

Artificial Intelligence Supporting Education: A Systematic Mapping of Digital Platforms and Unplugged Learning Activities

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Abstract. Artificial Intelligence (AI) has been incorporated into education through adaptive systems, conversational agents, and data-driven environments. In parallel, unplugged approaches have emerged in technologically limited contexts. This work presents a systematic mapping of 151 primary studies on AI-supported education. Results indicate predominance of machine learning systems and conversational agents, especially in higher education. Although less frequent, unplugged approaches enable accessibility in low-resource contexts and conceptual understanding through low-cost practices. Findings suggest an imbalance between technological expansion and pedagogical diversification in AI-supported education, highlighting the need for inclusive models.

1. Introduction

Artificial Intelligence (AI) is profoundly transforming education by enabling personalized learning, automated assessment, and adaptive instructional strategies. The rapid emergence of AI-driven technologies, particularly Large Language Models (LLMs), has intensified scholarly interest in understanding how intelligent systems can enhance teaching and learning across diverse educational contexts [Hmoud et al., 2025]. Despite these advances, integrating AI effectively in education remains challenging. Key concerns include pedagogical efficacy, equitable access, ethical governance, and the balance between technological automation and human-mediated instruction. Moreover, while digital platforms dominate AI education research, alternative strategies are needed to support conceptual understanding in contexts with limited digital infrastructure [Ifenthaler et al., 2024].

Recent studies highlight both digitally mediated and unplugged pedagogical approaches. Digital platforms, including intelligent tutoring systems, adaptive learning environments, and interactive AI tools, facilitate scalable, personalized, and data-driven learning experiences. In parallel, unplugged pedagogical approaches, which support the understanding of AI-related and computational concepts without requiring extensive digital infrastructure, have demonstrated potential to enhance computational thinking, foster embodied cognition, and provide accessible, low-cost learning opportunities [Song et al., 2024, Chen et al., 2023, Dai, 2024]. Unplugged activities have been used to illustrate abstract AI processes such as conversational agents and probabilistic reasoning through tangible simulations and role-based enactments, enabling students to explore complex concepts experientially.

In this context, we conducted a Systematic Mapping (SM) to synthesize research on AI in education, encompassing both digital and unplugged approaches. Our guiding research question was: *What digital platforms and unplugged approaches have been employed to support AI teaching and learning, and what benefits and challenges are associated with these approaches?* In this study, “AI teaching and learning” refers to educational processes supported or mediated by AI-related technologies, rather than exclusively to the teaching of AI as a curricular subject. We analyzed 151 primary studies retrieved from leading scientific databases and augmented through backward and forward snowballing. Data extraction and synthesis followed established SM protocols to ensure rigor, transparency, and reproducibility.

Findings reveal a dual landscape in AI education. Digital platforms predominate, particularly machine learning-based systems, conversational agents, and immersive technologies, offering adaptive, scalable, and analytics-driven pedagogical experiences. Unplugged approaches, though less frequent, emphasize conceptual clarity, engagement, and accessibility, offering alternative pedagogical pathways for supporting AI literacy and computational understanding. Reported benefits include personalized learning, engagement, accessibility, and reduced instructor workload; challenges encompass technical complexity, ethical concerns, infrastructural limitations, and insufficient pedagogical preparation.

The remainder of this paper is organised as follows. Section 2 reviews the related work on AI in education and unplugged learning approaches. Section 3 describes the planning and conduction of the SM, including the research protocol, search strategy, and selection criteria. Section 4 presents the results obtained from the analysis of the selected articles and discusses the implications of these findings for AI in education. Finally, Section 5 concludes the paper and outlines directions for future research.

2. Related Work

Several literature reviews and systematic studies have investigated the integration of artificial intelligence in educational contexts, analysing technological trends, pedagogical applications, and the educational impact of emerging computational technologies [Moroianu et al., 2023]. In parallel, previous studies have also reviewed the role of unplugged pedagogies in computer science and computational thinking education, highlighting the potential of computer-free activities to support conceptual understanding and student engagement [Huang and Looi, 2021]. However, the existing literature often examines digital platforms and unplugged approaches separately, offering limited broader perspectives on how these approaches individually and collectively contribute to AI-supported education.

