools within PBL settings. This research gap highlights the need to assess AI usability, cognitive load, user experience (UX), and ethical concerns related to AI-powered automated assessments, feedback mechanisms, and instructional decision-making.

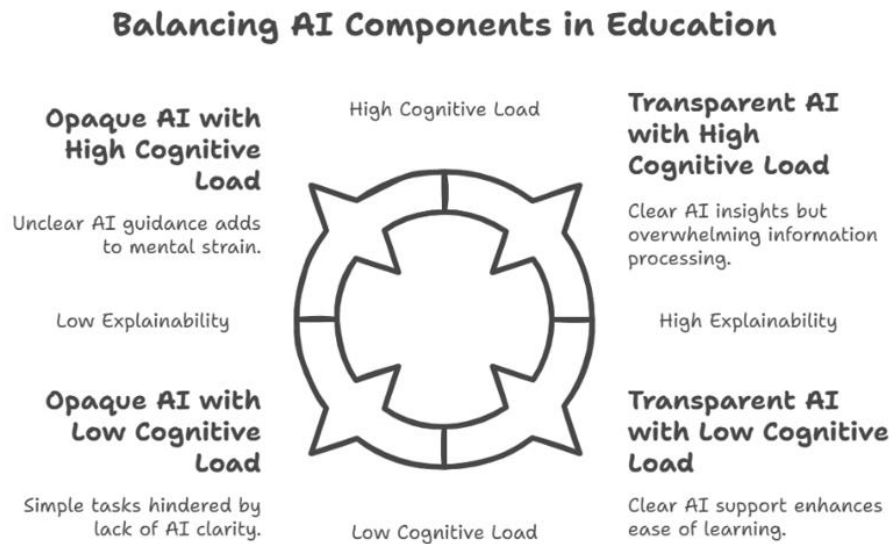
Additionally, AI-driven tutoring shifts the educator-student dynamic, increasing student reliance on AI feedback, which may affect engagement, teacher authority, and learning relationships (Amdan et al., 2024b).

### ***Bridging the research gap in AI-HCI for educators***

Malaysia's higher education institutions have widely adopted PBL methodologies as part of digital transformation efforts outlined in the Malaysia Education Blueprint (2013–2025). This national strategy promotes technology-driven pedagogy, critical thinking, and AI literacy to prepare students for 21st-century workforce demands (Maia et al., 2024). The integration of AI in PBL aligns with constructivist learning theories, enabling students to engage in real-world problem-solving through AI-assisted tools. However, educators often face challenges in effectively using AI-powered platforms, including navigating AI-driven decision-support tools, interpreting AI-generated recommendations, and ensuring fairness in automated assessments.

AI literacy training is a key barrier to AI integration in education. Effective AI implementation requires that educators understand AI decision-making processes, biases, and limitations. Lack of training may lead to misinterpretation or skepticism toward AI-driven assessments (Chen et al., 2020). Additionally, institutional resistance, lack of financial investment, and inconsistent AI policies within higher education institutions have slowed the adoption of AI-driven PBL, despite its potential to improve learning outcomes (Porayska-Pomsta et al., 2023). A critical factor in the successful adoption of AI-driven learning tools is the balance between AI transparency and cognitive load. Educators must be able to interpret AI-generated recommendations

without experiencing cognitive overload, which can negatively impact their engagement with AI-powered PBL systems. Research suggests that opaque AI models, which lack clear explanations for their decisions, increase educators' cognitive load, leading to lower trust and adoption rates (Nguyen et al., 2024). To illustrate this relationship, *Figure 2* presents a conceptual framework demonstrating how different levels of AI transparency influence educators' cognitive demand, highlighting the need for explainable and user-friendly AI interfaces.



