Rethinking Higher Education in the Digital Era: Integrating Artificial Intelligence, Critical Pedagogy, and Complex Thinking for Transformative and Human-Centered Learning

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Abstract. This study examines the integration of artificial intelligence (AI) into higher education through the lens of critical pedagogy and complex thinking. Although AI has been widely adopted to enhance personalization, efficiency, and access to learning, its pedagogical and ethical implications remain insufficiently explored. This study adopts a Systematic Mapping Study (SMS) approach to analyze recent academic literature on AI in education, focusing on its impact on teaching practices, student learning, and institutional dynamics. The findings revealed that AI contributes significantly to adaptive learning environments, student engagement, and competency development. However, it also introduces critical challenges including algorithmic bias, digital inequality, ethical concerns, and overdependence on technology. Furthermore, this study highlights the central role of teachers, showing that factors such as burnout, self-efficacy, and institutional support directly influence the effectiveness of AI integration. Drawing on the theoretical foundations of Paulo Freire, Henry Giroux, and Edgar Morin, this study proposes an integrated conceptual framework that positions AI as a sociotechnical phenomenon embedded in complex educational systems. The study concludes that meaningful AI integration requires a human-centered approach that combines technological innovation with critical awareness, ethical responsibility, and systemic understanding, contributing to the advancement of transformative, equitable, and human-centered higher education systems.

Keywords: Artificial Intelligence in Education; Higher Education; Critical Pedagogy; Complex Thinking; Educational Transformation.

Repensando la Educación Superior en la Era Digital: Integración de la Inteligencia Artificial, la Pedagogía Crítica y el Pensamiento Complejo para un Aprendizaje Transformador y Centrado en lo Humano

Resumen. Este estudio analiza la integración de la inteligencia artificial (IA) en la educación superior desde las perspectivas de la pedagogía crítica y el pensamiento complejo. Si bien la IA ha sido ampliamente adoptada para mejorar la personalización, la eficiencia y el acceso al aprendizaje, sus implicaciones pedagógicas y éticas aún no

han sido suficientemente exploradas. La investigación adopta un enfoque de mapeo sistemático de la literatura para examinar estudios recientes sobre IA en educación, centrándose en su impacto en las prácticas docentes, el aprendizaje estudiantil y las dinámicas institucionales. Los resultados evidencian que la IA contribuye significativamente a entornos de aprendizaje adaptativos, al compromiso estudiantil y al desarrollo de competencias. No obstante, también introduce desafíos críticos, como sesgos algorítmicos, desigualdad digital, preocupaciones éticas y dependencia tecnológica. Asimismo, se destaca el papel central del profesorado, evidenciando que factores como el burnout, la autoeficacia y el apoyo institucional influyen directamente en la efectividad de la integración de la IA. Con base en los fundamentos teóricos de Paulo Freire, Henry Giroux y Edgar Morin, el estudio propone un marco conceptual integrado que posiciona la IA como un fenómeno sociotécnico inmerso en sistemas educativos complejos. Se concluye que su integración significativa requiere un enfoque centrado en lo humano, que articule innovación tecnológica con conciencia crítica, responsabilidad ética y comprensión sistémica, contribuyendo al fortalecimiento de sistemas de educación superior más transformadores, equitativos y centrados en lo humano.

Palabras clave: Inteligencia Artificial en Educación; Educación Superior; Pedagogía Crítica; Pensamiento Complejo; Transformación Educativa.

1 Introduction

Higher education is undergoing profound transformation driven by the rapid integration of artificial intelligence (AI) and digital technologies. These innovations reshape teaching practices, learning environments, and institutional structures, enabling personalized learning, adaptive systems, and data-driven decision-making processes. Despite the growing adoption of AI in education, its pedagogical, ethical, and systemic implications remain insufficiently explored.

Most existing studies have focused on the functional benefits of AI, such as efficiency, scalability, and automation, often overlooking its broader impact on educational processes, teacher roles, and student development. This technocentric perspective risks reducing education to a purely instrumental process and neglecting its critical, social, and transformative dimensions.

From the perspective of critical pedagogy, education should not be limited to knowledge transmission, but must foster critical thinking, reflection, and social transformation. Similarly, complex thinking emphasizes the need to understand educational phenomena as dynamic, interconnected, and context-dependent. Despite their relevance, these perspectives have rarely been integrated into the analysis of AI in higher education (Bishop et al., 2022; İlhan et al., 2025; Rahimi & Sajed, 2014).

