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Exploring the landscape of GenAI and education literature: A taxonomy of themes and sub-themes

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Abstract

The research landscape surrounding Generative Artificial Intelligence (GenAI) and education is rapidly expanding, characterised by a dynamic array of themes and sub-themes. This paper aims to construct a comprehensive taxonomy that categorises the current literature on the integration of GenAI in educational settings. To do so, a systematic analysis was conducted first, which filtered and selected 30 pieces of literature. Within this literature, 369 phrases were identified, which culminated in the development of 5 overarching themes and 38 sub-themes. These themes within the systematic review ran parallel to a taxonomy that was developed from them, which subsequently revealed a tension between them. Emphasising an interpretivist approach, this research acknowledges the subjective nature of knowledge formation and interpretation, enhancing understanding of the complex interplay between GenAI and educational practices, with a predominant focus on GenAI in higher education. Unlike previous literature reviews, this paper presents a subsequent taxonomy derived from the systematic review, which holds an original narrative: that a critical tension exists between technical discussions of GenAI and the pedagogical realities faced by educators. This taxonomy presents evidence that supports a notion that the fledging field of 'GenAI and education' research has two developing strands: the technical and the pedagogical. Not

In memory of Professor Lynn Revell, whose guidance and support were invaluable to this work.

only are these two strands of foci emerging within the literature, but there is also a growing disconnect or void between the two. Without addressing this almost 'siloed' growth, conversations about GenAI's role in education risk becoming overly abstract, lacking practical relevance for educators. By illuminating this tension, this research invites further exploration into how educators can navigate the evolving landscape of GenAI in their classrooms.

KEYWORDS
education, Generative Artificial Intelligence (GenAI), pedagogy, taxonomy

Key insights

What is the main issue that the paper addresses?

The paper addresses the identified disconnect between technical advancements in Generative Artificial Intelligence (GenAI) and the pedagogical implications for educators in educational settings, highlighting the need for integrated discourse that bridges these two strands of research.

What are the main insights that the paper provides?

The paper provides a comprehensive taxonomy of themes and sub-themes in GenAI and education literature, revealing a critical tension between technical and pedagogical perspectives, and underscores the importance of interdisciplinary collaboration to enhance the practical integration of GenAI in educational practices.

INTRODUCTION

Educational practices in the twenty-first century have been characterised by often rapid advancements driven by the continuous emergence of new technologies. These technologies often serve as amplifiers of learning processes, significantly enhancing the educational experience by providing new tools and methods for teaching and learning (Petersen, 2021; Toyama, 2015). One of the most transformative of these recent technological developments is the advent of complex machine learning systems, which are commonly referred to as 'Artificial Intelligence' (AI) (Baidoo-Anu & Owusu Ansah, 2023; Hu, 2022). While this trend is apparent across all educational sectors, the academic work reviewed in this paper predominantly examines higher educational settings, but the findings can be applied with a certain degree across different sectors.

Despite the widespread influence of AI, there remains no universally accepted definition of the term (Niemi, 2021; Niemi et al., 2022; Roschelle et al., 2020). However, there is a consensus that any definition of AI must involve the concept of replacing human roles with machines or artificial entities (Richter et al., 2019; Roschelle et al., 2020; Stone et al., 2016). This replacement is seen in systems that can perform tasks autonomously, thereby reducing the need for human intervention (Richter et al., 2019; Roschelle et al., 2020; Stone et al., 2016). For a machine to be classified as AI, it must therefore be capable of executing tasks that typically require human intelligence, encompassing abilities such as perception, representation, reasoning, learning, interaction and impact (Holland, 2020). This paper focused on a form of AI known as 'GenAI' and, for the purposes of this paper, 'GenAI' can be understood as a shortened form of Generative Artificial Intelligence. GenAI is therefore a form of AI that can create, produce or 'generate' digital content (e.g., text) based on data input from a user (Grasse et al., 2023; Richter et al., 2019; Stone et al., 2016).