In this context, [Chen et al., 2023] conducted a systematic literature review and meta-analysis on the effectiveness of unplugged activities for developing computational thinking skills. Their findings indicate that computer-free strategies can significantly support conceptual understanding and student engagement across different educational levels. Nevertheless, the study mainly focuses on computational thinking outcomes and does not explore the broader technological ecosystem of digital platforms and AI-supported educational environments.

In parallel, conceptual and empirical studies have examined the role of AI in education. For example, [Ifenthaler et al., 2024] discuss the opportunities and challenges asso-

ciated with the adoption of AI in educational systems, including ethical, pedagogical, and institutional aspects. Additionally, [Hmoud et al., 2025] analyse the impact of AI-driven immersive technologies on student engagement and satisfaction. Although these studies provide valuable insights into the potential of AI technologies, they tend to focus on specific solutions rather than offering an integrated view of the technological and pedagogical ecosystem supporting AI education.

Unlike previous reviews that focus either on AI-driven educational technologies or on unplugged computational thinking activities separately, this study provides a broader mapping of digitally mediated and unplugged pedagogical approaches employed within AI-supported educational contexts. This perspective enables the identification of complementary pedagogical tendencies, infrastructural constraints, and emerging tensions between technological expansion and educational accessibility.

To address this broader perspective, the present work conducts a systematic mapping of research on AI-supported education that considers both digital platforms and unplugged pedagogical approaches within the same analytical scope. By analysing 151 studies retrieved from major scientific databases and complemented through snowballing procedures, this mapping identifies the principal technological platforms, categorises unplugged instructional strategies, and synthesises the benefits and challenges reported in the literature. This broader analytical scope allows the study to provide a comprehensive overview of the current research landscape and to highlight the complementary roles of digitally mediated and computer-free pedagogical approaches within AI-supported education.

3. Planning and Conduction of the Systematic Mapping

Our SM was conducted between July and August 2025 by researchers with expertise in Software Engineering, Information Systems, Production Systems, and Informatics in Education. We followed the guidelines proposed in [Petersen et al., 2015] and [Kitchenham and Charters, 2007]. This process comprises three primary phases: planning¹, conduction, and reporting. The first two phases are described in this section and the last one in Section 4.

3.1. Planning

Aiming to identify relevant primary studies for this research, we established the following Research Question (RQ): **What digital platforms and unplugged approaches have been employed to support Artificial Intelligence teaching and learning, and what benefits and challenges are associated with these approaches?**

Although the literature commonly distinguishes between Learning AI (the teaching of Artificial Intelligence as a curricular subject) and AI for Learning (the use of AI technologies to support educational processes), the present systematic mapping encompasses studies related to both perspectives. Accordingly, the expression "Artificial Intelligence teaching and learning" is used throughout this paper as an umbrella term encompassing both perspectives. This distinction is adopted to clarify the scope of this study and to avoid ambiguity regarding the interpretation of the research question.

¹The research protocol is available at <https://doi.org/10.5281/zenodo.20493988>

To address this question, we defined a search strategy structured around three main keywords: “learning AI”, “unplugged activities”, and “digital platforms”. To minimize the risk of overlooking relevant studies, synonyms were also incorporated into the search string. Additional terms were identified through consultation with experts from multiple disciplines, including Computer Science and Education, ensuring an interdisciplinary perspective in the refinement of the search strategy.

The search strategy was developed based on the research question. Since the objective was to identify studies on the teaching and learning of Artificial Intelligence supported by digital platforms and unplugged approaches, the search terms were selected to capture the educational approaches investigated in this study. Rather than using broad Artificial Intelligence-related terms, the search strategy prioritized expressions that were more closely aligned with the educational context, aiming to improve the precision of study retrieval.