Therefore, a critical gap emerges in the literature: the lack of an integrated framework that connects artificial intelligence with critical pedagogy and complex thinking while considering the human and institutional dimensions of education (Pacheco & Herrera, 2023; Silva-Pacheco & Iturra-Herrera, 2021).

In response to this gap, this study aims to analyze the integration of AI in higher education through a systematic mapping of recent academic literature, examining its pedagogical, ethical, and systemic implications. The main contribution of this research lies in proposing an integrated conceptual framework that redefines AI not as a purely technological tool, but as a socio-technical phenomenon embedded in complex educational systems.

2 Theoretical Framework

2.1 Critical Pedagogy in Contemporary Higher Education

Critical pedagogy constitutes a transformative educational framework that challenges traditional models based on passive knowledge transmission and hierarchical teacher–student relationships. Rooted in the seminal work of Paulo Freire and Henry Giroux, education is reconceptualized as a dialogical, emancipatory, and socially situated practice aimed at fostering critical consciousness and collective transformation (Freire, 1970; Giroux, 1988). Rather than viewing students as passive recipients of knowledge, critical pedagogy positions them as active agents that are capable of interrogating and reshaping social realities.

Recent empirical and theoretical studies have reinforced the relevance of critical pedagogy in higher education, particularly in contexts characterized by inequality and rapid technological change. Research indicates that this approach promotes active student engagement, reflexivity, and the capacity to critically examine power structures embedded within educational systems (Calado & Salles, 2015; Htwe, 2026; Walmsley & Wraae, 2022). Furthermore, alternative educational models grounded in resistance pedagogies demonstrate how critical pedagogy can cultivate democratic citizenship and social agency, even in adverse political contexts (Htwe, 2026).

Additionally, critical pedagogy redefines the role of educators as transformative intellectuals who mediate learning processes through dialogue, problematization, and ethical commitment. This perspective emphasizes the interplay between critical thinking and pedagogical practice, highlighting that education is inherently political and cannot be neutral (Rahimi & Sajed, 2014). In contemporary higher education, this is particularly relevant, as institutions increasingly integrate digital technologies that may either reproduce or challenge existing inequalities.

2.2 Complex Thinking and Educational Transformation

The paradigm of complex thinking developed by Morin (1999) provides a systemic and multidimensional framework for understanding educational phenomena as interconnected, dynamic, and context-dependent processes (Morin, 1999). This perspective challenges reductionist approaches that fragment knowledge, advocating instead of integrative thinking that recognizes uncertainty, interdependence, and nonlinearity.

Empirical research highlights that the incorporation of complex thinking in higher education enhances higher-order cognitive skills, including systemic reasoning, critical analysis, and creative problem solving (Pacheco & Herrera, 2023; Silva-Pacheco & Iturra-Herrera, 2021). These competencies are essential for addressing contemporary global challenges that are inherently complex and require interdisciplinary approaches.

Moreover, recent studies have suggested that artificial intelligence can serve as a catalyst for developing complex thinking competencies. For instance, AI-driven learning environments enable adaptive, data-informed, and interdisciplinary learning experiences that support the development of technological entrepreneurship and innovation skills (Alvarez-Icaza et al., 2025). However, this potential must be critically examined to ensure that technological mediation does not oversimplify or instrumentalize complex learning processes.

2.3 Artificial Intelligence in Higher Education

The integration of artificial intelligence into higher education represents one of the most significant transformations in contemporary education systems. AI technologies facilitate personalized learning, automate administrative tasks, and enhance access to educational

resources, thereby contributing to more flexible and scalable learning environments (Holtbrügge et al., 2025).

Simultaneously, the expansion of AI introduces critical ethical and social challenges. Studies have shown that AI systems can reproduce and amplify existing inequalities, particularly when biased datasets or opaque algorithms are involved (Matlin et al., 2025). This raises concerns regarding fairness, accountability, and transparency in educational contexts.

Furthermore, the emergence of generative AI redefines the traditional notions of knowledge production, authorship, and academic integrity. Systematic reviews indicate that generative AI is transforming educational practices by enabling new forms of interaction, creativity, and content generation while simultaneously challenging existing pedagogical frameworks (Chakraborty, 2026). These transformations necessitate a critical and reflexive approach to AI integration into higher education.