**Figure 2.** The interplay of AI explainability and cognitive load in education.

**Study contribution**

This study introduces a novel AI-PBL usability framework that integrates Explainable AI (XAI) with real-time educator decision-making models, filling a key gap in HCI research. Unlike prior research on student engagement, this study focuses on educators' interaction with AI, decision-making autonomy, and usability constraints in PBL (Zou et al., 2025). Additionally, this study aligns with ethical AI frameworks such as UNESCO's AI Ethics Guidelines 2021 emphasizing transparency, fairness, and human oversight in AI-assisted learning environments. While AI can assist in reducing educators' workload, concerns remain that excessive AI automation may lead to over-reliance on AI-generated feedback, reducing educators' ability to exercise professional judgment in instructional design (Selwyn et al., 2023). Therefore, this research provides practical recommendations for AI developers, educators, and policymakers to design human-centered AI tools that empower, rather than replace, educator agency.

**Study objectives**

This study aims to explore educators' engagement with AI-driven HCI tools in PBL and their alignment with SDG 4: Quality Education. Specifically, the study seeks to: (1) Analyze educators' experiences with AI-enhanced PBL tools, focusing on usability, decision autonomy, and adaptability; (2) Evaluate HCI-related usability factors, including learnability, efficiency, error tolerance, and adaptability, in AI-powered PBL, applying Norman's Seven Stages of Action, Cognitive Load Theory, and Explainable

AI (XAI) models; (3) Assess decision autonomy through survey-based perceived control scales, AI override feature utilization logs, and qualitative interviews on AI trust and adaptation; (4) Assess how AI-driven PBL aligns with SDG 4 goals, particularly in fostering equitable, technology-enhanced learning environments that prioritize educator agency and instructional autonomy.

**Materials and Methods**

This systematic literature review (SLR) follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines to ensure a rigorous and transparent research process. The PRISMA framework was applied to identify, screen, and analyze relevant peer-reviewed literature on educators' engagement with AI-driven Human-Computer Interaction (HCI) in Problem-Based Learning (PBL) and its alignment with Sustainable Development Goal 4 (SDG 4). A comprehensive literature search was conducted across multiple academic databases to collect high-quality, peer-reviewed journal articles. The search strategy was designed to retrieve empirical studies, systematic reviews, and case studies that examine the role of AI-driven HCI in PBL education and its contribution to SDG 4. To ensure coverage of high-impact research, the following academic databases were utilized: (1) Web of Science (WOS); (2) Scopus; (3) IEEE Xplore; (4) SpringerLink; (5) Taylor & Francis Online; (6) Elsevier (ScienceDirect); (7) Consensus; (8) Google Scholar. A combination of Boolean operators (AND, OR) and truncation (\*) was used to construct search queries shows in *Table 1*.

**Table 1.** Boolean operators used in the search strategy.

Concept	Search query
Human-computer interaction	"Human-Computer Interaction" OR "HCI"
Artificial intelligence	"Artificial Intelligence" OR "AI"
Problem Based Learning (PBL)	"Problem-Based Learning" OR "PBL"
Educator's engagement	"Educators' Engagement" OR "Teacher Interaction"

The search strategy was refined through pilot testing to ensure relevance and minimize irrelevant results. To ensure the quality and relevance of the included studies, predefined inclusion and exclusion criteria are shown in *Table 2*. The study process is shown in *Table 3*. The study selection followed the PRISMA 2020 guidelines, consisting of four stages: Identification, Screening, Eligibility, and Inclusion (*Figure 3*).

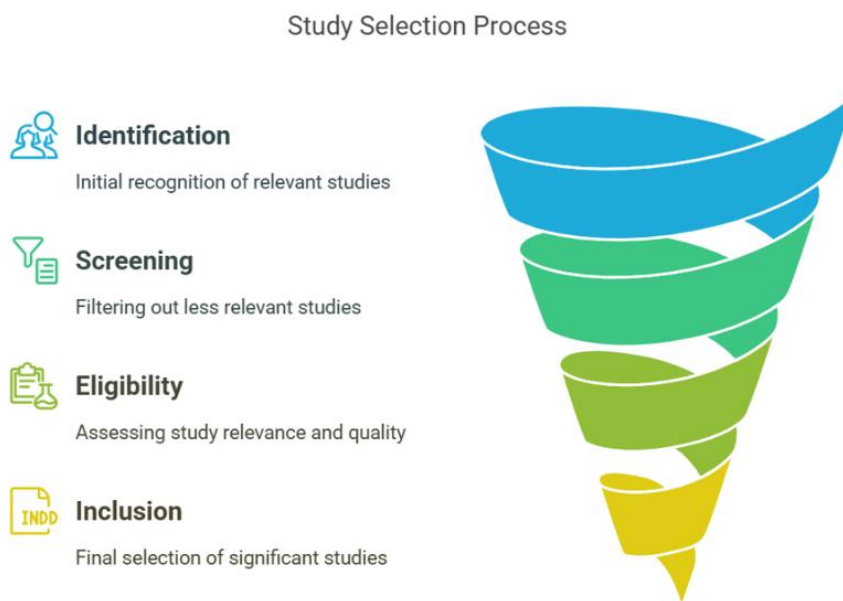
**Table 2.** Inclusion and exclusion criteria for selected literature.