The objective of this paper was to conduct a systematic review of the increasing literature that focuses on the integration of AI in the field of education. This review then led to the production of a taxonomy of parallel themes and sub-themes that are present among the literature that was systematically selected for analysis. The results of such an analysis, which will be discussed in more depth in later parts of the paper, revealed a compelling narrative: that the fledgling field of research on 'GenAI and education' has a probable chance of splitting into two sub-divisions. The analysis conducted found that there are those within the field who are focusing on AI in an educational setting, and those who are focusing on what education will look like in the age of GenAI. There is also an argument to be made that those wishing to explore the more technically advanced workings of GenAI within educational settings may find themselves unable to produce all-encompassing conclusions if their work lacks due consideration of GenAI's application within set pedagogical contexts and real-world scenarios.

RESEARCH AIMS, OBJECTIVES AND QUESTIONS

While other authors have also conducted systematic reviews of the literature (Ogunleye et al., 2024; Samala et al., 2025; Yusuf et al., 2024), often on a larger scale than this paper, the originality of this review is that it led to the production of a subsequent taxonomy that contributes a novel framework addressing a specific gap in the existing literature, unexplored before, thereby providing valuable insights that warrant further exploration. The identified disconnect between two opposing stances within the current research field of 'GenAI and education', unearthed by this taxonomy, acts as a rationale for its existence among the works of other researchers. This encapsulates the growing complexity of available literature (Masjel et al., 2024) on 'GenAI and education', characterised by rapid technological advancements (Jovanović & Campbell, 2022), making it a subject of relevance.

Research questions

1. How can the themes and sub-themes systematically identified in the literature be categorised and organised into a coherent taxonomy?
2. What are the existing research gaps, trends and insights in the literature that focuses on the integration of AI in education, and how can these findings inform the current understanding of this rapidly evolving field?
3. Based on the taxonomy developed from the systematic analysis of the literature, what recommendations can be proposed for future research directions and practical implications in the context of integrating AI in educational practices?

'GenAI and education' literature

To address these research questions, it is first pertinent to comprehend a brief history of this fledging area of academic inquiry. Within the wider field of GenAI research, there has been a substantive focus on providing comprehensive explanations (Buchanan & Shortliffe, 1984; Chakraborty et al., 2017; Clancey, 1981; Core et al., 2006), often in order to make GenAI a more accessible concept for non-specialists. As the field of research has evolved, explanations have become more specific along different lines of inquiry (Alonso et al., 2018; Doshi-Velez & Kim, 2017). With regard to the field of 'GenAI and education', there has been a focus on the importance of explanations of AI systems (Hoffman et al., 2018; Lipton, 2016). Researchers have explored how enhancing the understanding of these tools can lead to easier usage, improved decision-making and better problem-solving performance (Hoffman & Klein, 2017; Molnar, 2018; Nataksu, 2004).

Numerous studies have put forward recommendations on creating explanations (Byrne, 1991; Kass & Leake, 1987; Khemlani & Johnson-Laird, 2012; Sørmo et al., 2005), organising them into categories, or outlining the characteristics of explanations. This focus of producing developed explanations has been a central theme in various research papers over the years (Felten, 2017; Kulesza et al., 2013; Swartout et al., 1991; Van Der Linden, 2002). Additionally, there has been significant exploration of the application of analogies to enhance reasoning (Gentner et al., 2001; Hoffman et al., 2009) in computer science, philosophy of science and psychology (Keil et al., 2004). Computational systems for mapping coherent structures have been developed and assessed (Cañas et al., 2003), with efforts to evaluate the quality of these analogies.

These explanations have often incorporated—either as their main novelty or as one of numerous foci—a 'mental model', that is, a representation formed by an individual to understand complex systems (Caroll & Olson, 1987; Gentner & Stevens, 1983; Johnson-Laird, 1980). Drawing upon a separate field of research entirely, these mental models are simplified abstractions based on domain-specific concepts and principles (Byrne, 2002; Friedman et al., 2018). Research has investigated how these mental models are created and assessed (Wilson & Rutherford, 1989), particularly in relation to explainable AI (Felten, 2017).

Rationale

Moving away from this historical retrospective analysis of the literature's progression, the purpose of this paper is to provide a scholarly account of the current landscape of literature, particularly literature with direct relations to the search phrase 'GenAI and education'. This has been done in a novel way, using a systematic review of the literature to inform the creation of a taxonomy of parallel themes and sub-themes. Contemporary literature (published post-2013) on 'GenAI and education' has a relatively high degree of complexity and therefore an appropriate manner in which to present a synthesis of its themes and sub-themes is through a subsequent taxonomy.

