

A scoping study of reviews on artificial intelligence in education

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Abstract

This scoping study synthesizes recent developments in artificial intelligence in education (AIEd), addressing knowledge structures, research priorities, learning theories, ethical considerations, and impact evaluation. A bibliometric analysis of 31 review articles (2019-2023) indexed in Scopus (Social Sciences) was conducted using VOSviewer and complementary statistical methods. The corpus is concentrated in the United Kingdom, Hong Kong, China, Germany, the United States, and Taiwan, with Asian countries accounting for 48.4%. Multidisciplinary journals attract 4.4 times more citations than education-only outlets. Findings indicate a marked rise in AIEd research, primarily led by education-affiliated scholars, yet often lacking robust pedagogical grounding and systematic impact assessment. The prevalence of small samples, limited quantitative rigor, and inconsistent contextual reporting constrain generalizability and inference. To enhance educational relevance and fairness, the field should be anchored in pedagogical frameworks and advanced through collaborative efforts that build stronger theories, methods, and practices responsive to diverse educational needs.

Keywords: artificial intelligence in education, artificial intelligence teaching and learning, pedagogy, cognition, impact evaluation

INTRODUCTION

Artificial intelligence in education (AIEd) is an emergent and interdisciplinary area and field of study that has seen an astonishing development in the last five decades (du Boulay, 2024). It sits at the intersection of education, computer science, artificial intelligence (AI), and cognitive science. AIEd can be considered both an area and a field of study.

As an area, AIEd encompasses various technologies and methodologies that leverage AI techniques to enhance teaching and learning processes. This includes but is not limited to intelligent tutoring systems, adaptive learning and assessment platforms, educational data mining (EDM), natural language processing applications, and personalized learning systems.

As a field of study, AIEd involves research, development, and implementation of AI technologies specifically tailored for educational purposes. Thus,

researchers have been for years exploring ways to improve educational outcomes, optimize teaching methods, personalize learning experiences, and provide tailored support for learners through the application of AI techniques (du Boulay, 2024; du Boulay et al., 1981; Ishmuradova et al. 2025, Nikolopoulou, 2025, Quillian, 1967; Self, 1974). AIEd mobilizes a multitude of people and organizations in society. For example, education institutions are trying to establish AI-based systems (Yang, 2019; Yufei et al., 2020), researchers want to tap into the endless technological possibilities of AI to develop the most effective AI educational models (Kasirye, 2022), and educators and students want to foster excellence and facilitate the teaching-learning-assessment process through AI solutions (Almusaed et al., 2023; Dimitriadou & Lanitis, 2023; Gentile et al., 2023; Paaßen et al., 2022; Vázquez-Cano, 2021).

The growing need for a better understanding of how AIEd has been researched, developed, and implemented was the main motivation for this article. Therefore, the authors envisioned starting by quickly mapping the key

Contribution to the literature

- This article provides a comprehensive and integrative overview of recent developments in the field of AIED by examining how the domain is currently represented in recent review studies.
- It identifies and critically analyzes the main themes and research topics addressed.
- It analyzes the learning theories underpinning the studies, the primary concerns raised by authors along with potential strategies to address them, and approaches to impact evaluation.

concepts underlying the research theme, its main sources, and types of available evidence through the literature review method widely known as scoping review (Arksey & O'Malley, 2005; Levac et al., 2010; Pham et al., 2014). It is a valuable methodological approach when the research theme is complex or has not been comprehensively reviewed before (Pham et al., 2014). A scoping review encompasses evidence from various research methodologies and may incorporate information from non-research outlets, providing answers to broader research questions compared, for example, to the typically more focused systematic review method (Peters et al., 2020). According to Arksey and O'Malley (2005, p. 22), "the method adopted for identifying literature in a scoping study needs to achieve in-depth and broad results. (...) the scoping study method is guided by a requirement to identify all relevant literature regardless of study design".

Since 2019, AIED has been the subject of at least 31 literature reviews (see [Appendix D](#)), addressing several specific topics and making use of various review designs or methods, including systematic review, meta-analysis, narrative review, research synthesis, etc. More than 60% of the scientific production on the topic occurred after 2020, pointing to a sharp growth. To our knowledge, there hasn't been any previous study looking at the content of systematic reviews in order to provide a holistic view of the AIED field.

Therefore, this study pursues two primary objectives:

1. To examine the current representation of the AIED field in recent review articles, focusing on their core research questions, reported limitations, and the contributions of the most influential authors over the past two decades. This includes analyses of co-authorship networks, the emergence of new contributors, geographic diversity, and the longitudinal evolution of thematic content.
2. To identify and critically analyze the principal themes and topics addressed within these AIED studies, with particular attention to the learning theories employed, authors' primary concerns regarding AIED implementation and strategies for mitigation, as well as the approaches and extent of impact evaluation.

As justified above, it follows the five main stages (Arksey & O'Malley, 2005; Levac et al., 2010; Mak & Thomas, 2022) of a scoping study: identifying the research question; identifying relevant studies; study

selection; charting the data; and collating, summarizing, and reporting the results. Thus, the remaining part of the paper is organized as follows: after a brief literature review on AIED, the research questions are explicitly presented. Then, the methods are described. The results section is structured in accordance with the research questions. The paper also includes sections for conclusions, and study limitations. The corpus analyzed is provided in [Appendix D](#), and its references are cited throughout the article.

LITERATURE REVIEW

The term "artificial intelligence" was coined by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon in 1955 when the authors proposed to study AI for two months at Dartmouth College in Hanover, New Hampshire (McCarthy et al., 2006). AI was proposed as a field of study concerned with "the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it." (McCarthy et al., 2006, p. 2).

Early research focused on pioneer computer systems that were intended to help children learn (Robertson, 1976) and it was thought that AI would have an important role through intelligent computer-assisted instruction systems, facilitating student-initiated learning, assisting with educational diagnosis and assessment (Jones, 1985), supporting distance education (Whitson, 1999) and special education (Moore et al., 1985). Some early studies in the application of AIED were presented at the Computer Assisted Learning and Artificial Intelligence and Education conferences held in 1983 (Kaban, 2023), and in the 1983 and 1985 International Conference on Artificial Intelligence and Education, held in Exeter, United Kingdom.

AIED Today

Throughout its evolution, AI has transformed itself from a theoretical concept to a practical technology with widespread applications in various aspects of society. Today it is a broad and interdisciplinary field, encompassing various subfields that focus on different aspects of intelligence emulation and problem solving.

There are numerous applications currently available such as colleague robots (cobots) in early childhood education, adaptive web-based systems, personalized

learning for mobile phones, learning analytics (LA), EDM, and interactive learning environments (Chen et al., 2020a).

The work presented by Rienties et al. (2020) aimed to establish the boundaries between some subfields that have emerged from AIED: computer-supported collaborative learning (CSCL) that explores how learners and teachers can work together online; EDM that explores the learning process when using big data; and LA that tries to understand the learning process and improve it. The authors highlight that many innovations across these subfields are confined to small-scale studies and have limited large-scale adoption. They argue for the necessity of all these subfields working together to advance the theoretical models of learning.