Following several iterations of refinement and string calibration, the final search string adopted in this systematic mapping is presented below:

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("learning AI" OR "unplugged activities" OR "unplugged gamification")  
AND ("digital educational platforms" OR "educational technologies")
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It is worth highlighting that broad Artificial Intelligence-related terms, including “Artificial Intelligence”, “Machine Learning”, and “Generative AI”, were not included in the search string, as not all studies addressing unplugged computing explicitly employ these expressions. Moreover, terms associated with “digital platforms,” such as “learning platforms,” “AI education,” and “AI teaching”, were not incorporated into the search string. Results from a pilot study indicated that publications retrieved using these synonyms were already captured by the terms included in the final search string. This finding supported the decision to maintain a more parsimonious search expression without compromising the comprehensiveness of the study selection. To reduce the inclusion of studies unrelated to AI-supported educational contexts, the screening process also relied on the inclusion and exclusion criteria to verify whether the selected studies explicitly addressed Artificial Intelligence applications, pedagogical contexts involving AI-related technologies, or computational concepts associated with Artificial Intelligence.

To select the publication databases for this mapping, we followed established criteria reported in the literature [Dieste et al., 2009, Kitchenham and Charters, 2007]. The ACM Digital Library [ACM, 2026], IEEE Xplore [IEEE, 2026], and Scopus [Elsevier, 2026] were chosen due to their recognized relevance to Computer Science and their widespread use in Software Engineering research [Petersen et al., 2015, Kitchenham et al., 2010, Munir et al., 2014]. Semantic Scholar was additionally included because its advanced indexing capabilities support the efficient retrieval of relevant studies across multiple research domains. Furthermore, the systematic mapping was complemented by backward snowballing to identify additional studies not captured through the automated search [Wohlin, 2014].

3.1.1. Inclusion and Exclusion Criteria

We established explicit selection criteria to evaluate the primary studies retrieved from publication databases. These criteria were applied during the first and second screening rounds

to identify relevant studies. To include a study in our mapping, we had four inclusion criteria (IC). (i) **IC1**: Studies that report initiatives aimed at teaching or learning supported by Artificial Intelligence; (ii) **IC2**: Studies that describe practical experiences or propose educational methodologies grounded in unplugged activities; (iii) **IC3**: Studies that examine the use of digital platforms as tools to support teaching and learning processes; and (iv) **IC4**: Studies that present empirical data, results, or critical reflections on the potential application of Artificial Intelligence, unplugged activities, and digital platforms within educational contexts.

Additionally, a set of exclusion criteria (EC) was established to remove studies from our SM. A study was excluded if: (i) **EC1**: Studies that do not directly or indirectly address Artificial Intelligence applied to teaching or learning; (ii) **EC2**: Studies that do not directly or indirectly address the use of unplugged activities in educational contexts; (iii) **EC3**: Studies that do not directly or indirectly examine the use of digital platforms as pedagogical resources; (iii) **EC4**: Studies for which the full text is not available for comprehensive review; (iv) **EC5**: Studies published in languages other than English or Portuguese; (v) **EC6**: Duplicate studies or studies for which a more recent and comprehensive version is available; and (vi) **EC7**: Non-scientific materials or studies lacking analytical depth, such as blogs, news articles, social media posts, or gray literature without adequate theoretical grounding.

Studies were not required to simultaneously address both digital platforms and unplugged activities. Therefore, studies examining either dimension individually or in combination within AI-supported educational contexts were considered eligible.

3.1.2. Data Extraction and Synthesis Method

We managed the data extracted from each primary study using the Parsif.al² tool, Canva³, and Microsoft Excel. The first four authors conducted the data extraction, and the results were subsequently discussed and reviewed by the remaining authors to ensure accuracy and consistency. Concordance meetings were held whenever necessary to resolve disagreements and examine relationships among the data. We then employed qualitative analysis methods to synthesize and present the findings. The data are available at Zenodo⁴.

3.2. Conduction

The primary studies were selected following the protocol described in Section 3.1. A total of 168 studies were obtained: 165 unique studies were recovered from the four publication databases aforementioned. After removing duplicate studies (i.e., 3 of them), 165 studies remained for selection. During the initial selection, the title, abstract, and, when necessary, the introduction of each study were examined according to the established inclusion and exclusion criteria. This process resulted in 124 studies considered potentially relevant. Subsequently, a full-text screening was conducted, and the selection criteria were reapplied to assess eligibility. Following this phase, 112 primary studies were retained for data extraction. Furthermore, 39 additional studies were identified through backward and forward

²<https://parsif.al/>

³<https://www.canva.com/>

⁴<https://doi.org/10.5281/zenodo.20493988>

snowballing, leading to a final sample of 151 included studies. Figure 1 illustrates this process. A spreadsheet containing the primary studies collected, along with their identifier (ID), author names, source, URL, and publication year, are available at Zenodo.