Inclusion Criteria	Mean
Peer-reviewed journal articles and conference papers	Non-English studies (to ensure accessibility)
Published between 2013 and 2024	Studies focusing solely on student engagement (without educator perspectives)
Studies investigating AI-driven HCI in PBL education	Non-peer-reviewed sources (e.g., opinion pieces, editorials, unpublished reports)
Research analyzing educators' engagement with AI-enhanced learning environments	Duplicate studies from multiple databases
Studies aligning with SDG 4 (Quality Education)	Non-English studies (to ensure accessibility)

Empirical research, systematic reviews, and case studies      Studies focusing solely on student engagement (without educator perspectives)

**Table 3.** *The review process.*

Phase	Records Identified	Records Excluded	Final Selection
Identification	3,500	-	-
Duplicate Removal	-	1,000	2,500
Title/Abstract Screening	2,500	1,600	900
Full-Text Eligibility Check	900	650	250
Included Studies	250	200	50



**Figure 3.** *PRISMA 2020 flow diagram for study selection process.*

The study selection process followed the PRISMA 2020 guidelines to ensure a systematic and unbiased approach in identifying, screening, and synthesizing relevant literature. During the Identification phase, all retrieved articles were imported into Zotero for duplicate removal, ensuring that redundant entries were eliminated before further screening. In the Screening phase, titles and abstracts were reviewed against predefined inclusion and exclusion criteria, filtering out studies that did not meet the relevance or quality standards. Next, in the Eligibility phase, full-text articles were meticulously assessed for methodological rigor, relevance to AI-driven HCI in PBL, and alignment with SDG 4. Finally, in the Inclusion phase, studies that satisfied all criteria were incorporated into the final synthesis, forming the foundation for this systematic review. The final 50 articles that met the inclusion criteria are summarized in the dataset.

### **Data extraction and synthesis**

A structured data extraction framework was used to collect and organize relevant study details. Shown in *Figure 4*.

Educational Research Process Flowchart

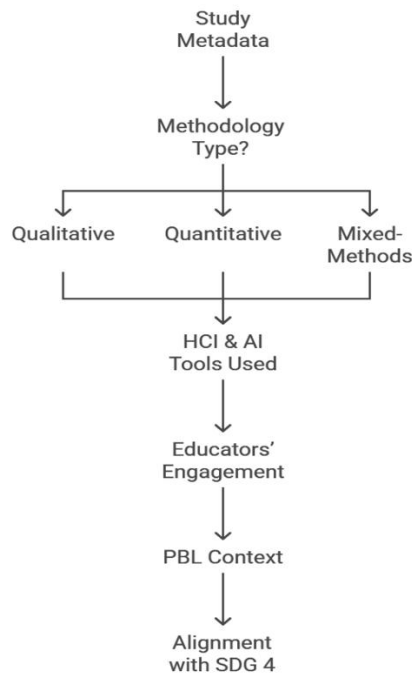


Figure 4. Data extraction framework.