The concern about the lack of new theoretical frameworks is also noted by Chen et al. (2020c). The authors present a systematic overview of AIED research based on 45 highly cited studies published from 1999 to 2016, demonstrating that most studies are related to the application of AI technologies in the contexts of online or web learning and few are about applying AI technologies in the physical classroom.

Feng and Law (2021) reviewed 1,830 research papers from 2010 to 2019 to show that research on AIED was mainly around two themes: intelligent tutoring systems and, since 2014, massive open online courses. They identified the following primary educational issues in AIED research: online, game-based and collaborative learning, assessment, affect, engagement and learning design. The authors conclude that the nature of AIED calls for interdisciplinary collaboration and training to advance.

The importance of inviting educators and researchers to work together in the technological innovation process is also emphasized by Zhang and Aslan (2021), who present a review of AIED papers published between 1993 and 2020.

Concerning the application of AI technologies in education, four key educational domains are explored by Chiu (2023) in a review of 92 articles published from 2010 to 2021: learning, teaching, assessment, and administration. The authors bring up the topic of ethical issues in AIED, highlighting the lack of AIED research on socio-emotional aspects, and draw attention to the necessity of developing new methods to assess the effectiveness of AI systems.

Worries about the possible effects of AIED have also emerged, such as the possibility of AI replacing some roles in education or diminishing the teacher's role (Humble & Mozellius, 2022; Wogu et al., 2018), or even the loss of meaningful teacher-student and student-student interactions (Kamalov et al., 2023). Teachers and students also need time to adapt to new technologies, and many institutions lack financial resources for training, technology acquisition and upgrading, which

could foster future inequalities (Kamalov et al., 2023; Pisica et al., 2023).

There is also a strong debate on AI ethics, with concerns on personal data privacy and security, potential biases in algorithms, accountability towards the actions of algorithms, chatbots and robots (Kamalov et al., 2023; Pisica et al., 2023). AI's psychological implications have been studied, since it could distort the valuable teacher-student relationship, hinder students' interpersonal development, increase narcissistic psychological characteristics, addictive behaviors, intellectual laziness, unethical behavior such as plagiarism (Humble & Mozellius, 2022; Wogu et al., 2018), cause physical harm such as eye problems or obesity (Humble & Mozellius, 2022) or diminish critical thinking abilities (Almusaed et al., 2023).

The lack of critical reflection on the pedagogical and ethical implications, namely privacy concerns about implementing AI, is emphasized by Zawacki-Richter et al. (2019), who reviewed 146 papers about AI in higher education from 2007 to 2018 and provided an overview of AIED applications in four main areas: intelligent tutoring systems, profiling and prediction, adaptive systems and personalization, and assessment and evaluation. The authors conclude that AI-based tools have the potential to support the entire student life cycle, but they claim that "educational technology is not (only) about technology—it is the pedagogical, ethical, social, cultural and economic dimensions of AIED we should be concerned about" (Zawacki-Richter et al., 2019, p. 21).

A quite different point of view is presented by du Boulay (2019) that defends that "pedagogy and cognition have been foci of AIED for a long time as have issues of social and cultural context" (du Boulay, 2024, p. 118). This author claims that it is important to distinguish between the market of AI tools for education and the academic research community (du Boulay, 2024). The last one has been researching and producing results on areas such as learner modelling (Greene et al., 2019; Rebolledo-Mendez et al., 2022) or pedagogic strategies (Aleven et al., 2023). Also, ethical and social issues have been addressed in several studies (Holmes & Porayska-Pomsta, 2023; Williamson et al., 2023).

However, despite the use of AI to advance education, we have yet to fully take advantage of AIED, since "the potential uses of AI in education have yet to be properly investigated and used" (Allam et al., 2023, p. 151), which calls for systematically integrating AI applications into school and university curricula (Huwer et al., 2025).

AIED Impact Evaluation

Addressing the concerns of several authors (Boulay, 2023; Brown, 2022; Perez-Felkner et al., 2024; Zawacki-Richter et al., 2019), the impact evaluation of AIED's interventions, projects, or programs is essential to ensure that these initiatives produce valid, reliable, and

actionable evidence to inform decision-making and improve educational outcomes. Here, 'evidence' means the result of a scientific process. Thus, three main general objectives must be attained from an AIED impact evaluation study. Firstly, changes in the outcome are attributable to that intervention, project, or program. Second, changes in the outcome have scientifically proven magnitude (e.g., Kraft, 2020); third, the sign of the changes indicates benefits in the outcome and that, therefore, a plan for a scalable intervention, project, or program can be the next step.

Its complexity is related to multiple aspects dependent on roles of intervention domains, strategies, goals, outcomes, outputs, levels, and the length of time in determining their effectiveness (Munda et al., 2020; Kraft, 2020; Perez-Felkner et al., 2024). In a broad sense, the educational evaluation setting by ten dimensions (Brown, 2022; Nevo, 1983, 2006) refers to a comprehensive approach that takes into account a multi-faceted view of educational quality and effectiveness, rather than focusing on a single aspect. For it to be considered, an impact evaluation plan would need to include minimum elements such as the goals and specific objectives related to measuring the effects of AIED and the respective outcomes; the methodologies employed to assess these effects (e.g., experimental designs, control groups, and statistical analysis); data collection and analysis aimed at determining the impact of AI on educational outcomes.

Our commitment to understanding the AIED's teaching-learning-assessment experiences in a holistic way prompted us to assess the quality of existing evidence on AIED interventions by synthesizing the corpus and analyzing the outcomes of each study regarding the impact of the evaluation studies conducted.

MATERIALS AND METHODS

The research questions in this study are:

- RQ1.** What is the broad picture of the AIED field concerning disciplinary area, authors by disciplinary area, citation number, authors' geographic origin, and core content?
- RQ2.** What are the main topics covered in AIED reviews?
 - RQ2.1.** Which learning theories are mobilized in AIED?
 - RQ2.2.** What are the main worries about AIED, and how can they be minimized/overcome?
 - RQ2.3.** How is the impact evaluation being conducted in AIED?

A bibliometric analysis aims to use quantitative methods to describe characteristics of publications (e.g., journal articles) and their publication patterns, to assess

the current AIED status and provide insight into its overall structure.

The inexistence of representation of the term "artificial intelligence in education (AIED)" in many thesauri, such as ERIC, the UNESCO Thesaurus or MeSH, made it more difficult to establish the correct term that should be used in databases to ensure precision in retrieving the relevant articles. Stracke et al. (2023) established some guidelines for a standardized protocol into AIED, built on the PRISMA model, but the simplicity of the research string retrieved too many records that would be too difficult to analyze. However, the initial analysis of titles and abstracts pointed us to important terms that were being widely used (such as AIED or artificial intelligence teaching and learning [AITL]). We also realized that the results retrieved a very small amount of medicine articles since "AIED" also stands for "Autoimmune inner ear disease", and "AITL" also stands for "acute insecticide toxicity loading". Therefore, we had to exclude them.

The search string constructed was the following:

((TITLE-ABS-KEY ("AI in education" OR "AI teaching and learning" OR aitol OR "artificial intelligence in education" OR "artificial intelligence and education" OR aied OR "AI-Enhanced education" OR "AI Design Education") AND NOT TITLE-ABS-KEY ("Autoimmune inner ear disease" OR "Acute insecticide toxicity loading")))

The search limits established were:

- Year range: from 2019 to 2023
- Subject area: social sciences
- Document type: article, review
- Publication stage: final
- Source type: journal
- Language: English, Spanish, Portuguese, and French
- Subject filter: Social sciences.