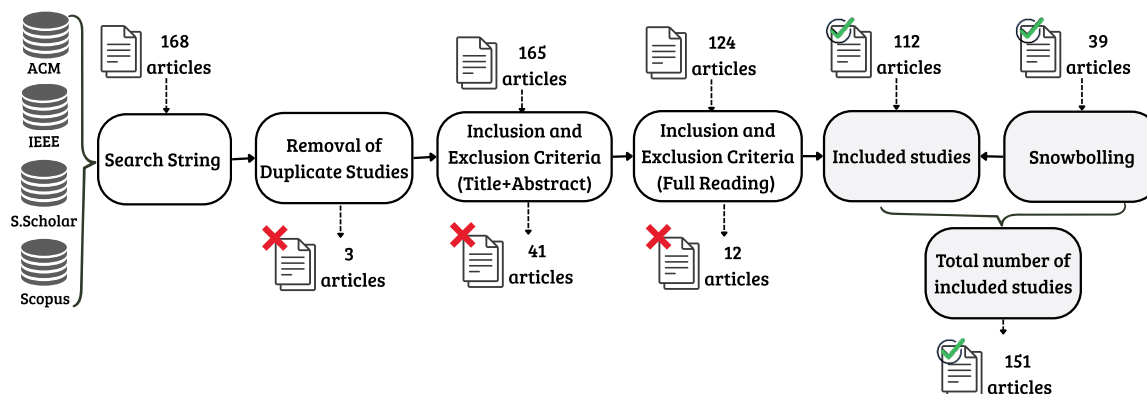


Figure 1. Selection protocol for the proposed systematic mapping.

3.3. Threats to Validity

To enhance the reliability of our SM and reduce potential author-introduced biases [Wohlin et al., 2012], we have identified possible threats to validity and outlined below the measures implemented to mitigate them.

- **External Validity:** Concerns the generalizability of the findings. As noted by Kitchenham and Charters [Kitchenham and Charters, 2007], it is not possible to guarantee the identification of all relevant primary studies. To mitigate this threat, the research protocol was validated with experts, a pilot study was conducted, and clear selection criteria were defined. In addition, widely recognized databases were queried [Petersen et al., 2015, Munir et al., 2014, Kitchenham et al., 2010], complemented by snowballing, and all procedures were documented to ensure transparency.
- **Internal Validity:** Refers to potential biases during study selection and screening. One threat is the design of the search strategy, including keyword choice and database coverage. To reduce this risk, the search string was refined through pilot testing and expert consultation. Multiple digital libraries were searched, and backward and forward snowballing were applied to identify additional studies.
- **Construct Validity:** Concerns whether the operationalization of concepts reflects the research objectives. In this study, threats may arise from how constructs such as Artificial Intelligence, unplugged activities, and digital platforms were interpreted. To mitigate this issue, clear definitions and inclusion and exclusion criteria were established and consistently applied, supported by a pilot selection phase to align researchers.
- **Conclusion Validity:** Relates to the reliability of data collection and analysis. Potential threats include errors in data extraction or inconsistencies in applying selection criteria. To address this, data extraction was conducted by multiple researchers, with disagreements resolved through discussion. Predefined extraction forms and explicit criteria were also used to standardize the evaluation process.

4. Results and Discussions

The following sections present the findings of our SM. First, we provide an overview of the primary studies included in this review. Next, the results are presented according to the

research question addressed in this study.

4.1. General Results

The corpus covers the period from 2002 to 2025; however, most publications are concentrated in recent years. As shown in Figure 2(a) of the companion visualization file, studies published in 2023, 2024, and 2025 alone comprise 82 articles, corresponding to 54.3% of the entire corpus. This distribution highlights a clear increase in publication activity in the most recent years.