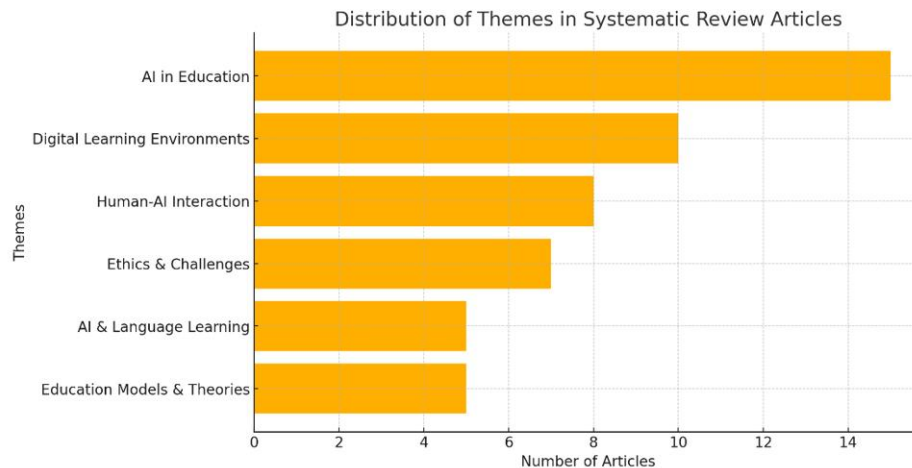
Thematic analysis was conducted using NVivo 14 software. Two independent coders analyzed themes, achieving an inter-rater reliability score of  $\kappa = 0.82$ , indicating strong agreement. This approach was chosen to identify recurring patterns in AI-driven PBL, ensuring rigor in qualitative synthesis. The theme coding is shown in Table 4.

Table 4. Thematic coding.

Theme	Description
"Educators' perceptions and challenges in AI-driven HCI adoption"	"Explores educators' views on AI in HCI, including barriers and opportunities."
"AI's effectiveness in supporting PBL methodologies"	"Analyzes how AI enhances Problem-Based Learning (PBL) strategies in education."
"Impact of AI on learning outcomes and educational equity (SDG 4 alignment)"	"Evaluates AI's role in promoting equitable learning outcomes aligned with SDG 4."

Results and Discussion

Figure 5 illustrates the distribution of key themes identified from the 50 articles analyzed in this review. The most prevalent themes include AI in Education (15 articles), Digital Learning Environments (10 articles), and Human-AI Interaction (9 articles). This suggests a strong focus on AI's role in educational settings, with increasing interest in digital learning environments and human-AI interactions." As shown in Figure 5, AI in Education (30%) and Digital Learning Environments (20%) were the most studied themes, reflecting a growing emphasis on AI pedagogy. However, only 10% of studies examined AI-driven assessments, suggesting a need for more research in this area.



**Figure 5.** Distribution of themes in systematic review articles.

### ***Artificial intelligence empowering education***

Artificial Intelligence (AI) has revolutionized education by enhancing learning processes, personalizing experiences, and providing intelligent automation. AI-powered tools, such as ChatGPT and machine learning models, are increasingly integrated into higher education institutions to optimize teaching methodologies. The role of AI extends to intelligent tutoring systems, automated grading, and predictive analytics that help educators tailor their approaches to student needs. Research highlights how AI fosters adaptive learning by assessing individual student performance and recommending personalized learning pathways. AI-driven intelligent tutoring systems improve the quality of higher education by dynamically adjusting content and feedback, ensuring real-time support and engagement for students. Moreover, AI enhances engagement through interactive learning experiences, such as AI-driven simulations, virtual tutors, and gamification strategies.

Studies emphasize that AI is not only transforming instructional delivery but also supporting administrative functions, such as attendance tracking, student assessments, and institutional decision-making. AI automates course generation and dynamic curriculum adaptation, helping educators design and refine educational content more effectively. However, challenges such as dependency on technology, digital equity, and ethical concerns must be addressed for effective AI integration in education. Ensuring equitable access to AI-driven education is critical, as AI-based tools have the potential to either bridge or widen educational gaps. Thoughtful implementation of AI-driven personalization can maximize its benefits while ensuring fairness and inclusivity. By leveraging AI for adaptive learning, automation, and student engagement, higher education institutions can create more innovative, inclusive, and effective learning environments.