We initiated with a broader search using b-on (a content aggregator portal for the Portuguese consortium of universities and research institutions available at <https://www.b-on.pt>) but realized that most results were on the Scopus database, so we decided to use only this database. In January 2024, a total of 234 results were obtained, and subsequently downloaded to an Excel database. Since many articles were classified by Scopus as reviews (a total of 31), we decided to focus this article on them. We hope to continue our analytical work on the topic dealing with the remaining 204 original papers.

The PRISMA flow diagram (Page et al., 2021; Tricco et al., 2018) is as shown in Figure 1.

RESULTS

The findings and data analysis are organized in alignment with the research questions. In the

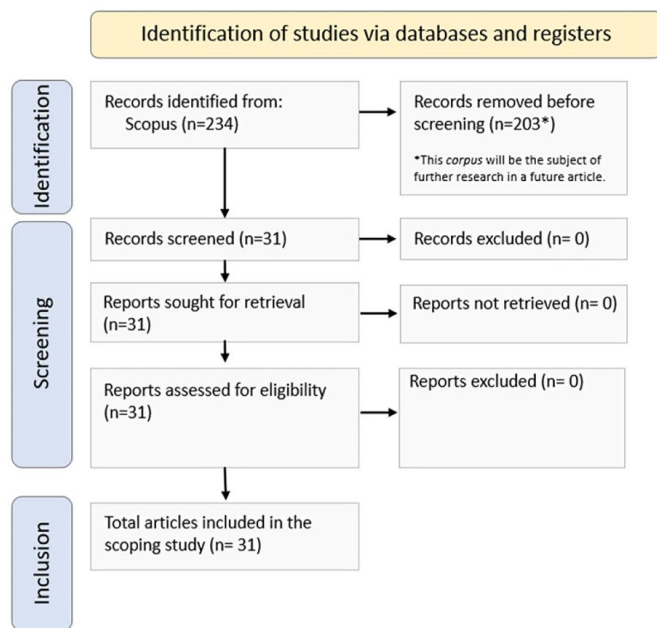


Figure 1. PRISMA flow diagram (Source: Authors' own elaboration)

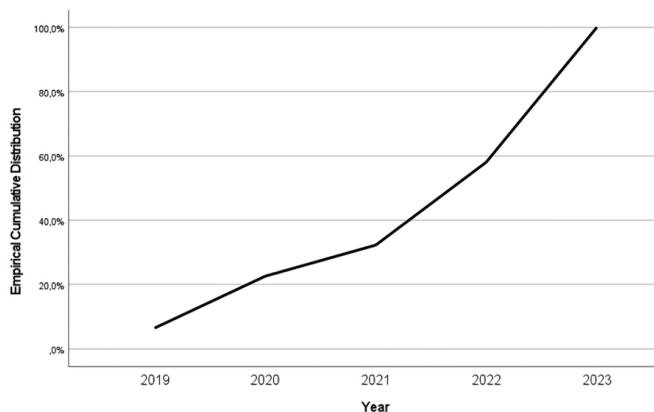


Figure 2. Cumulative distribution over time (Source: Authors' own elaboration)

bibliometric analysis, we report a range of quantitative summary metrics, including the growth rate of the literature, distribution across source titles, article counts and averages by disciplinary area and country, citation statistics, cluster analyses of authors' keywords, co-occurrence patterns of all keywords, and the distribution of the corpus according to the primary aims or research questions.

RQ1. What Is the Broad Picture of the AIED Field Concerning Disciplinary Area, Authors by Disciplinary Area, Citation Number, Authors' Geographic Origin, and Core Content?

The knowledge synthesis represented by the 31 review articles include mostly systematic reviews, and articles mainly published in English (only one article is in French). Other methods of synthesis in use are meta-analysis, critical reviews, bibliometric and mapping analysis.

Table 1. Scopus category for journals

Scopus category	Counts (n)	Percentage (%)
Only education	8	42.1
Education and others	10	52.6
Other than education	1	5.3
Total	19	100

Table 2. Number of authors (average) and disciplinary area

Disciplinary area	Average number of authors	Count (%)
Education	2.76	21 (67.7)
Computer science	2.75	4 (12.9)
Bibliometrics	1.00	1 (3.2)
Other	3.80	5 (16.1)
Total	2.87	31 (100)

Table 3. Articles, their number, and percentage of citations over time

Year	Count articles	Citations	
		Sum	Percentage (%)
2019	2	671	51.4
2020	5	334	25.6
2021	3	82	6.3
2022	8	126	9.6
2023	13	93	7.1
Total	31	1,306	100

In **Figure 2** we can see the distributions by year of publication. Over the last five years (from 2019 to 2023), the number of review articles on AIED published in Scopus indexed journals has increased by 650%. The sharp increase occurs in the post-pandemic years. Considering 2021 as the base year, the growth rate is 267% in 2022 and 433% in 2023. The same is to say that the growth rate is increasing.

Table 1 presents the Scopus category of source titles. We can see that the review articles on AIED were published in 19 different source titles, 18 (94.7%) of them classified in social sciences/education, with 42% in education only (e.g., British Journal of Educational Technology, Cogent Education, and International Journal of STEM Education). Two source titles (Computers & Education and Frontiers in Education) account for the 32% of the published reviews under analysis.

Table 2 indicates the average number of authors per article and their disciplinary area (based on the 1st author affiliation), and we can conclude that the main area is education (67.7%).

Table 3 presents the number of articles, their number and percentage of citations over time. Half of the citations refer to the article titled 'Systematic review of research on AI applications in higher education—where are the educators?' (Zawacki-Richter et al., 2019), whose keywords are "artificial intelligence, higher education, machine learning, intelligent tutoring systems, systematic review" (p. 1). This article reviews