A taxonomy, by definition, is a 'technique of classification into ordered categories' (Dictionary.com) that often follows a hierarchical structure (Knight, 2017) and is developed to organise a form of complex information (Carper & Snizek, 1980; Gillenson et al., 2000; Mace, 2004). The precedent for synthesising and presenting information in the form of taxonomy in education has been set by taxonomies such as Bloom's (1956) and the SOLO taxonomy (Biggs & Collis, 1982). Both of these taxonomies structure knowledge in a hierarchical manner (Seemiller & Whitney, 2020), and the one presented in this paper follows a similar model of construction.

The growing amount and complex landscape of current literature on AI (Masjel et al., 2024) warrants the production of this taxonomy. According to the Center for Security and Emerging Technology (2023), there were 242,290 publications worldwide in 2022 that contained AI and 81.07% of these were on the topic of 'education' (Center for Security and Emerging Technology, 2023). This represented an enormous majority share of recent publications, with the second most prevalent additional topic alongside AI being 'industry', at 7.89% of all total publications (Center for Security and Emerging Technology, 2023). Systematic reviews of this literature have already been conducted (Ogunleye et al., 2024; Samala et al., 2025; Yusuf et al., 2024), yet what they fail to capture are the interconnections—or, as this paper argues, the distinct lack of interconnections—between identified themes and sub-themes present within the available literature. This is the very reason why the decision was made to construct a subsequent taxonomy based on the findings of the systematic literature review.

Ogunleye et al. (2024) used the PRISMA approach to analyse 625 papers, with 355 meeting the inclusion criteria. They concluded that: there are no currently agreed-upon guidelines for the use of GenAI in higher education; there is a notable gap in understanding how GenAI can be effectively integrated into educational curricula for assessments and teaching; and there is a necessity for interdisciplinary and multidimensional research to enhance awareness among stakeholders (Ogunleye et al., 2024). Yusuf et al. (2024) completed a systematic review of 407 publications from various databases to map the thematic landscape of GenAI in education. They concluded that: GenAI in education is currently conceptualised in several ways, such as a tool for pedagogical enhancement or professional development; there is a lack of research on GenAI's application in K-12 education, experimental studies exploring its impact and the examination of GenAI's potential ethical concerns—particularly concerning cultural dimensions; and future research needs to address the identified gaps to fully explore the potential of GenAI in educational contexts (Yusuf et al., 2024). In their scoping review, Samala et al. (2025) analysed 453 articles, revealing that while the discourse surrounding GenAI's applications in educational settings has expanded, substantial gaps remain in understanding its effective integration and ethical implications (Samala et al., 2025). The taxonomy they propose categorises various themes, including applications, challenges and ethical considerations of GenAI in academia. Notably, their findings highlight the need for informed policies that address the ethical dimensions of GenAI usage in educational contexts, alongside the pressing call for interdisciplinary research to foster a nuanced understanding of its role in teaching and learning (Samala et al., 2025).

Methodology

Both large-scale systematic reviews note that there is a need for further research (Yusuf et al., 2024), particularly around the field of interdisciplinary and multidimensional research (Ogunleye et al., 2024; Samala et al., 2025). It is this very need that the subsequent taxonomy (and its findings) set forth in this paper, following a systematic review of the literature, aims to begin addressing. Employing an interpretivist paradigm (McChesney & Aldridge, 2019; Willis, 2007) with a novel focus on actively searching for linkages both within and between themes and sub-themes of analysed literature has provided a step forward in multidimensional critical analysis that has produced insight into the future development of the 'GenAI and education' field of research itself.

Systematic literature selection

To conduct this analysis, research on available databases (e.g., Springer Nature, Taylor & Francis Ltd, Wiley-Blackwell) was filtered using the PRISMA 2020 flow diagram (Page et al., 2021), which can be seen in Figure 1. From this comprehensive search, 30 articles were selected based on criteria of

- age range <10 years at the time of search
- language (English)
- peer-review status
- academic journal classification
- relevance to 'education' as the primary subject of the work.