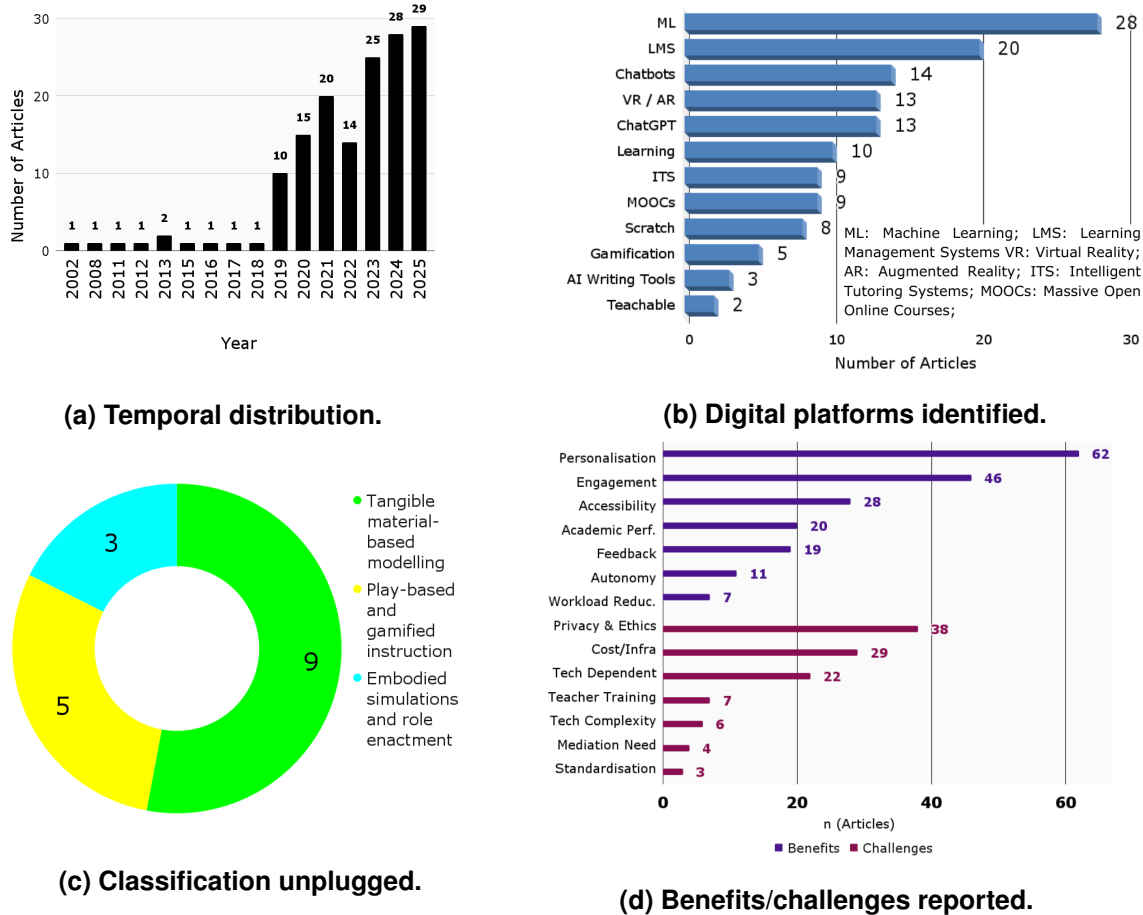


Figure 2. Main results identified in the systematic mapping.

Studies published before 2019 ($n = 8$; 5.3%) predominantly address foundational frameworks for computational thinking and early applications of intelligent tutoring systems. From 2019 onwards ($n = 141$; 93.4%), research increasingly centres on machine learning integration, adaptive platforms, and chatbot-assisted learning. Although large language models such as ChatGPT and Gemini have only emerged more recently, particularly after 2022, earlier studies had already explored conversational agents and educational chat systems that did not yet rely on LLM architectures. This expansion of research activity is also associated with the rapid development and dissemination of various machine learning techniques that enabled new educational applications. The observed increase in publications, from 10 articles in 2019 to 29 in 2025, indicates sustained research interest in the domain during the period analysed.

4.2. Answering the Research Question (RQ)

In this section, we answer the following research question based on the collected articles: “What digital platforms and unplugged approaches have been employed to support Artificial Intelligence teaching and learning, and what benefits and challenges are associated with these approaches?”.

