ETDC Indonesian Journal of Research and Educational Review
Volume 5, No. 4, 2026, pp 2318 - 2331
e–ISSN 2809-3682
p–ISSN 2809-7505

https://doi.org/10.51574/ijrer.v5i4.5010

AI-Integrated Classroom Action Research for Enhancing Students' Critical Thinking Skills: A Systematic Review

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Article Info

Article history:

Received May 01, 2026
Accepted July 08, 2026
Published July 10, 2026

Keywords:

Artificial Intelligence;
Classroom Action Research;
Critical Thinking Skills;
Systematic Literature Review.

ABSTRACT

The rapid development of Artificial Intelligence (AI) in education has opened new opportunities for pedagogical innovation, including in the practice of Classroom Action Research (CAR). This study aims to analyze and synthesize how AI is integrated across the CAR cycle and to examine its contribution to the development of students' critical thinking skills. A systematic literature review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. Twenty peer-reviewed articles published between 2023 and 2026, retrieved from Google Scholar, ScienceDirect, and ERIC, were analyzed through thematic categorization and narrative synthesis. AI is no longer positioned merely as an instructional tool; it is increasingly embedded across all stages of the CAR cycle, with the most prominent role emerging in the observation and reflection phases, where it supports learning data analysis and delivers rapid, adaptive feedback. AI integration is associated with improved student engagement and learning outcomes, as well as stronger analytical, evaluative, and argumentation skills. However, the benefits are not automatic: unstructured or excessive use of AI risks fostering dependency and reducing the depth of students' independent thinking. This review offers one of the first comprehensive syntheses of AI integration across the entire CAR cycle—planning, acting, observing, and reflecting—linking it explicitly to critical-thinking development within a reflective, teacher-led inquiry framework, an intersection that remains underexplored in the extant literature.

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1. INTRODUCTION

The transformation of education in the digital era has placed critical thinking among the core competencies that twenty-first-century learning must cultivate (González-Pérez & Ramírez-Montoya, 2022; Yani et al., 2026). Critical thinking encompasses the ability to analyze information in depth (Wibowo et al., 2026), to evaluate arguments (Qadariah et al., 2026), and to make rational decisions when confronted with complex problems

(Nag & Dwivedi, 2024). It is also widely regarded as a key indicator of the quality of a nation's education system.

Empirical evidence, however, suggests that this competency remains underdeveloped among Indonesian learners. The 2022 Programme for International Student Assessment (PISA) reported that Indonesian students achieved a reading literacy score of only 359 points, substantially below the OECD average of 476 points; mathematics and science scores were similarly low, at 366 and 383 points respectively (Ingram et al., 2023; OECD, 2023). These figures indicate persistent difficulty in comprehending information in depth, performing analysis, and evaluating knowledge claims, underscoring the need for pedagogical innovation that moves beyond content delivery toward the deliberate cultivation of higher-order thinking.

Teachers occupy a pivotal position in creating learning environments that stimulate students' critical thinking (Wang & Jia, 2023). Classroom Action Research (CAR) is one of the most relevant approaches for supporting this effort (Primandiri et al., 2025), as it enables teachers to engage in systematic reflection on their instructional practice through the cyclical stages of planning, acting, observing, and reflecting (Siregar et al., 2024). Through this cycle, teachers not only identify emerging problems but also design increasingly contextual and sustainable instructional solutions (Antoci & Borozan, 2024; Nopasari & Muarif, 2025).

Advances in digital technology have simultaneously opened new avenues for instructional innovation, particularly through the adoption of artificial intelligence (AI) (Tarwanto et al., 2025; Wang & Huang, 2025). AI enables computational systems to perform functions that typically require human intelligence, such as information analysis, natural language processing, and the generation of adaptive learning recommendations (Alqahtani et al., 2023; Hariyanto et al., 2025; Sajja et al., 2024). Within education, AI is no longer confined to the role of an instructional aid; it is increasingly positioned as a learning partner that supports cognitive engagement through responsive and interactive information delivery. Several studies report that AI tools, including learning-oriented chatbots such as ChatGPT, contribute positively to the enhancement of students' critical thinking and problem-solving abilities (Aprianto et al., 2025; Zhai et al., 2024).