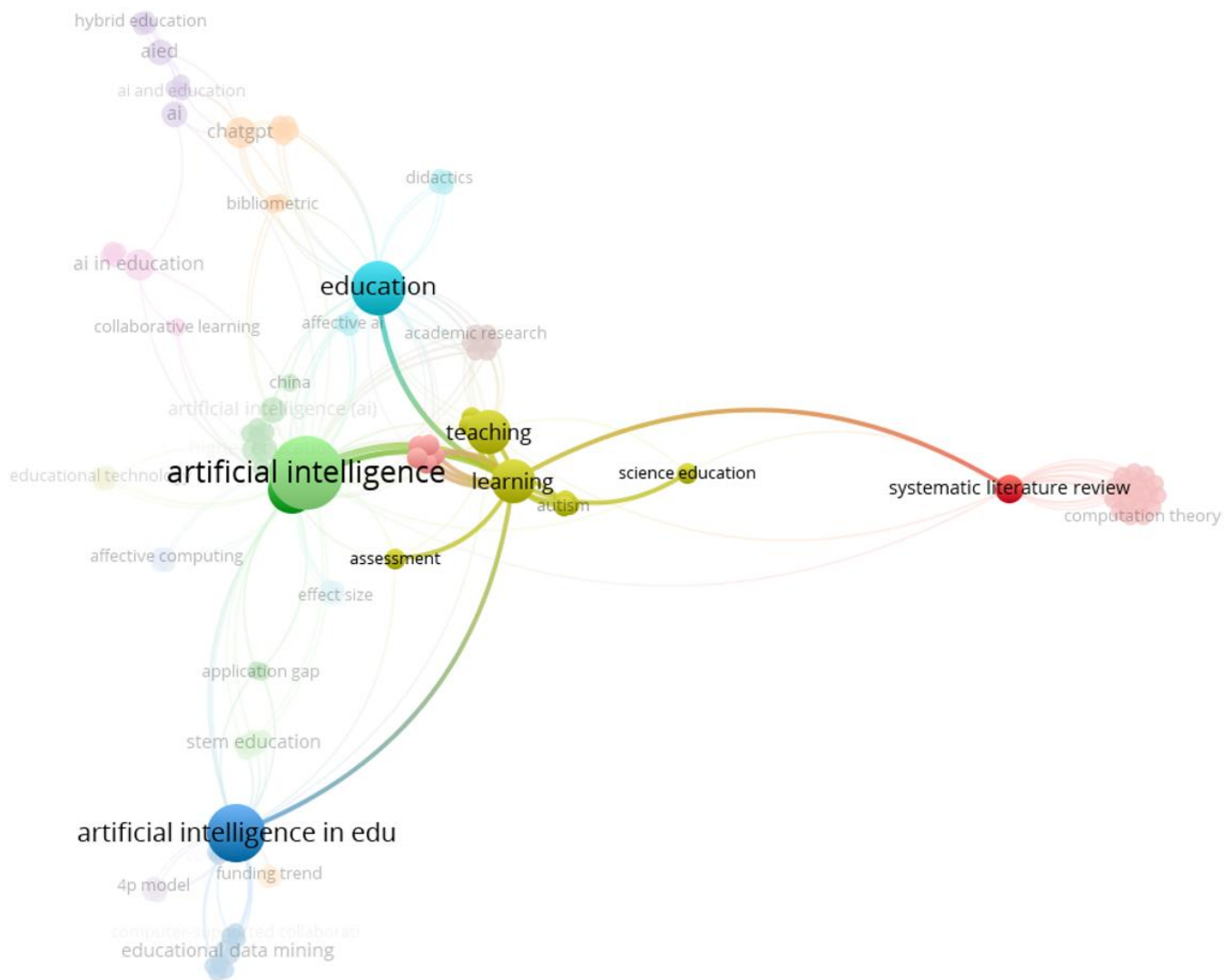


Figure 5. Network visualization of occurrences centered on “learning” (Source: Authors’ own elaboration)

Table 5. Summary of the content of the research questions and aims

Specific content of research questions/aims	Number of research questions/aims
AI applications and technologies in education context	33
Bibliometric analysis of a given subject	13
Learning theories and AI	11
Use of AI to increase student’s engagement/skills	3
Teaching AI	3
Other	2
Implications of current research on future research	1
Parental engagement	1
Risks Implementing AI	1
Connection of AI to other research fields	1
History of AI	1
AIEd grants	1
Public policies implementing AI in education	1

research questions and different subjects, which reiterates not only that AIEd is a multidisciplinary field, but also that it is being currently studied from numerous perspectives. Eleven reviews showed some emphasis about learning theories, and, therefore, a specific study was conducted and presented in RQ2.1.

We also considered it would be important to study the limitations presented by the authors of the articles. In the first analysis, we concluded that 19 articles had a clear “Limitations” section; 8 articles had the limitations written throughout the study (sometimes in the methodology section, others within the conclusions); 5 articles did not present any limitations (Dimitriadou &

Table 6. Methodological limitations identified

Methodological limitations	Articles
The keywords/nomenclature chosen for the search queries	Chiu et al. (2023), Giannakos and Cukurova (2023), Tan et al. (2022), Xu and Ouyang (2022), & Zhang and Aslan (2021)
Lack of a specific search query	Paaßen et al. (2022)
The databases used to retrieve information	Dai and Ke (2022), Nti et al. (2023), Pradana et al. (2023), Qian et al. (2023), Tan et al. (2022), Zawacki-Richter et al. (2019), & Zhang and Aslan (2021)
The typology of documents that has been established	Almusaed et al. (2023), Chen et al. (2020c), Chiu et al. (2023), Reindl (2021), Tan et al. (2022), Xu and Ouyang (2022), Zawacki-Richter et al. (2019), & Zhang and Aslan (2021)
The selected languages	Nti et al. (2023), Pradana et al. (2023), Qian et al. (2023), & Zawacki-Richter et al. (2019)
The restriction to specific subfields	Ahmad et al. (2022), Forestier (2020), Imran and Almusharraf (2023), Kent et al. (2022), Nti et al. (2023), Qian et al. (2023), Reindl (2021), Vázquez-Cano (2021), Xu and Ouyang (2022), Yu and Guo (2023), & Zheng et al. (2023)
The risk of bias identified	Dai and Ke (2022) & Giannakos and Cukurova (2023)

Table 7. Content limitations identified

Content limitations	Articles
The lack of literature/studies on a specific topic	Heeg and Avraamidou (2023), Nti et al. (2023), & Zawacki-Richter et al. (2019)
The existence of very few appropriate studies	Heeg and Avraamidou (2023), Rienties et al. (2020), Vázquez-Cano (2021), Yufei et al. (2020), Zawacki-Richter et al. (2019), & Zheng et al. (2023)
The literature/studies found that do not yet cover the latest developments in the field/subfield	Imran and Almusharraf (2023)
The literature/studies found only cover the latest developments in the field/subfield	Almusaed et al. (2023) & Yu and Guo (2023)
The literature/studies that were found lack concrete empirical evidence	Heeg and Avraamidou (2023) and Yue et al. (2022)
The literature/studies are too generalized	Chiu et al. (2023)
The literature/studies are too specific of a study area or social context	Chen et al. (2020c)
Lack of theoretical definition of crucial subject terms	Tan et al. (2022)
Lack of novel educational theories or theoretical frameworks	Chen et al. (2020b, 2020c)

Lanitis, 2023; Gentile et al., 2023; Vázquez-Cano, 2021; Yang, 2019).

From the analysis undertaken, we concluded that there are two major limitation types in the review studies: methodological limitations and content limitations. The methodological limitations presented by the authors take into consideration various aspects of the search pattern and strategy. In [Table 6](#) authors present difficulties with the keywords chosen for the search queries, which indicate that the field is not yet fully established; limitations in the databases, types of documents, and selected languages used to retrieve information.

The content limitations presented in the reviews refer to constraints regarding the literature/studies, and a considerable number of authors refer to the inexistence of appropriate studies for AIED, which constitutes an indicator that further research is necessary in this field. Other limitations reported were concerned with the lack

of literature on specific topics, the lack of novel educational theories or theoretical frameworks, the lack of concrete empirical evidence, literature that only covers the latest developments or that do not yet cover the latest developments, among other limitations, as presented in [Table 7](#).