### ***Digital learning environments in education***

Digital learning environments (DLEs) leverage AI to create immersive, accessible, and personalized educational experiences. Virtual learning platforms, learning management systems (LMS), and AI-powered chatbots facilitate seamless communication between educators and students. The use of digital twins and virtual

models that replicate real-world learning environments has gained traction, providing students with hands-on experiences in a controlled, simulated space. AI-enhanced computer-assisted learning models improve comprehension by dynamically adapting content based on real-time student performance. Studies also highlight the role of natural language processing (NLP) tools, such as ChatGPT, in assisting students with writing, research, and problem-solving). Digital learning environments break geographical barriers, making education more inclusive, particularly for remote and rural areas. By integrating AI-powered tools in digital learning, educators can enhance engagement, personalize instruction, and foster interactive educational experiences, ultimately shaping the future of digital education.

### ***Human-AI interaction***

The interaction between AI and humans in education is a critical area of research, focusing on collaboration, personalization, and engagement. AI-driven tools are designed to complement human educators rather than replace them. Research explores the impact of AI on teacher-student interactions, emphasizing that AI can support but not substitute the role of a teacher. One of the key aspects is AI-driven personalization, where AI analyzes student behavior, preferences, and performance to provide customized learning recommendations. However, excessive reliance on AI tools can lead to reduced critical thinking and over-dependence on automation. Studies also investigate the role of conversational AI in fostering human-like interactions, such as chatbots that provide instant feedback and virtual mentors that guide students through learning paths. Another critical aspect is the emotional dimension of AI-human interaction. AI-powered sentiment analysis tools help educators gauge student emotions, engagement levels, and motivation. However, researchers caution against over-reliance on AI for emotional intelligence assessment, as human nuances may not always be accurately interpreted by algorithms.

### ***Ethics & challenges in AI adoption***

The ethical considerations surrounding AI in education revolve around privacy, bias, and accountability. One of the most pressing concerns is data privacy. The AI systems collect vast amounts of student data, raising questions about how this data is stored, used, and protected. Bias in AI algorithms is another major issue, as AI models may unintentionally reinforce existing disparities in education, particularly affecting marginalized groups. AI's influence on human decision-making is another critical ethical concern. While AI can enhance decision-making by providing data-driven insights, over-reliance on AI recommendations might lead to reduced human autonomy in educational settings. Systematic reviews discuss the long-term effects of AI on learning quality, questioning whether AI-driven personalization truly enhances deep learning or simply optimizes performance metrics. After that, there are concerns regarding academic integrity in AI-generated content, such as essays produced by ChatGPT, raises questions about plagiarism, originality, and authenticity in student work. Policymakers and educators must establish guidelines and ethical frameworks to govern AI usage in education responsibly (Porayska-Pomsta et al., 2023).

### ***AI & language learning***

Artificial intelligence plays a significant role in language education, particularly in personalized language learning. AI-powered tools such as ChatGPT, Grammarly, and Duolingo assist learners in developing linguistic skills through real-time feedback, error detection, and personalized content recommendations. One of the key advantages of AI in language learning is its ability to provide instant feedback and adaptive learning paths. AI systems assess a learner's proficiency level and adapt lesson plans accordingly. Speech recognition technology enables pronunciation assessments, while NLP-based chatbots facilitate conversational practice. However, challenges persist, including AI's inability to fully grasp contextual and cultural nuances in language learning. While AI can provide structured learning, human interaction remains essential for developing advanced linguistic skills and cultural competence.

### ***Education models & theories in AI integration***

AI's influence on educational models and theories is a growing field of study. The constructivist approach, which emphasizes active and experiential learning, aligns well with AI-driven personalized learning environments. AI tools facilitate problem-based learning (PBL) by guiding students through real-world scenarios and providing instant feedback. AI is reshaping traditional learning theories, such as behaviorism, cognitivism, and connectivism. In behaviorist models, AI reinforcement techniques such as gamified learning rewards will enhance motivation. In cognitivism, AI-driven analytics support meta-cognitive strategies, allowing students to track their progress and adjust their learning methods. In connectivism theories, AI fosters networked learning by linking learners to vast knowledge sources and global collaborations.