At the same time, recent scholarship cautions that the integration of AI in education is not without risk. Concerns include potential overreliance on technology, disparities in digital literacy, and the need for critical evaluation of AI-generated information (Ali, 2025; Bauer et al., 2025). These concerns imply that the adoption of AI in learning must be deliberately designed to genuinely support the development of critical thinking rather than functioning merely as a technological convenience (Walter, 2024).

Although research on AI in education has expanded rapidly, most existing studies examine AI predominantly as a medium or tool for instruction (Williamson & Eynon, 2020). Scholarships that explicitly integrates AI into the CAR cycle remains comparatively limited, despite the considerable potential of embedding AI across each stage—from data-informed planning and adaptive instructional implementation to analytics-assisted reflection—for systematically and sustainably improving

instructional quality. Moreover, comprehensive investigations linking AI-integrated CAR with the enhancement of students' critical thinking skills are still scarce, revealing a research gap that spans both the technological dimension and the pedagogical approach required to reconcile technology with teachers' reflective practice.

Building on this gap, the present study aims to analyze and synthesize prior research on the integration of artificial intelligence within classroom action research and its contribution to the enhancement of students' critical thinking skills, using a systematic literature review approach. The novelty of this study lies in providing a comprehensive synthesis of how AI is integrated across the entire CAR cycle—planning, acting, observing, and reflecting—an angle that has received limited attention in prior work. In addition, this study foregrounds the relationship between AI utilization and the development of critical thinking within a reflective and sustainable instructional framework, thereby offering both conceptual and practical contributions to the advancement of instructional innovation in the digital era.

2. METHOD

This study adopted a rigorous systematic literature review (SLR) design, systematically integrated with qualitative descriptive analysis and narrative synthesis, to meticulously investigate the confluence of Artificial Intelligence (AI) implementation within Classroom Action Research (CAR) paradigms and its subsequent impact on fostering students' critical thinking faculties. To ensure a comprehensive and representative sample of literature, electronic research was systematically executed across three preeminent academic databases: Google Scholar, ScienceDirect, and the Education Resources Information Center (ERIC). The search strategy utilized targeted Boolean-aligned keyword configurations, specifically capitalizing on combinations of "Artificial Intelligence in Education," "Classroom Action Research," "AI and Critical Thinking," and "AI in Learning." This robust approach allowed for the capture of diverse empirical perspectives at the intersection of advanced educational technologies and practitioner-led pedagogical inquiry.

To guarantee transparency, reproducibility, and methodological integrity, the study selection process strictly adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, executing a structured four-phase pipeline encompassing identification, screening, eligibility, and final inclusion. The initial electronic database interrogation yielded a preliminary pool of approximately 75 records. During the initial screening phase, titles and abstracts were independently evaluated against predefined inclusion and exclusion criteria, which narrowed the selection to 40 potentially relevant documents. These remaining manuscripts were subjected to a meticulous, full-text critical appraisal to assess their methodological relevance and alignment with the central research objectives. Ultimately, 20 high-quality articles satisfied all stringent eligibility criteria and were synthesized in the final cohort, with the comprehensive, step-by-step selection workflow visually operationalized in Figure 1.