An analysis of the time frame of each *corpus* studied in each review was compiled in [Appendix B](#). There were two important groups: the first group includes a corpus beginning in the 20th century (the oldest one starting from 1917 onwards) and ending in the 21st century (the more recent ones go up to 2022), and it is clear that a lot of focus is given in presenting the history of AIED; the second group focuses only on the 21st century, with eight articles having recent coverage, generally starting from (or right after) 2010, and two articles only cover one very recent AI technology—ChatGPT—from 2022 to 2023. There were also 5 reviews that did not present any information about the covered years, which limited the comparison.

RQ2.1. Which learning theories are used in AIED?

An important issue raised when analyzing the corpus was the learning theories used. Therefore, we selected the eleven articles (see [Table 6](#)) that specifically had research questions about these pedagogical theories. However, only 3 of these referred to specific theories (Chen et al., 2020c; Giannakos & Cukurova, 2023; Yue et al., 2022).

Chen et al. (2020c) found six theories proposed by the influential AIED studies (learning styles, situated learning, bi-directional theory, collaborative learning, personalized learning, and adaptive learning theory), and only one proposed theoretical framework (called “theory of movement-pattern perception with the basis of the bi-directional theory personalization”). Chen et al. (2020c) concluded that “educational theories have not been commonly adopted within the influential studies ...” (p. 15).

Yue et al. (2022) separated learning theories (behaviorism, cognitivism, [social] constructivism, constructionism) from pedagogical approaches (direct instruction, hands-on activity only, interactive learning, collaborative learning, inquiry-based learning, participatory learning, game-based learning, project-based learning, design-oriented learning). Yue et al. (2022) concluded that K12 AI education “rely on a broad range of pedagogical approaches owing to their interdisciplinary nature” (p. 19).

Only Giannakos and Cukurova (2023) provided a deeper theoretical basis for multimodal learning analytics (MMLA), separating three different types of theories: theories that focus on cognitive aspects of learning (e.g., Piaget and Bruner); theories that focus on affective aspects of learning (e.g., Moreno and Csikszentmihalyi); theories that focus on the social aspects of learning (e.g., Vygotsky and Moll). In the papers selected for review, the authors also attributed four roles to these learning theories: descriptive role; application role; analysis role; synthesis role. However, they concluded that there wasn’t much focus on learning theories in the selected papers and suggest the MMLA community should “recognize the importance of engaging with learning theory in a mutually beneficial manner, to facilitate a more comprehensive understanding of the learning process and use (or even develop) a scientifically acceptable frame to rationalize observations coming from MMLA research and explain learning phenomena” (Giannakos & Cukurova, 2023, p. 1261).

RQ2.2. What are the main worries about AIED, and how can they be minimized/overcome?

We found many benefits and disadvantages of several AIED technologies, as well as suggestions regarding the means to address the disadvantages. The positive aspects were extensive and diverse, and aiming

at a plethora of digital resources, making data collection, analysis and process very difficult and painstaking. We also believe the over-emphasized positive aspects are due to general enthusiasm with the novelty of some recent technologies, and the eagerness to promote their use.

Therefore, an option was taken to collect data only on the disadvantages of AI technologies applied to education, as well as many considerations regarding the means to minimize or overcome them, since they could provide important insights into further research in specific AIED subjects and technologies.

Our initial analysis revealed that:

- 24 articles mention disadvantages and point out solutions (Chen et al., 2020c; Chiu et al., 2023; Dai & Ke, 2022; Dimitriadou & Lanitis, 2023; Gentile et al., 2023; Giannakos & Cukurova, 2023; Heeg & Avraamidou, 2023; Kent et al., 2022; Paaßen et al., 2022; Pradana et al., 2023; Qian et al., 2023; Reindl, 2021; Rienties et al., 2020; Salas-Pilco & Yang, 2022; Tan et al., 2022; Vázquez-Cano, 2021; Xu & Ouyang, 2022; Yu & Guo, 2023; Yue et al., 2022; Yufei et al., 2020; Zawacki-Richter et al., 2019; Zhang & Aslan, 2021; Zheng et al., 2023).
- 3 articles mention disadvantages but do not offer solutions (Almusaed et al., 2023; Forestier, 2020; Imran & Almusharraf, 2023).
- 4 articles do not refer to any disadvantages (Ahmad et al., 2022; Chen et al., 2020b; Ouyang et al., 2023; Yang, 2019).

Data collection and analysis provided an insight into four theme clusters raised by the largest number of articles: general problems concerning AIED (11 articles); problems with AIED research & methodology (10 articles); problems faced by teachers (8 articles), and AI ethics (7 articles). A detailed list is provided in [Appendix C](#).

Regarding the first cluster, authors indicate difficulties integrating AI in education, namely network infrastructure deficiencies, device and software unreliability, financial barriers both in school and in students’ homes, generalized lack of digital literacy, and the need to develop AI teaching materials together with a unified curriculum standard in order to facilitate teaching and learning. Also, some studies refer to the unclear impact of AI on education, and the possible alienation in teaching spaces. To overcome these problems, authors suggest integrating the technologies with the learning content and pedagogical approaches; engaging teachers, students, and educational researchers; fostering partnership between schools and families; engaging system designers and human stakeholders; developing advanced and innovative algorithms to maximize learning performance and emulate human skills such as teamwork and social skills.

There are also plenty of challenges regarding AIED research and methodology, namely the fact that many studies lack quantitative assessment, do not have appropriate sample sizes, do not clearly present the learning domains, the types of organization, and other important context information. It was also noted that there was a generalized lack of critical reflection on the risks of implementing AI technologies, together with the lack of analysis of the pedagogical and ethical implications. Frequently, research is scarce in specific contexts (e.g., emotion AI; integration of AIED with CSCL, EDM and LA; intersection of AI, education, and creativity) and, overall, AIED research is still scattered and not organized. To overcome these problems, authors suggested the need for further research in a multitude of specific contexts, as well as the need for interdisciplinary research. Furthermore, the field of study needs to have deeper theoretical and methodological foundations (e.g., explicit theories that underpin empirical studies; development of quantitative and qualitative assessment methods; establishment of the types of data that should be used in AI models).

Cluster three focuses on the challenges faced specifically by teachers. Authors often refer to low levels of digital skills, difficulties keeping pace with ever-evolving technologies, and insufficient training about AI technologies. Teachers often feel unable to teach students how to use AI technologies effectively and frequently face problems with equipment. Authors refer that these challenges can be minimized by empowering the teacher's role in our society, by designing and implementing innovative teaching methods that could foster students' 21st century skills, by providing ongoing professional training, and fostering teachers' collaboration with AI developers.

Cluster four presents important insights into a generalized lack of critical awareness of AI ethics. Furthermore, there is insufficient research on this subject, and the studies that address AI ethics lack critical reflection on the risks of implementing AI, and on the pedagogical implications. This can only be overcome with extensive further research.

RQ2.3. How is the impact evaluation being conducted in AIED?

Three out of the 31 review articles searched for works that examine the effects of using AI in education (Heeg & Avraamidou, 2023; Xu & Ouyang, 2022; Zheng et al., 2023). By comparing the corpus of these three studies, it can be observed that they share two or fewer papers, indicating that they are distinct studies that will be analyzed next.