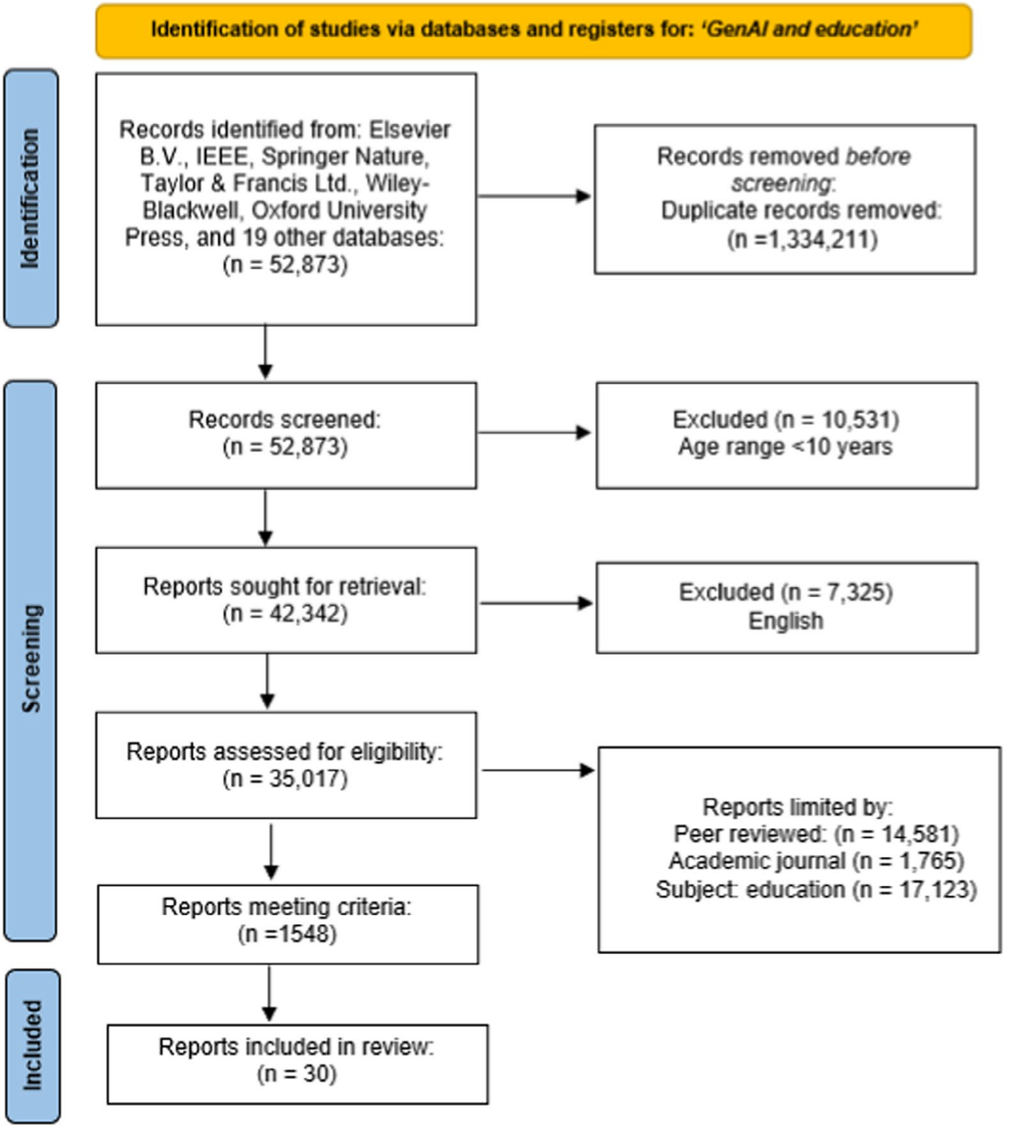

FIGURE 1 PRISMA 2020 flow diagram (Page et al., 2021).

The decision to include only articles published post-2013 is based on the need to focus on recent literature to ensure that the analysis reflects the most current trends and developments in the field of GenAI and education. By limiting the search to articles published after 2013, the study aims to capture the latest research findings and insights that are relevant to the present context (Greenhalgh, 2019). Selecting articles in the English language ensures that the research is accessible to a wider audience and aligns with the language proficiency of the researcher conducting the analysis. English is a dominant language in academic publishing and by including only English-language articles, the study can reach a broader readership and facilitate cross-cultural understanding (Flowerdew & Habibie, 2021).