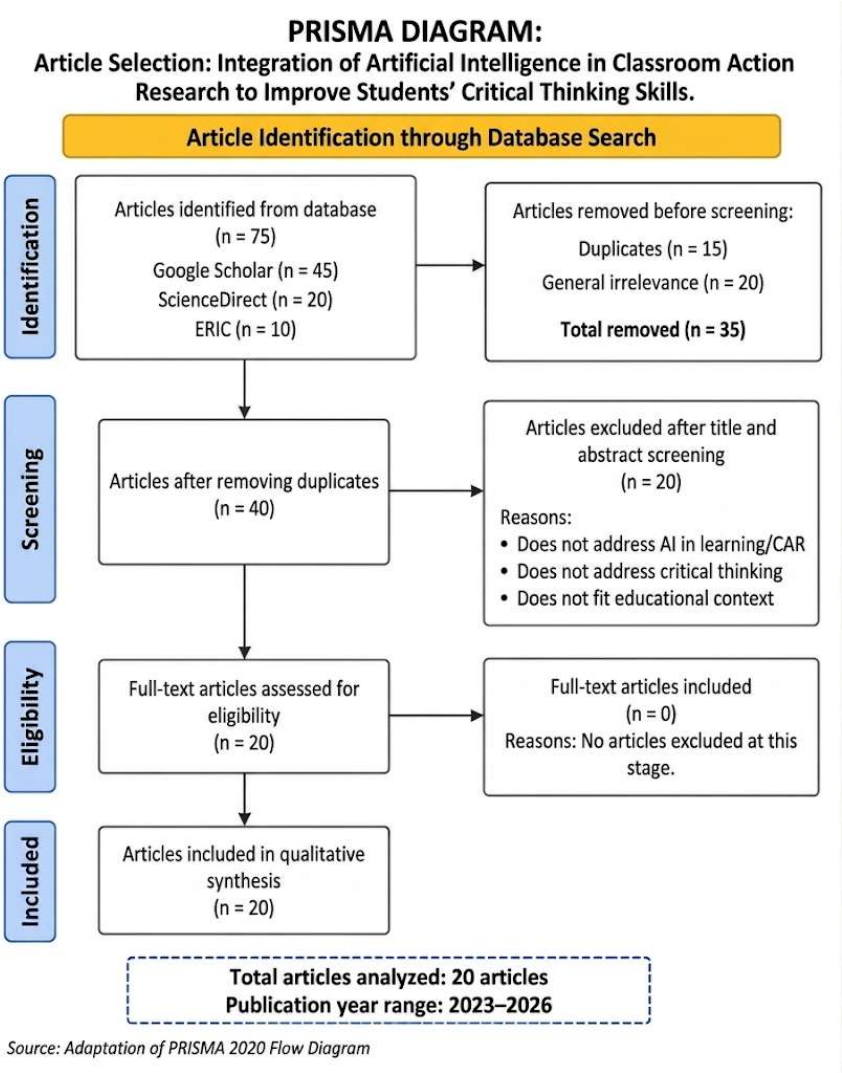

Figure 1. PRISMA Flow Diagram of the Article Selection Process

Table 1 summarizes the inclusion and exclusion criteria applied during the screening and eligibility stages.

Table 1. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Publication year	Published between 2023 and 2026	Published before 2023
Topical relevance	Addresses AI in learning and/or Classroom Action Research	Not related to AI in education or CAR
Construct focus	Examines critical thinking or higher-order thinking skills (HOTS)	Does not address critical thinking / HOTS constructs
Accessibility	Full text available	Full text inaccessible, or lacking a clear scholarly/empirical basis

Articles that were irrelevant to the review's focus, lacked a clear scholarly foundation, or could not be accessed in full text were excluded from the synthesis. Data extraction and analysis proceeded through four stages: (1) data reduction, in which key information from each article—author(s), year, research method, thematic focus, and principal

findings—was extracted; (2) thematic categorization, in which findings were grouped according to recurring conceptual patterns; (3) synthesis mapping, in which categorized findings were presented in a structured synthesis matrix (Table 2) to facilitate cross-study comparison; and (4) narrative synthesis, in which conclusions were drawn based on patterns and tendencies observed across the included studies. This analytic procedure allowed the review to move systematically from discrete study-level findings toward an integrated understanding of how AI relates to both the CAR cycle and the development of critical thinking.

3. RESULTS AND DISCUSSION

Results

This section presents the findings derived from the synthesis of the 20 included articles, organized according to three recurring themes identified during thematic categorization: (1) the utilization of AI within the Classroom Action Research cycle, (2) the contribution of AI to the development of critical thinking skills, and (3) patterns in how AI is positioned across the stages of the CAR cycle. Table 2 summarizes the characteristics and principal findings of each included study; interpretation of these findings is presented subsequently in the Discussion section.