The study conducted by Heeg and Avraamidou (2023) reviews 22 articles published between 2010 and 2021 with the goal of evaluating, among other factors, the impact of AI applications on science education in

schools. The paper demonstrates that the impact on students' learning achievements, scientific argumentation skills, or learning experiences, as identified in 17 studies, was mainly assessed using quantitative methods involving pre- and post-tests. Seven studies used mixed methods that, besides pre- and post-tests, incorporated interviews, surveys, or questionnaires. Only one study is purely qualitative, based on interviews, surveys, and observations. Two of the studies were classified as experimental, two as quasi-experimental, and the remaining were observational.

Regarding the sample size used in the studies, six studies had a sample size smaller than 50, eight studies had a sample size between 50 and 300, and three studies had a sample size greater than 300. The AI applications under study were essentially the following: intelligent tutoring systems, adaptive learning systems, and automatic assessment & feedback tools. Besides the study of the impact on learning achievements, seven papers also discussed the impact of AI applications on science teaching. However, the studies only presented design concepts and did not evaluate actual teaching practices by educators. A potential positive impact is mainly reported in time-consuming tasks, such as learning assessment through automated tools, or the use of predictive models to identify students who require additional assistance.

The authors' conclusion is that while most of the studies reveal a positive impact of AI applications, in the reviewed corpus there is not sufficient concrete empirical evidence to support claims about the impact of AI in science education. "The majority of the studies reviewed have used quantitative methods that lack depth and attention at the microlevel aspects of learning" (Heeg & Avraamidou, 2023, p. 145).

The research outlined in Xu and Ouyang (2022) scrutinizes 24 papers spanning from 2011 to 2021, with the aim of addressing the research question, "What are the effects of AI in STEM education?" The investigation delved into various facets such as learning performance, affective perception, and high-order thinking. Among the 22 papers discussing the impact on students' learning performance, only two studies found no significant effect when employing AI technologies. Conversely, the remaining papers unanimously reported a noteworthy positive impact. The emotional perception impact was examined in 17 studies, indicating that most of the majority of students showed positive attitudes towards the utilization of AI. The impact of AI on students' higher-order thinking skills was reported in seven papers and it was also found to be positive. The authors call attention to the fact that, "since AI-STEM is a highly technology-dependent field, some studies might highlight the technology rather than the educational context" (Xu & Ouyang, 2022, p. 16).

The final work examines the impact of AI on learning achievement and perception by calculating its effect size (Zheng et al., 2023). Effect size quantifies the magnitude of the relationship between variables or the difference between groups, and its value is influenced by the number of moderating variables included in the model. This raises the question of whether such relationships are truly comparable, making the quantification of heterogeneity essential. All studies included in this work meet the following criteria: they are experimental or quasi-experimental, include both an experimental and a control group, and report learning achievements for both groups to enable effect size calculation. Thirteen moderator variables were considered: educational level, sample size, learning domains, learning methods, research design, research design, research settings, intervention duration, types of organization, role of AI, areas of AI applications, AI software, AI hardware, and AI technologies.

The results indicate that the overall effect size of using AI for learning achievement is high, although the heterogeneity test revealed that this effect size is not uniform. In contrast, the overall effect size for students' learning perception is small and similarly heterogeneous. Furthermore, the effect size for each moderator variable related to learning achievement was calculated. The authors conclude: "Researchers who seek to use AI to improve learning achievement and perception should consider an appropriate sample size, learning domains, types of organization, and AI software and hardware" (Zheng et al., 2023, p. 5661).

Analyzing the results presented in detail, we can note the following: the variability among the effect size of the 24 studies is high. This evidence suggests that studies may be measuring different incomparable phenomena or that there are methodological differences between studies that may make their results not comparable. The number of studies is limited, especially for comparisons between groups defined by moderate variables. Moreover, each study's sample size is mostly less than 300 cases (in 96% of the studies), implying that the respective population representativeness could be compromised. This is a major concern in terms of the inferential potential of the study's findings, and successful generalization of AIED methodology.

LIMITATIONS AND FUTURE RESEARCH

The results presented above may be affected by the methodological design of this study, namely the fact that we deliberately chose a corpus indexed in the Scopus database, wanting to investigate the social sciences subject area. Additionally, we only took into consideration the articles classified as "review" in Scopus. While developing this scoping study, we detected that from the initial selected papers, some reviews in nature were not classified as such, and

therefore, not included in our analysis (Cox, 2021; Feng & Law, 2021).

This scoping study identified several opportunities for future research as AIED undergoes significant advances. Suggested directions include:

- (1) conducting mixed-method analyses of original articles,
- (2) expanding the corpus by exploring other databases, especially in engineering and computer science,
- (3) investigating public policies on AIED implementation across countries,
- (4) examining AIED's impact on teachers' professional development and students' learning in relation to learning theories,
- (5) deepening contextual studies on participants, institutions, technologies, and cultural factors, and
- (6) exploring the relationship between the COVID-19 pandemic and AI development.

Future AIED research should strengthen theoretical foundations by integrating robust pedagogical frameworks, enhance methodological rigor with larger samples and standardized methods, and expand interdisciplinary collaboration. Ethical concerns like data privacy and responsible AI deployment require increased focus, alongside broadening geographic diversity to ensure culturally sensitive, inclusive development.

CONCLUSIONS

This review summarizes how the AIED field has been developed to identify trends related to the main themes and subjects addressed. Our analysis of 31 review articles shows a remarkable 650% increase in the publication of review articles on the topic, mainly from 2020 onwards, mostly developed by researchers whose main disciplinary area is education.

Our results suggest that the systematic review method is the one more frequently chosen, that 94.7% of source titles are classified by Scopus in education and, on average, the number of authors per paper is less than three. Regarding citation statistics, on average, papers published in journals classified simultaneously in education and in other categories are cited 4.4 more times than articles published in journals classified solely in education. The geographic origin of papers as assessed by their first author affiliation is mostly from China and the share of Asian countries (China, Hong Kong, and Taiwan) is 48.4% of the corpus. Moreover, six countries account for 77% of the corpus.

The multidisciplinary/interdisciplinary essence of the AIED field was clear in the numerous authors' keywords, the majority of which being fundamentally

from the area of education. In addition, the content analysis of the research questions and/or aims suggests that the topics more frequently addressed are related to AI applications and technologies in educational contexts, bibliometric analysis of a given subject, and learning theories and AI. Thus, the exploration of the content of all research questions or topics led to the conclusion that although the majority were about AI applications and technologies, there were numerous others about diverse subjects such as the teacher's role, the use of AI to increase student's engagement or skills, concerns about AI implications and consequences, learning theories about AI, among many others.

The study of the methodological and content limitations of the reviews led us to conclude that there is still a profound lack of literature on AIED. Our research also selected eleven articles that specifically had research questions about pedagogical theories, but we realized that only three referred to specific theories. This highlights a generalized lack of studies on the learning theories that should form the foundation for AIED implementation.

The analysis of the worries about AI technologies in education presented an excellent opportunity for researchers to improve AIED research & methodology, and to develop specific research on topics such as the impact of AIED on teaching practices and AIED ethics.

The impact evaluation of AIED interventions, projects, or programs revealed several methodological frailties. These include a very small number of articles analysed, insufficient empirical evidence to support claims about the impact of AI, an emphasis on technology rather than the educational context in AI-STEM studies, and studies that may be measuring different, incomparable phenomena or have methodological differences that make their results not comparable.