### ***Future directions in AI-Education research***

Future studies should explore the long-term effects of AI-driven education on cognitive development and knowledge retention. Additionally, research should focus on ethical AI frameworks, regulatory policies, and teacher training programs to ensure responsible AI adoption. The integration of AI with emerging technologies such as augmented reality (AR), virtual reality (VR), and blockchain could further enhance educational experiences and learning outcomes. AI's integration into education presents transformative opportunities and challenges. While AI enhances personalization, engagement, and accessibility, ethical concerns, human-AI collaboration, and the need for regulatory oversight remain crucial. The systematic literature review underscores the need for a balanced approach that leverages AI's strengths while preserving the human essence of education. Future research should aim to develop ethical guidelines, improve AI transparency, and ensure equitable AI access to bridge the digital divide in education. The findings of this systematic literature review highlight the transformative potential of Artificial Intelligence (AI) in Problem-Based Learning (PBL) environments, particularly in enhancing adaptive learning, real-time analytics, and automated tutoring. However, the effectiveness of AI-driven PBL depends largely on educators' ability to engage with, trust, and integrate AI tools into their instructional. The interplay between Explainable AI (XAI), cognitive load management, and decision autonomy emerges as a crucial factor in determining the usability and acceptance of AI in PBL (Mahto, 2024). While AI offers innovative solutions for personalized learning, its implementation presents significant challenges, particularly regarding educators' trust in AI-driven decision-making, ethical considerations, and institutional barriers to adoption.

Addressing these challenges is essential to ensuring that AI serves as a support mechanism for educators rather than replacing their pedagogical expertise (Zhang et al., 2025).

One of the key implications of this study is the necessity for structured AI usability training programs for educators (Do Rêgo and Araújo-Filho, 2024). Existing literature suggests that a significant proportion of educators lack the confidence to effectively utilize AI-driven learning platforms without additional training (Amdan et al., 2025). This gap in AI literacy affects their ability to interpret AI-generated feedback, personalize learning pathways, and maintain control over instructional decisions. Without adequate training, educators may struggle to navigate AI-driven assessments, potentially leading to frustration and resistance to AI adoption (Wu et al., 2020). To mitigate this issue, institutions must provide structured AI training programs that equip educators with the necessary skills to interact with AI-driven PBL tools effectively (Maia et al., 2024). While AI is increasingly embedded in PBL methodologies, trust in AI systems remains a critical issue among educators (De La Cruz Martínez and Zamorano, 2019). A lack of transparency in AI decision-making processes often leads to skepticism regarding AI-generated assessments and learning recommendations (Alfaro-Viquez et al., 2025). Studies indicate that educators frequently encounter challenges in understanding how AI algorithms produce feedback, particularly when AI-generated scores or recommendations do not align with their professional judgment (Hawamdeh and Adamu, 2021).

The ethical use of AI in education necessitates a balance between AI automation and educator decision autonomy (Coelho et al., 2025). Ethical AI frameworks emphasize the importance of human oversight in AI-powered learning environments to prevent educators from becoming passive recipients of AI-generated outputs (Su and Yang, 2024). Furthermore, bias mitigation techniques should be integrated into AI-driven PBL tools to prevent algorithmic biases from influencing educational outcomes. Despite the potential benefits of AI in PBL, various institutional barriers hinder its widespread adoption. Many educational institutions face financial constraints that limit their ability to invest in AI infrastructure, faculty training, and long-term AI system maintenance. To facilitate the effective adoption of AI in education, policymakers must develop regulatory guidelines that establish transparency, accountability, and best practices for AI-driven PBL integration. By implementing these policies, educational institutions can enhance the usability of AI-PBL tools, ensure equitable access to AI-driven learning experiences, and empower educators to maintain control over AI-assisted instructional decisions while leveraging AI to achieve Sustainable Development Goal 4 (SDG 4) (Zhang et al., 2025).

### ***Theoretical and practical implications***

#### ***Theoretical implications***

This study extends the Technology Acceptance Model (TAM) by demonstrating that perceived ease of use alone does not drive AI adoption. Educators also prioritize ethical AI considerations, such as transparency and fairness, when evaluating AI tools for PBL environments (Cheng et al., 2019). Additionally, our findings integrate Constructivist Learning Theory, reinforcing that AI-driven HCI supports self-directed learning by providing real-time scaffolding tailored to individual learners (Chounta et al., 2022).