2.4 Critical Digital Literacy and Teacher Role

Critical digital literacy has emerged as a fundamental competence in the digital era, extending beyond technical proficiency to include ethical, critical, and reflective engagements with digital technologies. This concept emphasizes the ability of individuals to analyze, evaluate, and question the sociopolitical implications of digital tools and platforms.

Recent research has underscored that the effective integration of digital technologies in education requires comprehensive teacher training that incorporates both technical and pedagogical dimensions (Syahruddin & Agus, 2026). Teachers play a central role in mediating digital learning environments and their competencies directly influence the quality and equity of educational processes.

Moreover, studies highlight that digital literacy must be understood as a socially situated practice shaped by contextual factors such as access, infrastructure, and institutional support. Without a critical perspective, digital literacy initiatives risk reinforcing instrumental and technocratic approaches to education and neglecting broader ethical and social considerations.

2.5 Integration of Critical Pedagogy and Complex Thinking

The articulation of critical pedagogy and complex thinking provides a comprehensive theoretical framework for analyzing educational transformation in the digital era. While critical pedagogy contributes to an ethical and political lens focused on emancipation and social justice, complex thinking offers epistemological tools for understanding the multidimensional and interconnected nature of educational processes.

This integration allows for a more holistic understanding of education, recognizing that technological transformation is not merely a technical phenomenon but also a deeply social, cultural, and political process. It also enables the identification of the tensions between innovation and equity, efficiency and ethics, technological advancement, and human development.

The combined framework supports the development of educational models that are both critically informed and contextually responsive, ensuring that the integration of artificial intelligence contributes to meaningful and socially transformative learning processes.

3 Methodology

This study adopts a Systematic Mapping Study (SMS) approach to provide a structured overview of the research field concerning the integration of artificial intelligence in higher

education. The analysis was based on a structured and systematic selection of academic literature aligned with the defined search strategy and inclusion criteria.

3.1 Research Design

Systematic mapping studies are designed to identify, classify, and analyze the existing literature in a given domain, enabling the identification of research trends, gaps, and emerging directions. Unlike systematic literature reviews that focus on answering highly specific research questions, SMS aims to structure the knowledge base of a research area (Kitchenham, 2004; Petersen et al., 2015).

In this study, the SMS approach was used to analyze how artificial intelligence is integrated into higher education, considering its pedagogical, ethical, technological, and human implications.

3.2 Research Questions (RQ)

To guide the mapping process, the following research questions were defined:

- **RQ1.** What are the main applications of artificial intelligence in higher education?
- **RQ2.** What pedagogical approaches are associated with the use of AI in education?
- **RQ3.** What ethical, social, and institutional challenges emerge from AI integration?
- **RQ4.** Which factors influence the effectiveness of AI implementation, particularly in relation to teachers and students?

These questions provide a structured framework for analyzing the literature and identifying patterns across studies.

3.3 Search Strategy

The search strategy was designed to identify relevant studies related to artificial intelligence in higher education. The main search string used was: ("artificial intelligence" OR "AI" OR "generative AI") AND ("higher education" OR "university" OR "tertiary education") AND ("teaching" OR "learning" OR "education").

The primary search was systematically conducted across four leading electronic databases: Scopus, Web of Science, IEEE Xplore, and ScienceDirect, which provide comprehensive coverage of high-impact literature on both computing education and educational technologies (Martínez, 2016). The search window was strictly bounded between 2015 and 2026 to capture the accelerated evolution of artificial intelligence frameworks and generative models within higher education ecosystems.

To minimize publication bias and ensure a robust knowledge base, the protocol integrated **twelve (12) additional records** during the initial identification phase (as illustrated in the PRISMA diagram). These alternative sources were retrieved via backward and forward snowballing (citation tracking) from the reference lists of highly cited foundational papers, as well as grey literature searches within specialized institutional repositories, specifically targeting contextualized educational reports from Latin American higher education networks. This multilayered search strategy directly supported the comprehensive identification of the multi-perspective approaches required for systemic analysis.

3.4 Inclusion and Exclusion Criteria

Inclusion Criteria: a) peer-reviewed journal articles and conference papers; b) studies focused on AI in higher education; c) research addressing pedagogical, ethical, or technological aspects; d) full-text availability; and e) Publications in English or Spanish.

Exclusion Criteria: a) duplicated studies, b) non-academic publications, c) articles not directly related to higher education, and d) opinion papers without empirical or theoretical contributions.