Although frequency analysis allows the identification of dominant technological and pedagogical tendencies in the literature, the reported frequencies should not be interpreted as direct indicators of educational effectiveness or pedagogical superiority, since the mapped studies vary substantially in methodological design, educational context, theoretical grounding, and empirical scope. Therefore, the findings primarily indicate recurrent research tendencies rather than definitive evidence of educational impact.

4.2.1. Digital Platforms Supporting AI-Integrated Education

The analysis examined the digital platforms and technologies employed in AI-integrated educational contexts across the 151 primary studies included in this mapping. Fourteen digital platforms were identified, as illustrated in Figure 2(b). Because individual studies frequently referenced multiple technologies, the reported frequencies represent occurrences rather than mutually exclusive classifications. Among the identified categories, Machine Learning (ML)-based systems and related intelligent computational approaches emerged as the most prominent. This category includes machine learning algorithms, neural network architectures, adaptive assessment mechanisms, and data-driven instructional models. Their prevalence reflects a broader shift in AI-integrated education toward adaptive and analytics-driven pedagogical environments that support learning personalisation, predictive monitoring, and data-informed instructional decision-making. These adaptations frequently involve personalised feedback, dynamic recommendation of learning materials, automated difficulty adjustment, and predictive monitoring of student performance and participation. These trends indicate the consolidation of predictive modelling and data-centric techniques as central technological foundations of contemporary educational innovation. For example, [S01] [Smirnov et al., 2021] describe a hybrid intelligent system for mathematics education that integrates neural network modelling to enhance learning diagnostics and instructional adaptation, demonstrating how AI-driven systems can support structured assessment and targeted pedagogical intervention.

Conversational technologies, particularly chatbots and intelligent conversational agents, also appeared frequently across the corpus. These tools are commonly employed to support tutoring activities, provide automated feedback, and facilitate interactive clarification of learning concepts. The literature generally associates such systems with increased learner engagement and improved accessibility to instructional support, although several studies report challenges related to implementation, pedagogical alignment, and system reliability. Accessibility was associated with continuous tutoring availability, asynchronous interaction, and immediate access to instructional guidance without requiring constant teacher mediation. Learning Management Systems (LMS), particularly platforms such as Moodle, were consistently identified as institutional infrastructures supporting technology-enhanced learning environments and the integration of AI-based educational tools. As discussed by [Oproiu, 2015], Moodle supports the organisation of university-level teaching processes by facilitating communication, content distribution, and blended

learning practices. Within the mapped studies, LMS platforms frequently function as operational environments through which AI-supported activities are implemented, while simultaneously revealing institutional challenges related to digital readiness, instructional design, and pedagogical integration.

The corpus also indicates a diversification of digital learning environments supporting AI-oriented educational practices. Immersive technologies such as virtual and augmented reality, massive open online courses (MOOCs), learning analytics infrastructures, and intelligent tutoring systems were identified across multiple studies. These technologies contribute to experiential learning, scalable course delivery, continuous performance monitoring, and adaptive instructional design. Adaptive instructional design frequently included automated sequencing of activities, personalised content delivery, and learning analytics mechanisms capable of identifying learner difficulties and recommending targeted interventions. Gamification strategies integrated into digital educational ecosystems were also observed, particularly in professional and specialised training contexts. For instance, [S08] [Efremova, 2023] discusses the use of gamification resources in digitally transformed educational environments, highlighting their potential to enhance learner motivation and competency development while acknowledging structural and methodological constraints. Taken together, these findings reveal a heterogeneous and multidimensional technological ecosystem supporting AI-integrated learning.

4.2.2. Unplugged Approaches for AI Literacy and Computational Understanding

Despite the predominance of digital approaches, a subset of studies adopted unplugged pedagogical strategies for teaching artificial intelligence and computational thinking. Seventeen studies (11.3%) incorporated unplugged activities within their instructional designs. Some studies implemented entirely computer-free learning environments, where all activities were conducted through physical interaction, paper-based exercises, and collaborative problem-solving tasks. Others adopted hybrid instructional designs, combining unplugged activities with technological tools so that students first explored computational concepts through tangible or embodied simulations and later interacted with digital platforms. A qualitative categorisation revealed three predominant strategies: (1) tangible material-based modelling, (2) play-based and gamified instruction, and (3) embodied simulations and role enactment. In purely unplugged contexts, these strategies simulated computational processes such as algorithms, sequencing, decomposition, and logical reasoning through physical artefacts and role-based interactions, while in hybrid designs unplugged activities frequently served as an introductory stage for conceptual understanding before engagement with programming environments. Figure 2(c) illustrates the distribution of these strategies: tangible material-based modelling was the most frequent (9 studies), followed by play-based and gamified instruction (5 studies) and embodied simulations and role enactment (3 studies), indicating a strong reliance on physical artefacts to represent computational processes.