Table 2. Synthesis Matrix of Included Studies

No.	Study (Author, Year)	Method	Focus	Key Finding
1	Sari & Zuraya (2025)	CAR	AI in CAR	AI supported analysis of learning data and feedback provision, strengthening evaluation, reflection, and teachers' capacity to design corrective action.
2	Aripuspita et al. (2026)	CAR	AI in CAR	AI (ChatGPT) provided immediate textual feedback that improved writing skills (grammar, structure, content); scores rose from 68 to 82.8.
3	Pratiwi & Zahra (2026)	CAR	AI in CAR	AI-based drawing tools facilitated idea development and visualization, enhancing creativity, engagement, and learning outcomes.
4	Annastiar et al. (2026)	CAR	AI in CAR	Canva AI increased student engagement through interactive instruction; outcomes rose from 49 to 80.
5	Riyanto et al. (2025)	CAR	AI in CAR	AI as an interactive medium improved social-studies outcomes from 68.79 to 83.10, with significant gains in mastery learning.
6	Putri et al. (2023)	CAR	CAR & Critical Thinking	Project-Based Learning within CAR raised critical-thinking attainment from 33.3% to 80% and improved collaboration/communication.
7	Sopacua et al. (2026)	Meta-analysis	AI & Critical Thinking	AI showed a moderate-to-strong effect on critical thinking and problem-solving (effect size ≈ 0.64–0.83).

No.	Study (Author, Year)	Method	Focus	Key Finding
8	Aprianto et al. (2025)	Quantitative	AI & Critical Thinking	AI (ChatGPT) enhanced higher-order thinking, particularly analysis, evaluation, and problem-solving.
9	Hong et al. (2025)	Action research	AI & Critical Thinking	Generative AI functioned as cognitive scaffolding via structured prompts, enhancing reflection, argumentation, and metacognition.
10	Lawasi et al. (2024)	Mixed methods	AI & Critical Thinking	AI helped students evaluate information and construct arguments, though independent interpretation/verification remained necessary.
11	Vildósola et al. (2025)	Systematic review & meta-analysis	AI & Critical Thinking	AI tools enhanced critical thinking through adaptive feedback and reflective, writing-based activities in language learning.
12	Melisa et al. (2025)	Systematic review	AI & Critical Thinking	AI supported analysis and argumentation, but passive/excessive use reduced independent reflection and depth of thinking.
13	Aini & Putranta (2025)	Quantitative	AI & Critical Thinking	Simulation-based AI facilitated visualization of abstract physics concepts, supporting comprehension and analysis.
14	Arifin et al. (2025)	Systematic review	AI & Critical Thinking	AI aided visualization of abstract mathematical concepts, supporting analysis, contingent on usage strategy.
15	Shukor & Osman (2025)	Systematic review	AI & Critical Thinking	AI increased engagement and conceptual understanding in science through interactive, simulation-based experiences.
16	Syahputra et al. (2024)	Literature & sentiment analysis	AI & Critical Thinking	Problem-based AI integration with real-time feedback supported analysis, evaluation, and reflection.
17	Salido et al. (2025)	Bibliometric & systematic review	AI Integration	AI's effectiveness for critical thinking depended on structured, pedagogically grounded design with scaffolding.
18	Alkhawaja et al. (2025)	Quantitative	AI & HOTS	AI enhanced higher-order skills, including problem-solving and digital literacy.
19	Garzón et al. (2025)	Systematic review	AI in Education	AI improved personalization, motivation, and learning outcomes via adaptive, data-driven systems.
20	Isnur & Alrasi (2026)	Literature study	CAR & Technology	Technology-based CAR strengthened instructional quality, teacher reflection, and 21st-century pedagogical innovation.

AI Utilization within the Classroom Action Research Cycle

Across the reviewed studies, AI was reported to support teachers in analyzing learning data and formulating corrective instructional actions (Sari & Zuraya, 2025), and technology integration more broadly was found to strengthen the quality of reflection and drive instructional innovation within CAR (Isnur & Alrasi, 2026). AI-based tools were also reported to provide direct feedback that helped students incrementally improve the quality of their writing (Aripuspita et al., 2026), to enhance learning outcomes in social studies instruction (Riyanto et al., 2025), to support the development of ideas and visualization in creativity-oriented tasks for early-childhood learners (Pratiwi & Zahra, 2026), and, through interactive media such as Canva AI, to increase student engagement and raise learning outcomes from a mean score of 49 to 80 (Annastiar et al., 2026). In a study combining AI-supported instruction with Project-Based Learning, critical-thinking scores rose from 33.3% to 80%, alongside gains in collaboration and communication (Putri et al., 2023).