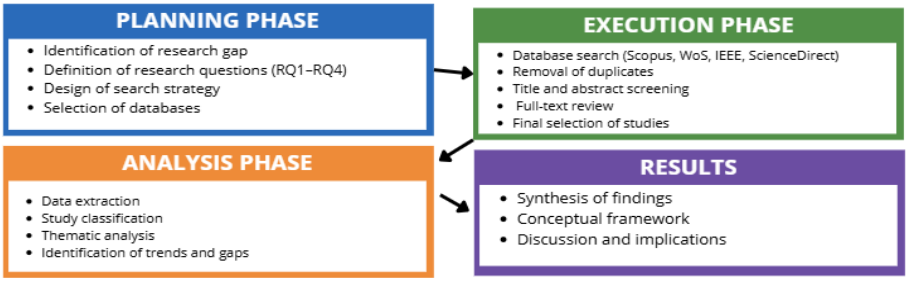

Figure 1. *Systematic Mapping Study process.*

Figure 1 delineates the operational lifecycle of this Systematic Mapping Study (SMS), structured to ensure algorithmic transparency and conceptual alignment. In the Planning Phase, the initial socio-technical research gap was operationalized into four distinct research questions (RQ1–RQ4), bounding the scope of the study to higher education ecosystems. The Execution Phase transited from abstract concepts to an empirical boundary-setting, where the main search string was deployed across Scopus, Web of Science, IEEE Xplore, and ScienceDirect, capturing 145 initial database records and 12 alternative contextual sources. This phase systematically filtered out 25 duplicates and subjected 132 unique items to independent double-blind title and abstract screening, narrowing the pool to 54 papers for rigorous full-text eligibility assessment. Finally, the Analysis Phase driven by our unified coding scheme (as detailed in Section 3.6) categorized the final 25 primary studies into realigned Technological, Pedagogical, Ethical, and Human dimensions. This precise workflow directly facilitated the multi-perspective synthesis, macro-level thematic frequencies, and conceptual conclusions mapped in the Results section.

3.5 Study Selection Process (PRISMA)

To guarantee the reliability, traceability, and strict execution of the systematic mapping study, the study selection process followed a multistage screening pipeline based on the PRISMA guidelines, executed independently by multiple reviewers from the authoring team to mitigate subjective bias.

1. **Identification and De-duplication:** Initial database outputs (***n* = 145**) and additional records (***n* = *12***) were pooled into a reference management system. Automated and manual cross-referencing eliminated 25 duplicate records, leaving 132 unique studies for active screening.
2. **Title and Abstract Screening:** Two reviewers independently evaluated the titles and abstracts of 132 records using predefined inclusion and exclusion criteria. Studies that clearly diverged from the scope of higher education or those that did not involve AI implementation were excluded. Disagreements were resolved through open dialogue and consensus, resulting in the exclusion of 78 records.
3. **Full-Text Eligibility Assessment:** A total of 54 full-text articles were retrieved and subjected to an exhaustive and independent review by three members of the research team. The reviewers evaluated the methodological soundness, presence of clear research questions, and relevance to the pedagogical, ethical, and human dimensions of the study.
4. **Conflict Resolution:** In instances where discrepancies arose regarding article eligibility during the full-text analysis (***n* = 6**), a fourth senior reviewer evaluated the contested papers to make a final determination based strictly on the inclusion protocol. Following

the exclusion of 29 papers that failed to fulfill the rigorous criteria, a final cohort of **25 primary studies** was unanimously selected for data extraction and thematic synthesis.

3.6 Data Extraction

Owing to space limitations enforced by the 55JAIIO guidelines, the bibliographic list of the 25 primary studies was omitted. Data extraction was standardized using a unified conceptual coding scheme, in which qualitative evidence and theoretical frameworks were directly mapped against the research questions (RQ1–RQ4). Consequently, the dimensions synthesized in the Results section represent the rigorous aggregated output of the selected corpus.