Tangible material-based modelling employs manipulable resources such as cards, board games, LEGO blocks, and symbolic artefacts to represent computational structures and AI-related processes, enabling learners to explore concepts like sequencing, classification, pattern recognition, repetition, variables, and conditional logic. For example, [S36][S45] [Threekunrapam and Yasri, 2020, Singhal, 2022] implemented play-based activities using blocks, cards, and sorting tasks to introduce data interpretation, algorithmic

reasoning, and optimisation strategies to preschool learners, demonstrating how physical artefacts can externalise abstract computational processes and support conceptual understanding. Play-based and gamified instruction constitutes a second approach, organising learning through rule-based challenges and collaborative missions without computers; in this context, [S50] [Triantafyllou et al., 2024] developed Computer Science Unplugged activities enriched with gamification mechanics to strengthen computational thinking through collaborative gameplay. A third strategy involves embodied simulations and role enactment, where students physically enact algorithmic roles and decision-making processes, transforming abstract computational mechanisms into observable group dynamics. Through physical interaction and role-based activities, abstract concepts such as sequencing, branching, probabilistic reasoning, and decision-making become observable and experientially accessible to learners, enabling students to experience rule-based logic through movement and interaction [Song et al., 2024]. Recent research also extends unplugged methods to AI-specific topics: [S41] [Connelly et al., 2025] proposed unplugged and hybrid activities to explain large language models (LLMs) through tangible simulations of Natural Language Processing processes such as tokenisation, bag-of-words representations, and probabilistic word selection. Students manipulate word cards, probability wheels, and sentence-building tasks and later experiment with the web-based tool *The Engine Room*⁵, illustrating how AI concepts can be explored without direct interaction with complex machine learning systems.

Across these studies, unplugged approaches emphasise conceptual clarity, embodied cognition, and accessibility. Although less prevalent than digital methodologies, their presence reflects deliberate pedagogical design and offers alternative pedagogical pathways for AI literacy, particularly in contexts with limited technological infrastructure. Because these activities primarily rely on physical artefacts, collaborative interaction, and low-cost materials rather than continuous Internet access or advanced computing devices, they can support participation in schools with restricted technological resources. Empirical evidence also indicates that unplugged activities can contribute measurably to learning outcomes. For instance, [S40] [Namli and Aybek, 2022] reported that integrating unplugged coding activities with block-based programming environments significantly improved fifth-grade students' computational thinking skills, self-efficacy, and academic performance. Overall, the findings show that Artificial Intelligence in Education (AIED) continues to expand, especially through digitally mediated learning environments; recent empirical work reports growing adoption of AI-driven and immersive systems, including the integration of AI and XR technologies to enhance engagement and learning satisfaction [S134] [Hmoud et al., 2025]. However, the analysis indicates that pedagogical integration has not advanced at the same pace as technological development. Consequently, current AIED research reveals a structural duality characterised by the simultaneous presence of AI-supported digital platforms and less frequent unplugged learning approaches: digital methods prioritise automation, scalability, and computational intelligence often in higher education contexts with stronger technological infrastructure, while unplugged approaches foreground cognition, embodiment, conceptual understanding, and inclusion.

⁵<https://maskinrummet.github.io>

4.2.3. Benefits and Challenges

The analysis of the mapped studies revealed several benefits and challenges associated with the integration of AI-based technologies in educational contexts. Based on recurrence analysis and conceptual grouping of the reported findings, eight categories of benefits and eight categories of challenges were identified, as illustrated in Figure 2(d).