### ***Practical implications***

For educators, this study underscores the need for structured AI training programs to build digital competencies (Zou et al., 2025). Institutions should adopt AI-focused professional development initiatives to ensure that educators can effectively leverage AI tools in PBL settings (Amin et al., 2025). For policymakers, the study recommends regulatory frameworks to address AI bias and enhance transparency in AI-generated assessments. Finally, for AI developers, the findings highlight the need for human-centered AI design, ensuring that AI interfaces are intuitive and ethically aligned with pedagogical objectives.

### **Conclusion**

This systematic review highlights the transformative role of Artificial Intelligence (AI) in Problem-Based Learning (PBL) within the context of Human-Computer Interaction (HCI) in education. The findings underscore AI's ability to enhance personalized learning, facilitate adaptive feedback, and improve educator-student interactions, all of which contribute to the broader goal of Sustainable Development Goal 4 (SDG 4) in ensuring inclusive and quality education. The integration of AI in PBL has demonstrated significant potential in fostering critical thinking, collaboration, and knowledge retention, particularly in digital learning environments. However, challenges persist, particularly regarding ethical concerns, data privacy, accessibility, and the digital divide. The ethical implications of AI-powered education, including bias in algorithms, student data security, and the risk of over-reliance on automation, must be carefully managed. Additionally, while AI can support educators in administrative and pedagogical tasks, it is essential to recognize that AI should function as an assistive tool rather than a replacement for human educators. AI-driven education requires a balanced approach, aligning technology with pedagogical integrity. Policymakers, educators, and technology developers must collaborate to establish clear frameworks for ethical AI integration, ensuring that it remains a tool for empowerment rather than exclusion. Future research should explore AI's cognitive impact, inclusivity, and regulatory policies. Ultimately, AI has the potential to revolutionize education, but its success will depend on how well it is integrated into learning environments in a manner that is ethical, equitable, and centered on student engagement. By leveraging AI's capabilities while upholding human values, education can move towards a future where learning is more accessible, personalized, and impactful for diverse student populations.

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### **Conflict of interest**

The authors confirm that there is no conflict of interest involve with any parties in this research study.