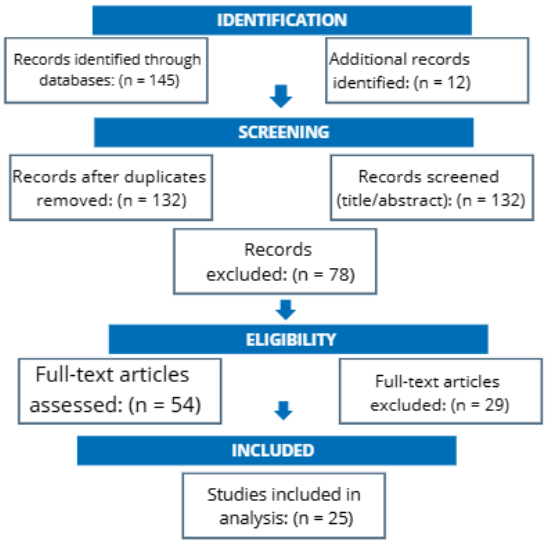

Figure 2. *PRISMA flow diagram of the study selection process for the Systematic Mapping Study.*

Figure 2 shows the PRISMA flow diagram used to describe the study selection process. In total, 157 records were initially identified through database searches and additional sources. After removing duplicates, 132 records remained for screening.

After title and abstract screening, 54 studies were selected for full-text assessment. Ultimately, 25 studies met the inclusion criteria and were included in the analysis.

3.7 Classification Framework

A classification framework was developed to organize and examine the selected studies from a systemic, critical, and multidimensional perspective. To ensure seamless alignment between the protocol and the subsequent synthesis of findings, the literature was categorized into four comprehensive sociotechnical dimensions:

1. **Technological and Teleological Dimension:** Focuses on specific AI applications, generative systems, and automated tools implemented, evaluating how their technical design aligns with overarching educational purposes and institutional scalability (Addressing RQ1).
2. **Pedagogical Mediation and Evaluative Dimension:** Analyzes teaching-learning configurations, adaptive environments, and transformed assessment practices,

identifying whether AI integration fosters dialogical knowledge construction or merely replicates traditional transmission models (Addressing RQ2 and RQ1).

3. **Ethical and Axiological Dimension:** Investigate foundational educational values, algorithmic transparency, data privacy, and digital divides, examining how structural inequalities are either challenged or reproduced by automated implementations (Addressing RQ3).
4. **Human, Contextial, and Training Dimension:** Evaluates the systemic interplay of human factors, focusing on teacher and student well-being, digital literacy demands, professional competencies, and structural pressures such as instructor burnout (Addressing RQ4).

This framework allows for a comprehensive analysis of AI integration in higher education from a systemic perspective.

4 Results and Discussion

The systematic execution of the mapping protocol culminated in the extraction of data from 25 primary studies, published between 2015 and 2026. A macro-level thematic analysis revealed progressive temporal evolution, with 68% (***n***=17) of the selected literature concentrated between 2023 and 2026, capturing the post-generative AI paradigm shift in higher education. Geographically and institutionally, the corpus exhibits a diversified distribution, balanced between empirical case studies (52%, ***n***=13) and theoretical-methodological frameworks (48%, ***n***=12). In terms of primary thematic frequencies, the technological-teleological dimension (RQ1) was addressed by 40% of the papers, pedagogical mediation (RQ2) by 28%, ethical challenges (RQ3) by 16%, and human factors/burnout (RQ4) by 16%. A complete traceable distribution matrix is available in the companion open data repository.

The following analysis is structured around the key dimensions of education, allowing for a comprehensive examination of the implications of digital transformation from both critical and complex perspectives.

The analysis presented in this section was structured according to the key dimensions of education identified in this study. These dimensions were directly aligned with the research questions (RQ1–RQ4), allowing for a comprehensive interpretation of the applications, pedagogical approaches, ethical challenges, and human factors associated with the integration of artificial intelligence in higher education.

4.1 Technological and Teleological Dimension: AI Applications and Educational Purposes (RQ1)

From the perspective of critical pedagogy, educational purposes are inherently linked to the development of critical consciousness and social transformation rather than merely technical or instrumental training (Freire, 1970; Giroux, 1988). This contrasts with the dominant trends in higher education, where digital transformation, particularly through artificial intelligence, tends to emphasize efficiency, scalability, and performance optimization (Holtbrügge et al., 2025).

This tension reveals a fundamental contradiction: while AI-driven systems enable personalized and adaptive learning experiences, they often operate within technocratic frameworks that neglect the ethical and emancipatory dimensions of education (Parra-López et al., 2025). In line with this, recent studies suggest that technological integration alone does not guarantee improvements in educational quality, particularly when pedagogical foundations remain unchanged (Funa & Gabay, 2026).