Contribution of AI to Critical Thinking Development

A meta-analytic study reported a moderate-to-strong effect of AI integration on critical thinking and problem-solving skills, with effect sizes ranging from approximately 0.64 to 0.83 (Sopacua et al., 2026), consistent with findings that AI use enhances higher-order thinking—particularly analysis, evaluation, and problem-solving—among higher-education students (Aprianto et al., 2025). Generative AI functioning as cognitive scaffolding, delivered through structured prompts and interactive dialogue, was found to enhance reflection, argumentation, and metacognition in EFL writing instruction (Hong et al., 2025), while adaptive AI feedback was reported to help students evaluate information, consider multiple perspectives, and construct more systematic arguments, provided that students retained interpretive and verification responsibility (Lawasi et al., 2024). A systematic review and meta-analysis further linked AI tools to critical-thinking development through adaptive feedback and writing-based reflective activities in language learning (Vildósola et al., 2025). In science and mathematics instruction, AI-based simulation and visualization tools were reported to facilitate comprehension of abstract concepts and to support analytical skills, with effectiveness contingent on how the tools were used (Aini & Putranta, 2025; Arifin et al., 2025; Shukor & Osman, 2025). Conversely, one systematic review reported that passive or excessive AI use could reduce independent reflection and constrain the depth of critical thinking (Melisa et al., 2025), and another study emphasized that the effectiveness of AI in developing critical thinking depends substantially on structured pedagogical design and instructional scaffolding (Salido et al., 2025).

Patterns of AI Integration across the CAR Cycle

Taken together, the included studies indicate that AI functions differently across the four stages of the CAR cycle. In the planning stage, AI was reported to support the identification of students' learning needs. In the acting stage, AI operated as an adaptive and interactive instructional medium. In the observing stage, AI assisted in the

collection and analysis of learning data. In the reflecting stage, AI supported the evaluation of instructional effectiveness and the design of subsequent corrective action. Several studies also associated AI use with gains in personalized learning, motivation, and learning outcomes (Garzón et al., 2025) and with the development of twenty-first-century competencies such as higher-order thinking (Alkhawaja et al., 2025).

Discussion

AI as an Emerging Partner within the CAR Cycle

The results indicate that AI's role within Classroom Action Research is shifting from that of a peripheral technological aid to that of an active participant in the instructional-reflective process. Rather than being confined to content delivery, AI increasingly supports teachers in interpreting the dynamics of student learning at a more granular level. This shift is consistent with the observation that AI enables more data-informed and precisely targeted reflection (Sari & Zuraya, 2025; Isnur & Alrasi, 2026). At the same time, the evidence suggests that this role remains concentrated at the technical level, principally data analysis and feedback provision—while AI's capacity to inform pedagogical decision-making within CAR has not yet been fully realized. This suggests that AI integration in CAR is still at an early, largely instrumental stage of maturity, and a more systematic approach is required before its contribution can become genuinely comprehensive.

The findings on engagement and learning outcomes (Aripuspita et al., 2026; Riyanto et al., 2025; Pratiwi & Zahra, 2026; Annastiar et al., 2026) further suggest that AI's influence within CAR extends beyond cognitive gains to affective and motivational dimensions of learning. However, the evidence involving Project-Based Learning (Putri et al., 2023) indicates that these benefits are not attributable to AI in isolation; rather, they emerge from the interaction between well-designed pedagogical models and technology. This reinforces the position that AI cannot be treated as a stand-alone solution but must instead be embedded within a clearly articulated pedagogical framework.

Mechanisms Linking AI Use to Critical Thinking Development

The moderate-to-strong effect sizes reported in the meta-analytic evidence (Sopacua et al., 2026; Aprianto et al., 2025) indicate that AI's contribution to critical thinking is not incidental but reflects a substantive instructional mechanism. Closer examination of the studies included suggests that this contribution originates less from the technology itself than from the way AI is deployed pedagogically. When positioned as a source of adaptive feedback, AI appears to function as a form of cognitive scaffolding—prompting students to evaluate information, weigh alternative perspectives, and construct arguments more systematically (Lawasi et al., 2024; Hong et al., 2025; Vildósola et al., 2025). This scaffolding function appears to generalize across disciplinary contexts: in language learning it manifests through structured, dialogic feedback, whereas in science and mathematics it manifests through visualization of abstract concepts that reduces the cognitive load associated with comprehension,

thereby freeing cognitive resources for higher-order analysis (Aini & Putranta, 2025; Arifin et al., 2025; Shukor & Osman, 2025).