Personalisation and adaptive learning emerged as the most frequently reported benefits. These approaches support differentiated instruction by allowing learners to progress at their own pace, receive tailored feedback, and address individual learning needs more effectively. Reported implementations included systems capable of dynamically recommending exercises, adapting task difficulty according to learner performance, and generating automated formative feedback based on interaction data. Engagement and motivation were also widely highlighted across the studies. Interactive tools such as chatbots, gamified learning environments, and virtual or augmented reality applications were associated with increased participation, extended time-on-task, and more active learning behaviours.

Accessibility and inclusion represent additional advantages identified in the literature. AI-supported platforms can help mitigate barriers faced by learners in geographically remote regions, disadvantaged socioeconomic contexts, or those with accessibility needs. The educational benefits associated with AI-supported systems are strongly conditioned by infrastructural and institutional factors. Personalised learning, adaptive feedback, and continuous tutoring depend not only on technological capabilities, but also on adequate digital infrastructure, teacher preparation, and institutional digital readiness [S12] [Akhmetshin et al., 2020]. Consequently, unequal technological conditions may directly affect the accessibility and effectiveness of AI-supported educational practices. Reported barriers included limited access to qualified instructors, geographical isolation, insufficient educational infrastructure, and difficulties in maintaining continuous instructional support. AI-supported systems mitigated these barriers through remote access to educational resources, asynchronous tutoring, automated feedback mechanisms, and adaptive interaction environments. Furthermore, automated feedback mechanisms were frequently reported to improve learning efficiency by enabling timely corrections and reinforcing conceptual understanding during the learning process. Other benefits include reductions in teacher workload through the automation of routine tasks. These reductions were primarily associated with automated grading systems, recommendation mechanisms, attendance monitoring, and AI-assisted evaluation processes. Additional reported benefits include the scalability of digital learning environments and the promotion of student autonomy in self-directed learning activities. However, the mapped studies indicate that empirical evidence demonstrating sustained improvements in long-term academic performance remains relatively limited.

In parallel, several challenges related to the implementation of AI in education were identified. Financial costs and infrastructural constraints were frequently reported as barriers, particularly in low-resource educational environments. Concerns regarding data privacy, ethical implications, and potential algorithmic bias were also prominent, highlighting issues related to transparency, fairness, and data governance in AI-supported systems. Additionally, technical complexity and insufficient teacher preparation were commonly mentioned, indicating the need for improved institutional readiness and professional development for educators.

Some studies also highlighted concerns regarding increasing reliance on digital infrastructures and externally managed educational platforms, particularly in relation to long-term sustainability, information security, institutional readiness, and governance of educational data [S08] [Efremova, 2023]. These challenges reinforce the importance of transparent governance models and critical evaluation of technological dependencies in AI-supported education.

5. Conclusion and Future Work

This systematic mapping provides an overview of current research trends in AI in Education (AIED), revealing a rapidly expanding field characterised by significant technological advances and increasing adoption of AI-based educational tools. The results highlight the predominance of digitally mediated approaches, particularly machine learning systems, conversational agents, and immersive technologies, while also identifying emerging pedagogical strategies such as unplugged activities that emphasise conceptual understanding and accessibility. Despite these advances, the findings indicate that technological development has progressed faster than pedagogical consolidation, suggesting the need for stronger theoretical and instructional foundations.

The analysis also shows a concentration of studies in higher education, highlighting the need for broader empirical research across diverse educational contexts. Although a rigorous systematic protocol was adopted, limitations include the scope of selected databases and reliance on information explicitly reported in the studies. Future research should prioritise longitudinal and large-scale empirical investigations to assess the long-term educational impact of AI. In particular, important research gaps remain regarding the effectiveness of AI-supported and unplugged approaches across different educational levels, the design and evaluation of hybrid pedagogical models combining digital platforms and unplugged activities, and the educational implications of emerging technologies such as Generative AI. Further studies should also develop evidence-based frameworks addressing ethical governance, transparency, teacher training, accessibility, and inclusive design to support the responsible and sustainable integration of AI in education. Addressing these research opportunities may contribute to narrowing the gap between rapid technological advances and pedagogical innovation identified in this systematic mapping.

Using of AI tools

During the preparation of this manuscript, generative AI tools were used to assist with text structuring and grammatical revision. The systematic mapping study was planned and conducted entirely by the authors without AI support.

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