From the perspective of complex thinking, educational purposes must be understood as dynamic and context dependent, requiring the development of competencies that enable individuals to navigate uncertainty, interdependence, and systemic challenges (Alvarez-Icaza et al., 2025; Morin, 1999). Therefore, the integration of AI should not be reduced to technological adoption but rather reoriented toward fostering critical awareness of its social, ethical, and political implications.

These findings align with those of previous studies that highlight the potential of AI-driven systems to enhance adaptive learning and student engagement (Holtbrügge et al., 2025). However, this contrasts with traditional educational approaches that have historically prioritized standardized instruction and limited student agency.

4.2 Ethical and Axiological Dimension: Systemic Educational Values and Challenges (RQ3)

Critical pedagogy positions education as a value-laden practice, emphasizing principles such as equity, dialogue, participation, and social justice (Stroupe & Hancock II, 2022). However, AI integration introduces new ethical dilemmas that challenge these foundational values.

Empirical evidence indicates that AI systems can reproduce structural inequalities, particularly when they rely on biased datasets or lack transparency (Matlin et al., 2025). This creates a paradox in digital education: Technologies designed to enhance access and inclusion may simultaneously reinforce exclusion and inequity.

From a complex systems perspective, these ethical tensions cannot be analyzed in isolation but must be understood as emerging from the interaction between technological, institutional, and sociocultural factors (Macmillan, 2026; Morin, 1999). In this regard, the persistence of the digital divide and teacher burnout reflects deeper systemic imbalances that undermine the axiological coherence of educational systems (Yao & Abdullah, 2025).

Thus, aligning digital transformation with educational values requires a critical reevaluation of how technologies are designed, implemented, and governed within higher education contexts.

These findings align with research indicating that AI systems can reproduce structural inequalities when implemented without ethical oversight (Matlin et al., 2025). This contrasts with the optimistic perspective, which portrays AI as a neutral and inherently beneficial tool.

4.3 Pedagogical Dimension: Mediation, Learning Environments, and Evolving Assessment Practices (RQ2 & RQ1)

Critical pedagogy conceptualizes pedagogical mediation as a dialogical and problem-posing process that fosters collaborative knowledge construction (Cruz-Alvarado et al., 2017; Freire, 1970; Sandí-Delgado & Sanz, 2020). However, the expansion of digital and AI-mediated environments has introduced new forms of mediation that may either enhance or constrain this dialogical potential.

Research on online education suggests that, without a critical pedagogical foundation, digital environments tend to replicate traditional transmission-based models, reinforcing passive learning behaviors rather than active student engagement (Peuler & Harlow, 2025; Silva-Pacheco & Iturra-Herrera, 2021). This finding aligns with the critique of instrumental approaches to technology, which prioritize functionality over meaningful learning.

From the perspective of complex thinking, learning environments must be understood as dynamic ecosystems shaped by multiple interacting elements, including technological infrastructure, pedagogical strategies, and socio-cultural contexts (Damşa et al., 2025). Consequently, effective pedagogical mediation in digital contexts requires integration of critical and systemic approaches that account for this complexity.

In this sense, AI should not replace pedagogical mediation but rather augment it, enabling more adaptive, contextualized, and participatory learning processes.

From a critical perspective, these results suggest that digital environments can reinforce traditional transmission-based models. This aligns with previous studies on online education but contrasts with the transformative potential attributed to AI in more optimistic narratives.

4.4 Assessment Practices (RQ1)

Assessment practices represent a critical dimension in which tensions between traditional and transformative educational paradigms become evident. Critical pedagogy challenges assessment models based on control, standardization, and memorization advocate for formative, reflective, and participatory evaluation processes.

However, empirical studies indicate that the implementation of such approaches remains limited, as institutional structures often favor standardized and performance-oriented assessment systems (Nyamekye et al., 2024; Stroupe & Hancock II, 2022). This creates a disconnection between pedagogical discourse and practice.

The integration of AI into the assessment further complicates this scenario. Although AI offers opportunities for real-time feedback and adaptive evaluation, it also raises concerns regarding algorithmic bias, data privacy, and the reduction of learning to quantifiable metrics.

From a complex-thinking perspective, assessment must be understood as a multidimensional process that cannot be fully captured through automated systems. Therefore, AI-based assessment tools should be critically integrated to support, not replace, human judgment and pedagogical reflection.