Overall, AI has the potential to enhance teaching and learning experiences, promote individualized instruction, improve educational outcomes, and increase accessibility and inclusion in education. However, it is important to address ethical considerations, data privacy concerns, and ensure that AI technologies are deployed responsibly and ethically in educational settings.

The findings of this review provide valuable insights for both policymakers and educators. The sharp increase in AIED-related research, particularly since 2020, underscores the need for strategic policy initiatives to support evidence-based adoption of AI in education, with clear ethical guidelines and data privacy regulations. The geographic concentration of studies, predominantly from Asia, suggests that global policy efforts could help reduce disparities in AIED research and foster international collaboration. For educators, the results highlight the importance of integrating AI tools within solid pedagogical frameworks, as the current

literature reveals a significant lack of grounding in learning theories. Educators can leverage AI's potential for individualized instruction, engagement, and inclusion, but must remain critical of tools that prioritize technology over educational context. Overall, this study encourages stakeholders to promote responsible and theory-informed AIED practices that enhance both teaching and learning.

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APPENDIX A

Table A1. Research questions or aims

Reference	Research questions or aims	Review type
Imran and Almusharraf (2023, p. 2)	(...) this current study is set to contribute to the state-of-art of ChatGPT in teaching and learning as a writing assistant by presenting a systematic literature review. In addition, this study examines the gaps and so-far unexplored areas of ChatGPT chatbot (...).	Systematic
Nti et al. (2022, p. 58)	RQ1. What are the growing trends in SCTAE research in Africa? RQ2. Which authors, papers, and institutions in the SCTAE literature in Africa have had the highest impact on citations over the last 61years? RQ3. What is the intellectual framework of the SCTAE knowledge base in Africa? RQ4. What issues in the SCTAE literature have received the most attention and have been studied most frequently in Africa?	Bibliometric analysis
Heeg and Avraamidou (2023, p. 126)	(1) What types of AI applications are used in school science? (2) For what teaching content are AI applications in school science used? (3) What is the impact of AI applications on teaching and learning of school science?	Systematic
Ouyang et al. (2023, p. 411)	RQ1: What are the functions of AI applications in STEM educational assessment? RQ2: What AI algorithms are used to achieve those functions in STEM educational assessment? RQ3: What are the effects of AI applications in STEM educational assessment?	Systematic
Pradana et al. (2023, p. 2)	This study aims to fill this gap by reviewing the available literature in the broad field of ChatGPT in education sector, identifying the main contributing authors, journals, and keywords through bibliometric analysis and suggesting future research directions related to different ChatGPT in education sector.	Systematic and bibliometric analysis
Gentile et al. (2023, p. 01)	(...) this study analyses the change in the teacher's role triggered by the integration of AI into educational systems.	Systematic
Almusaed et al. (2023, p. 1)	This article examines the advantages and disadvantages of hybrid education and the optimal approaches for incorporating AI in educational settings.	Review analysis
Yu and Guo (2023, p. 1)	This article provides a detailed overview of the development and technical support of generative AI. It conducts an in-depth analysis of the current application of generative AI in the field of education and identifies problems in four aspects: opacity and unexplainability, data privacy and security, personalization and fairness, and effectiveness and reliability.	-
Dimitriadou and Lanitis (2023, p. 3)	(...) the main contribution of this survey includes the review of the latest technologies and discussion of future directions that could support the creation of a next-generation smart classroom, and the understanding of the use of AI in connection to the technologies used in a smart classroom (...)	-
Giannakos and Cukurova (2023, p. 1249)	(RQ). What is the role of learning theory in MMLA research and to what extent can MMLA research advance learning theory? To address this RQ, we investigate the following sub-RQs: (RQ1). Which theoretical positions and theories of learning are used in MMLA research, and how are they used? (RQ2). What is the relationship between the theories used in MMLA and the data modalities? (RQ3). What is the relationship between the theories used in MMLA and the intended goals of researchers?	Semi-systematic
Qian et al. (2023, p. 3)	(1) What factors influence learners' willingness, efficiency, and improvement of skills to adopt the metaverse in education? (2) What strategies, frameworks, and ecosystems support metaverse teaching, and how can a comprehensive teaching paradigm be developed? (3) What metaverse platforms (commercial or self-developed) are applicable for teaching purposes? (4) What are the various types of software used in metaverse education, and what supportive hardware is necessary to facilitate their use? (5) What are the potentials of generative AI and metaverse synergy in education?	Systematic
Dai and Ke (2022, p. 2)	(...) the research question guiding this systematic exploration is: What are the trends of educational applications using AI in simulation-based learning?	Systematic mapping review
Zhang and Aslan (2021, p. 2)	1. What is the landscape of research publications on AIED in the Web of Science Database and selected AIED specialized journals? 2. What are the AIED Technology applications and their educational benefits, as reported in eligible research publications? 3. What implications does current research have on future research and practice of AIED?	Comprehensive review
Chiu et al. (2023, p. 2)	RQ1. How do AI technologies support learning, teaching, assessment, and administration in education, and what are the challenges in their research and development? RQ2. What student and teacher learning outcomes are fostered by AI technologies?	Systematic
Tan et al. (2022, p. 2)	1. What are the main characteristics of studies focusing on collaborative learning supported by AI in terms of publication year, interaction platforms, group size, and learner types?	Systematic