## **REFERENCES**

- [1] Alfaro-Viquez, D., Zamora-Hernandez, M., Fernandez-Vega, M., Garcia-Rodriguez, J., Azorin-Lopez, J. (2025): A Comprehensive Review of AI-Based Digital Twin Applications in Manufacturing: Integration Across Operator, Product, and Process Dimensions. – *Electronics* 14(4): 28p.
- [2] Amdan, M.A., Janius, N., Jasman, M.N., Kasdiah, M.A.H. (2024a): Advancement of ai-tools in learning for technical vocational education and training (TVET) in Malaysia (empowering students and tutor). – *International Journal of Science and Research Archive* 12(1): 2061-2068.
- [3] Amdan, M.A.B., Janius, N., Kasdiah, M.A.H.B., Amdan, M.A.B., Janius, N., Kasdiah, M.A.H.B. (2024b). Concept paper: Efficiency of Artificial Intelligence (AI) tools for STEM education in Malaysia. – *International Journal of Science and Research Archive* 12(2): 553-559.
- [4] Amdan, M.A.B., Janius, N., Saidin, M.S.B., Kasdiah, M.A.H.B. (2025): Impact of Artificial Intelligence in TVET and STEM Education among Higher Learning Students in Malaysia. – *Journal of Research in Mathematics, Science, and Technology Education* 2(1): 1-14.
- [5] Amin, A.M., Karmila, F., Rijal, S., Hujjatusnaini, N., Adiansyah, R. (2025): The Development of Integrated Project-Based and 4C-Scaffolding Model with AI to Overcome Misconceptions. – *Journal of Education and e-Learning Research* 12(2): 336-345.
- [6] Chen, L., Chen, P., Lin, Z. (2020): Artificial intelligence in education: A review. – *IEEE Access* 8: 75264-75278.
- [7] Cheng, E.W. (2019): Choosing between the theory of planned behavior (TPB) and the technology acceptance model (TAM). – *Educational Technology Research and Development* 67(1): 21-37.
- [8] Chounta, I.A., Bardone, E., Raudsep, A., Pedaste, M. (2022): Exploring teachers' perceptions of artificial intelligence as a tool to support their practice in Estonian K-12 education. – *International Journal of Artificial Intelligence in Education* 32(3): 725-755.
- [9] Coelho, H., Silva, F., Correia, M., Rodrigues, P.M. (2025): Artificial Intelligence in Patient Blood Management: A Systematic Review of Predictive, Diagnostic, and Decision Support Applications. – *Journal of Clinical Medicine* 14(23): 36p.
- [10] De La Cruz Martínez, G., Zamorano, C.A. (2019): Teaching artificial intelligence using project-based learning. – In *ICERI2019 Proceedings, IATED* 6p.
- [11] Do Rêgo, A.C.M., Araújo-Filho, I. (2024): Leveraging artificial intelligence to enhance the quality of life for patients with autism spectrum disorder: A comprehensive review. – *European Journal of Clinical Medicine* 5(5): 28-38.
- [12] Hariyanto, Kristianingsih, F.X.D., Maharani, R. (2025): Artificial intelligence in adaptive education: a systematic review of techniques for personalized learning. – *Discover Education* 4(1): 18p.
- [13] Hawamdeh, M.M.K., Adamu, I. (2021): Problem-based learning (PBL): A deep approach to learning in the 21st century. – In *Improving Scientific Communication for Lifelong Learners*, IGI Global Scientific Publishing 18p.
- [14] Mahto, M.K. (2024): Explainable artificial intelligence: Fundamentals, approaches, challenges, XAI evaluation, and validation. – In *Explainable Artificial Intelligence for Autonomous Vehicles*, CRC Press 24p.
- [15] Maia, D.M., Dos Santos, S.C., Lima, L.G., Franca, V.L., Lima, A.H., Andrade, D. (2024): Critical factors for a reliable ai in tutoring systems on accuracy, effectiveness, and responsibility. – In *2024 IEEE Frontiers in Education Conference (FIE)*, IEEE 9p.
- [16] Nguyen, A., Kremantzis, M., Essien, A., Petrounias, I., Hosseini, S. (2024): Enhancing student engagement through artificial intelligence (AI): Understanding the basics, opportunities, and challenges. – *Journal of University Teaching and Learning Practice* 21(6): 1-13.

- [17] Omeh, C.B., Ayanwale, M.A. (2025): Artificial Intelligence Meets PBL: Transforming Computer-Robotics Programming Motivation and Engagement. – *Frontiers in Education* 10: 12p.
- [18] Porayska-Pomsta, K., Holmes, W., Nemorin, S. (2023): The ethics of AI in education. – *In Handbook of Artificial Intelligence in Education*, Edward Elgar Publishing 33p.
- [19] Tan, L.Y., Hu, S., Yeo, D.J., Cheong, K.H. (2025): Artificial Intelligence-Enabled Adaptive Learning Platforms: A Review. – *Computers and Education: Artificial Intelligence* 9: 12p.
- [20] Selwyn, N., Hillman, T., Bergviken-Rensfeldt, A., Perrotta, C. (2023): Making sense of the digital automation of education. – *Postdigital Science and Education* 5(1): 1-14.
- [21] Su, J., Yang, W. (2024): Artificial Intelligence (AI) literacy in early childhood education: An intervention study in Hong Kong. – *Interactive Learning Environments* 32(9): 5494-5508.
- [22] Wu, F., Lu, C., Zhu, M., Chen, H., Zhu, J., Yu, K., Li, L., Li, M., Chen, Q., Li, X., Cao, X. (2020): Towards a new generation of artificial intelligence in China. – *Nature Machine Intelligence* 2(6): 312-316.
- [23] Zhang, Y., Zhang, M., Wu, L., Li, J. (2025): Digital transition framework for higher education in AI-assisted engineering teaching: Challenge, strategy, and initiatives in China. – *Science & Education* 34(2): 933-954.
- [24] Zou, D., Xie, H., Kohnke, L. (2025): Navigating the Future: Establishing a Framework for Educators' Pedagogic Artificial Intelligence Competence. – *European Journal of Education* 60(2): 16p.