4.5 Teacher Training and Conditions (RQ4)

Teachers play a central role in mediating the integration of AI and digital technology in education. However, current evidence highlights a growing global concern regarding teacher burnout, which significantly affects both teaching quality and student outcomes (Yao & Abdullah, 2025).

From a complex systems perspective, burnout emerges from the interaction of multiple factors, including increased workload, technological demands, institutional pressures, and a lack of support (Macmillan, 2026). This finding suggests that the challenges associated with digital transformation cannot be addressed solely through technological solutions.

Although AI has the potential to support teaching processes, for instance, by automating administrative tasks or providing instructional assistance (Tang & Liao, 2025) —its implementation must be critically examined. Without adequate training and institutional support, AI may exacerbate existing tensions, rather than alleviate them.

Thus, teacher training must move beyond technical skill development to include critical digital literacy, ethical reflections, and pedagogical innovation.

These findings align with those of studies that highlight the impact of teacher burnout on educational quality (Yao & Abdullah, 2025). However, this contrasts with the dominant technological discourses that underestimate the central role of teachers in the digital transformation processes.

4.6 Contextual Analysis: Costa Rica (RQ3)

While the scope of systematic mapping encompasses international literature, the targeted contextual analysis of Costa Rica is methodologically grounded as a critical case study within the SMS protocol. Costa Rica represents a highly specific and illustrative socio-technical ecosystem in Latin America, characterized by robust public university structures undergoing rapid, centralized digital transformation alongside severe structural tensions, such as emerging institutional digital divides and documented spikes in teacher burnout.

Investigating this specific context allows the study to operationalize the abstract global trends identified in the 25 primary studies into localized concrete phenomena. Consequently, this cross-examination provides the necessary empirical grounding to validate the macro-conclusions of the integrated conceptual framework within real-world resource-constrained higher education settings.

From a critical pedagogy perspective, these transformations highlight the risk of adopting technology-driven reforms without addressing underlying social inequalities. At the same time, the prevalence of teacher burnout underscores the need to consider the human and institutional dimensions of educational change.

Applying a complex thinking framework allows for a more nuanced interpretation of these developments, recognizing that educational transformation is shaped by multiple interacting factors, including policy decisions, institutional cultures, and socioeconomic conditions.

These findings align with global trends in digital transformation in higher education but also highlight the importance of contextualizing technological innovation within local socio-economic realities.

4.7 Contribution of the Study

This study contributes to the field by articulating a theoretically grounded framework that integrates critical pedagogy and complex thinking to analyze AI-driven transformations in higher education. Unlike purely technological approaches, this framework emphasizes the ethical, social, and epistemological dimensions of digital transformation.

Furthermore, the study advances the discussion by demonstrating that the challenges associated with AI integration cannot be understood in isolation but must be analyzed within broader educational, institutional, and societal contexts.
In doing so, it provides a foundation for future research and practice aimed at developing equitable, reflective, and context-sensitive educational models.

These findings not only extend the existing literature but also redefine the role of artificial intelligence within a human-centered, critically informed, and systemically grounded educational paradigm, positioning it as a key driver of transformative learning in higher education.

Overall, the findings provide a comprehensive response to the research questions. Specifically, RQ1 was addressed through the systematic identification and analysis of key AI applications in adaptive learning, assessment, and administrative processes; RQ2 through the critical examination of dialogical and pedagogical approaches associated with AI integration; RQ3 through the analysis of ethical, social, and institutional challenges; and RQ4 through the identification of key human and contextual factors influencing effectiveness, particularly those related to teachers and students.

5 Implications for Computing Education

The systematic findings of this socio-technical mapping yield concrete, transformative implications for core computing curricula and informatics pedagogy:

- **Beyond Syntax:** Critical Digital Competencies in Software Engineering: Informatics education must transcend purely technical proficienciessuch as code syntax or algorithmic optimization. Integrating generative AI models (IAG) into programming environments requires sub-disciplines such as Software Engineering and Data Science to embed critical digital competencies into their foundational structures. Students must be explicitly trained in algorithmic auditing, data provenance evaluation, and bias detection

to mitigate the reproduction of structural inequalities embedded within automated systems.