Table A1 (Continued). Research questions or aims

Reference	Research questions or aims	Review type
Vázquez-Cano (2021, p. 7)	This study is a review article, which presents a brief literature review on the possible applications and functionalities of AI in education.	Brief review
Zheng et al. (2023, p. 5651)	1. What is the overall effectiveness of AI on students' learning achievement and perception? 2. How do various moderator variables influence the effects of AI?	Meta-analysis
Salas-Pilco and Yang (2022, p. 2)	1. RQ1. What and how AI-based applications are being used by higher education institutions in Latin America? 2. RQ2. What are the common AI techniques, software tools, and AI algorithms used in Latin American higher education? 3. RQ3. What education topics and issues are being addressed by AI applications in Latin American higher education institutions?	Systematic
Ahmad et al. (2022, p. 2)	This study aims to explore AI applications and how they transform and assist in various academic and administrative activities.	-
Yue et al. (2022, p. 5)	RQ1. What is the status of research in teaching AI in K-12? RQ2. What are the pedagogical characteristics of current AI teaching units? RQ3. What are the evaluation methods and the outcome of the teaching units?	Systematic
Paaßen et al. (2022, p. 2)	(1) Reviewing the existing work on creativity in learning, (2) Distilling a conceptual, graph-based model of creativity in learning from our review, and (3) Discussion of potential applications and challenges of putting the developed conceptual model into practice.	Graph-based
Xu and Ouyang (2022, p. 3)	RQ1. What are the categories of the AI element in the AI-STEM system? RQ2. What are the characteristics of other system elements (i.e., information, subject, medium, environment element) as well as the distribution of AI in these elements? RQ3. What are the effects of AI in STEM education?	Systematic
Reindl (2021, p. 288)	This paper reviews and discusses emotion AI in the context of education.	-
Kent et al. (2022, p. 1)	In this review paper, we summarize the evidence about the impact of parental engagement, as opposed to involvement, on the learning of children. Via that, we critically look at the design choice of most western mainstream public education systems to distance parents from their children's education, which, as the review results indicate, can be detrimental to children's learning.	Critical review
Zawacki-Richter et al. (2019, p. 2)	How have publications on AI in higher education developed over time, in which journals are they published, and where are they coming from in terms of geographical distribution and the author's disciplinary affiliations? How is AI in education conceptualized and what kind of ethical implications, challenges and risks are considered? What is the nature and scope of AI applications in the context of higher education?	Systematic
Chen et al. (2020c, p. 4)	RQ1. How did broad and narrow AIED studies distribute? RQ2. What journals, institutions, and countries/regions contributed the most to the highly cited AIED studies? RQ3. What were the major research issues and AI technologies adopted in the highly cited AIED studies? RQ4. What theories and frameworks had been used in the highly cited AIED studies?	Systematic review
Rienties et al. (2020, p. 1)	This review aims to provide a concise overview of four distinct research fields: AIED, CSCL, EDM, and LA.	-
Yang (2019, p. 347)	Purpose: This article summarizes recent developments in the use of AI in Chinese education, paying particular attention to the different applications of AI at a number of different levels. The article reviews key government policies and guidelines and suggests a course for future development.	-
Yufei et al. (2020, p. 548)	This paper briefly discusses the history of the development of AI technology and its application in the field of education including teaching and learning innovations, effective teaching and learning approaches and smart campus lifestyles.	-
Chen et al. (2020b, p. 2)	RQ1. What was the trend of grants in relation to AIED? RQ2. What were the major conferences and journals related to AIED? RQ3. What were the major software tools concerning AIED? RQ4. What was the trend of AIED publications? RQ5. What were the top frequently used keywords in AIED publications? RQ6. What were the active institutions and researchers in the field of AIED?	-
Forestier (2020, p. 437)	This article highlights the interest of the developmental approach of the digital for three (related) subjects that the author was led to address. (1) The debate currently underway in the field of human sciences, which conceive education as a "therapeutic" for digital technology. (2) The design of a public policy of AI in education, in particular in favor of a more inclusive school, (3) The more specific use of digital tools to support people with autism.	-

APPENDIX B

Table B1. Dates of the corpus studied in the reviews

Reference	Dates from corpus
Yang (2019)	History of AI in China from 1917 to 2019
Yufei et al. (2020)	History of AI from 1943-2019
Nti et al. (2022)	1960-2021
Dimitriadou and Lanitis (2023)	Technologies used from 1980-2022
Yu and Guo (2023)	History of AI from 1980 to 2022
Zhang and Aslan (2021)	1993-2020
Dai and Ke (2022)	1998-2021
Paaßen et al. (2022)	1998-2012
Chen et al. (2020)	1999-2019
Zheng et al. (2023)	2001-2020
Tan et al. (2022)	2002-2022
Reindl (2021)	2005-2020
Gentile et al. (2023)	"Since 2005" (p. 2)
Zawacki-Richter et al. (2019)	2007 and 2018
Giannakos and Cukurova (2023)	2010-2022
Yue et al. (2022)	2010-2022
Heeg and Avraamidou (2023)	2010-2021
Xu and Ouyang (2022)	2011-2021
Ouyang et al. (2023)	2011-2023
Chiu et al. (2023)	2012-2021
Qian et al. (2023)	2013-2022
Salas-Pilco and Yang (2022)	2016-2021
Almusaed et al. (2023)	"Previous five years" (p. 5)
Imran and Almusharraf (2023)	2022-2023 (only covers ChatGPT)
Pradana et al. (2023)	2022-2023 (only covers ChatGPT)
Ahmad et al. (2022)	No information
Forestier (2020)	No information
Kent et al. (2022)	No information
Vázquez-Cano (2021)	No information
Rienties et al. (2020)	No information

APPENDIX C

Table C1. Main worries about AIED and possible solutions

Theme & references	Problems presented
General problems concerning AIED (Almusaed et al., 2023; Avraamidou, 2023; Chiu et al., 2023; Forestier, 2020; Gentile et al., 2023; Heeg & Nti et al., 2022; Kent et al., 2022; Pradana et al., 2023; Yue et al., 2022, Yufei et al., 2020; Zheng et al., 2023)	• Difficulties integrating AI in education • Unclear impact of AI on education • Anxieties about the safe use of technologies • Network infrastructure deficiencies • Device and software unreliability • Financial barriers in homes and schools • The need to develop AI teaching materials with a unified curriculum standard on how to employ these tools to facilitate teaching • Alienation in the teaching spaces • Lack of familiarity with the technologies • Lack of digital literacy
Problems with AIED research & methodology (Chen et al., 2020c; Chiu et al., 2023; Paaßen et al., 2022; Reindl, 2021; Rienties et al., 2020; Yue et al., 2022; Zawacki-Richter et al., 2019; Zheng et al., 2023)	• Researchers should consider an appropriate sample size, learning domains, types of organization, and AI software and hardware • Research missing in specific contexts (e.g., emotion AI; integration of AIED with CSCL, EDM and LA) • Lack of studies with quantitative based assessment of students' learning outcomes • Lack of critical reflection of the pedagogical and ethical implications as well as risks of implementing AI applications • Abundance of position studies in which authors expressed their personal understanding and opinions – they may involve bias and may not objectively reflect the practical situations since they can be subjective without or with little support evidence bibliographically • AIED research is scattered and not organized
Problems faced by teachers (Chiu et al., 2023; Gentile et al., 2023; Heeg & Avraamidou, 2023; Nti et al., 2022; Pradana et al., 2023; Xu & Ouyang, 2022; Zheng et al., 2023)	• Concerns about being replaced by AI • Low level of digital skills which lead to difficulties adapting to or operating AI technologies, difficulties keeping pace with ever-evolving technologies, and inability to teach students how to use technologies effectively • No sufficiently training and equipment to deal with AI • Lack of research on teacher's professional through AI
AI ethics (Chen et al., 2020c; Chiu et al., 2023; Dai & Ke, 2022; Heeg & Avraamidou, 2023; Salas-Pilco & Yang, 2022; Zawacki-Richter et al., 2019; Zhang & Aslan, 2021)	• Lack of research on AI ethical issues during the design or implementation phase • Lack of critical reflection on the pedagogical and ethical implications as well as risks of implementing AI applications • Lack of critical awareness of AI ethics

APPENDIX D

Table D1. Studies included in the corpus of this scoping review

- Ahmad, S. F., Alam, M. M., Rahmat, M. K., Mubarik, M. S., & Hyder, S. I. (2022). Academic and administrative role of artificial intelligence in education. *Sustainability*, 14(3), Article 1101. <https://doi.org/10.3390/su14031101>
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- Heeg, D. M., & Avraamidou, L. (2023). The use of artificial intelligence in school science: A systematic literature review. *Educational Media International*, 60(2), 125-150. <https://doi.org/10.1080/09523987.2023.2264990>
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- Nti, I. K., Umar Bawah, F., Quarcoo, J. A., & Kalos, F. (2022). A bibliometric analysis of soft computing technology applications trends and characterisation in educational research: Africa. *Africa Education Review*, 19(3), 55-77. <https://doi.org/10.1080/18146627.2023.2284744>
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Table D1 (Continued). Studies included in the corpus of this scoping review

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