Nonetheless, the contradictory evidence reported by Melisa et al. (2025) is theoretically significant: it suggests that AI's benefits for critical thinking follow an inverted pattern relative to the degree of student agency retained in the interaction. When students engage with AI passively—accepting outputs without independent evaluation—the scaffolding function appears to collapse into a substitution function, in which AI performs the cognitive work that would otherwise develop the student's own reasoning. This distinction between AI as scaffold versus AI as substitute offers a useful theoretical lens for reconciling the mixed findings across the reviewed literature and underscores that instructional design, not the technology per se, determines whether AI use strengthens or erodes critical thinking.

Toward a Pedagogically Grounded Model of AI–CAR Integration

Conceptually, embedding AI across the CAR cycle offers a more systematic framework for cultivating students' critical thinking, because CAR supplies the reflective, iterative structure through which instructional improvement is continuously enacted, while AI supplies data-informed support at each stage of that structure (Walter, 2024). The pattern identified in the results—AI supporting needs identification in planning, adaptive interaction in acting, data analysis in observing, and evaluative reflection in reflecting—suggests a natural complementarity between the iterative logic of CAR and the data-processing capacity of AI. This complementarity echoes the argument that the effectiveness of AI integration is contingent on structured, scaffolded pedagogical design rather than on technology adoption alone (Salido et al., 2025).

At the same time, this integration carries clear boundary conditions. Frequent, undirected use of AI risks fostering technological dependency and reducing students' inclination to reason independently (Abubakar et al., 2025; Yavich, 2025). Because AI-generated information is not always accurate or contextually appropriate, it must be critically verified by users; absent such verification, misconceptions may be inadvertently reinforced. These boundary conditions reaffirm the centrality of the teacher's role: rather than being displaced by AI, teachers remain essential in directing its use so that it genuinely supports—rather than substitutes for—students' critical thinking.

Theoretical and Practical Implications

Theoretically, this review contributes a synthesis that repositions AI within CAR from an auxiliary tool to an integral, cycle-spanning component of reflective instructional inquiry, while offering a scaffold-versus-substitute framework for interpreting divergent findings on AI and critical thinking. Practically, the findings suggest that teacher professional development should extend beyond technical proficiency in AI tools to encompass pedagogical strategies for structuring AI-mediated tasks—such as requiring students to justify or critique AI-generated output—so that AI use actively demands, rather than replaces, independent reasoning. School leaders and

curriculum designers may likewise consider embedding explicit checkpoints for critical evaluation of AI output within CAR-based lesson cycles to safeguard against passive use.

Limitations and Directions for Future Research

This review is subject to several limitations. First, the synthesis is based on 20 articles drawn from three databases, which, while purposively selected through a PRISMA-guided process, may not capture the full breadth of relevant literature indexed elsewhere. Second, the qualitative, narrative-synthesis approach does not permit a pooled quantitative estimate of AI's effect on critical thinking across the full body of included studies. Third, most of the reviewed studies were conducted within relatively short intervention periods, leaving the long-term and cumulative effects of AI-integrated CAR on critical thinking largely unexamined. Future research would benefit from longitudinal classroom action research designs that track critical-thinking development over successive CAR cycles, as well as from primary studies that explicitly operationalize and empirically test the scaffold-versus-substitute distinction proposed in this review.

4. CONCLUSION

Based on the synthesis of 20 articles, this review concludes that the integration of Artificial Intelligence (AI) within Classroom Action Research (CAR) is no longer confined to the role of an instructional aid but has become embedded within the instructional process across the entire CAR cycle. AI's utilization is most pronounced during the observing and reflecting stages, particularly in supporting the analysis of learning data and the provision of rapid, adaptive feedback. This integration contributes to improved student engagement and learning outcomes while fostering the development of critical thinking skills, particularly in the domains of analysis, evaluation, and argument construction. However, the effectiveness of AI use is not automatic; it depends substantially on the instructional design within which AI is embedded. Undirected use of AI carries the risk of fostering dependency and diminishing the depth of students' independent thinking.

Accordingly, the principal strength of AI within CAR lies in its capacity to support reflective, sustainable, data-informed instruction. This review affirms that the integration of AI must be designed pedagogically, contextually, and systematically so that it functions as a genuine mechanism for strengthening critical thinking rather than as a mere technological convenience—thereby reinforcing AI's position as an integral component of classroom-action-research-based instructional innovation in the digital era.

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