- **Complex Thinking as a Core Computing Architecture:** In alignment with Morin's systemic framework, modern computing pedagogy must transition from reductionist, linear problem-solving paradigms to multidimensional complex thinking. Computing curricula must feature socio-technical project-based learning, in which software design is analyzed as an interconnected, non-linear ecosystem. This ensures that future computing professionals evaluate computational solutions not only by execution efficiency or functional scalability, but also through their systemic impacts on diverse human, institutional, and cultural environments.
- **Emancipatory Pedagogies in Tech-Driven Classrooms:** Computing educators must challenge traditional transmission-based laboratory models by adopting Freirean dialogical practices. Given the rapid adoption of automated grading and AI-assisted instruction, informatics classrooms must leverage these tools to augmentrather than replacehuman mediation. By fostering critical digital literacy as a socially situated practice, computing departments can cultivate democratic citizenship, transforming technology from an instrument of technocratic control into a catalyst for social transformation and equitable engineering practices.

6 Conclusions

The integration of artificial intelligence in higher education represents a profound transformation that transcends technological innovation and demands a reconfiguration of the pedagogical, cognitive, and human dimensions of education. The findings of this study demonstrate that artificial intelligence, particularly through AI-driven hybrid learning and generative AI systems, enhances personalization, engagement, and adaptive learning processes, thereby contributing to more flexible and student-centered educational environments. Empirical evidence confirms that factors such as self-efficacy, emotional engagement, and institutional support play a critical role in shaping student acceptance and effective use of AI in educational contexts (Wang et al., 2025).

However, the study also revealed that the transformative potential of artificial intelligence is not inherently guaranteed. While AI offers significant opportunities for improving learning experiences, it also introduces critical challenges related to ethical use, algorithmic bias, digital inequality, and overdependence on technology. These findings reinforce the need to understand artificial intelligence as a socio-technical phenomenon embedded within complex educational systems, rather than as a neutral or purely instrumental tool (Matlin et al., 2025).

From a critical pedagogy perspective, grounded in the work of Paulo Freire and Henry Giroux, education must move beyond passive knowledge transmission toward the development of critically conscious individuals capable of questioning, interpreting, and transforming their realities (Freire, 1970; Giroux, 1988). In this sense, the integration of artificial intelligence without a critical pedagogical foundation risks reinforcing existing power structures, limiting critical thinking, and perpetuating unexamined assumptions within educational systems.

Furthermore, incorporating Edgar Morin’s perspective, this study highlights that educational transformation must be approached through a lens of complex systems, recognizing the interdependence between technological, pedagogical, institutional, and human factors (Morin, 1999). This perspective becomes particularly relevant when considering the growing phenomenon of teacher burnout, which has emerged as a critical variable affecting educational quality. Evidence shows that teacher burnout negatively

impacts student engagement, instructional effectiveness, and overall learning outcomes, demonstrating that educational innovation cannot be sustained without addressing teachers' well-being (Franco et al., 2025).

In this context, artificial intelligence presents a dual role. On the one hand, it can contribute to alleviating the teacher workload, providing emotional support, and enhancing classroom dynamics through intelligent systems capable of detecting and responding to emotional and cognitive needs. On the other hand, without appropriate pedagogical, ethical, and institutional frameworks, it may exacerbate stress, increase technological demand, and deepen existing inequalities. Therefore, meaningful integration of artificial intelligence requires a human-centered approach that prioritizes both student learning and teacher well-being (Tang & Liao, 2025).

The main contribution of this study lies in proposing an integrated conceptual framework in which artificial intelligence, critical pedagogy, and complex thinking converge to redefine the role of education in the digital era. This integration allows for a shift from instrumental and efficiency-driven uses of technology to transformative educational practices that promote critical awareness, ethical reflection, and systemic understanding.

Finally, this study calls for future research to explore the long-term impact of artificial intelligence on educational equity, critical thinking development, and teacher well-being as well as the design of pedagogical models that ensure responsible, inclusive, and context-sensitive AI integration. Ultimately, the challenge is not merely to incorporate artificial intelligence into education but to ensure that its use contributes to the formation of critically aware, ethically grounded, and socially responsible individuals capable of navigating the complexities of contemporary society.

These findings not only extend the existing literature but also redefine the role of artificial intelligence within a human-centered, critically informed, and systemically grounded educational paradigm, positioning it as a catalyst for transformative learning in higher education.

Authors' Contribution

The authors contributed to the study as follows: Conceptualization, methodology, investigation, validation, writing—original draft preparation, and writing—review and editing.

Competing Interests

The authors have declared that no competing interests exist.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT to improve the language and readability of the manuscript. After using this tool, the authors reviewed and edited the content as necessary and took full responsibility for the content of the publication.

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