Peer review is a rigorous process that involves evaluation by experts in the field to validate the research methodology, findings and conclusions. By prioritising peer-reviewed articles, this paper maintains a high standard of scholarly rigour and reliability in the analysis (Jefferson et al., 2002). Focusing on articles that primarily address the topic of ‘education’ ensures that the selected literature directly relates to the research context of GenAI and its implications for educational practices, enabling a more targeted and in-depth analysis of the subject matter (McMillan & Schumacher, 2013).

Data analysis, interpretation and reporting

The qualitative data gathered by the researcher—in this instance, phrases selected from identified literature—were scrutinised through thematic analysis (Braun & Clarke, 2019). This analysis included coding and categorising data (McChesney & Aldridge, 2019) of phrases within analysed singular literature, leading to the identifying of themes and subthemes across the entire systematically selected literature and, ultimately, the uncovering of a discourse between two domains of study within the fledgling ‘GenAI and education’ research field.

The study's data analysis was shaped by the researcher's social context (Harkness et al., 2010; Kvale, 2007), leading to self-reflexivity during interpretation. This practice involved examining how personal circumstances influenced data understanding (Alvesson & Sköldberg, 2018; Merriam & Grenier, 2019). Self-reflexivity is vital in interpretivist research, recognising that knowledge construction is influenced by researcher biases (Alvesson & Sköldberg, 2018). Through this process, the researcher acknowledged the subjective nature of their work and the impact of their experiences and biases on the research (Lincoln et al., 2011).

Thematic analysis

After systematically selecting relevant (meaning notable, credible and recent) literature, each piece underwent thorough examination, with the researcher identifying and documenting phrases from it. These phrases were selected by a researcher who was themself a formal educator, with a predisposition to analyse written work. Phrases were selected if they met one (or more) of the following criteria:

- *Significance and impact*. Phrases that encapsulate major findings or innovative concepts within a piece of work due to their potential implications for practice or theory within the field.
- *Clarity and conciseness*. Phrases that articulate complex ideas in a clear and concise manner, making them easier to understand and communicate, therefore having greater implications for other works in the same field.

- *Repetition of concepts*. Phrases that appear frequently within a text may indicate not only their author's own given weighting but also a consensus in the field, thus warranting particular attention.

These phrases were then analysed through thematic analysis—a qualitative data analysis method that involves data collection, data familiarisation, coding and grouping of similar codes to derive themes (Braun & Clarke, 2019). This process often reveals similarities, differences and unexpected insights (King & Brooks, 2017), offering a comprehensive understanding of the data. While various approaches exist within thematic analysis (Attride-Stirling, 2001; Tuckett, 2005), the study utilised reflexive thematic analysis, which encourages critical reflection on the researcher's involvement in the study (Braun & Clarke, 2019) and enhances trustworthiness in the researcher's findings (Nowell et al., 2017). Operating within the inductive reasoning paradigm (Braun & Clarke, 2019), data collection occurred without a predefined hypothesis, with patterns and themes identified post-collection to inform overarching theories (Pope and Mays, 2006) related to the discourse between two domains of study within the fledgling 'GenAI and education' research field.

How was this taxonomy developed?

The first stage of the taxonomy development was the systematic selection of relevant literature, which was conducted using the methods outlined in Figure 1. This led to the selection of literature that met the previously discussed selection criteria; the works selected are listed in Figure 2.

The second stage of producing the taxonomy was to identify and document phrases believed to capture the core focus or findings of the text. These phrases were then assigned unique codes and an example of this is shown in Figure 3—the full record of this process can be found in Appendix A.

This selection of literature primarily focuses on the intersection of AI and education, highlighting its transformative impact. Abdelghani et al. (2023) investigate innovative AI methodologies for enhancing data analysis in educational settings, while Aydin and Karaarslan (2023) examine how AI tools are reshaping teaching practices and learning experiences. Baidoo-Anu and Owusu Ansah (2023) discuss the cultural implications of AI technologies in educational contexts. Celik et al. (2022) explore the role of AI in promoting sustainability in educational institutions, and Chan and Hu (2023) analyse the influence of AI-driven social media platforms on student engagement. Chen et al. (2023) present findings on AI applications in mental health support for students, highlighting their potential benefits. Recent studies, including Feffer et al. (2023) and Khalil et al. (2023), emphasise the importance of AI in developing personalised learning pathways. Collectively, these works underscore the significant role AI plays in shaping modern educational practices, enhancing both teaching and learning outcomes.

The next step was to group these unique codes into recurrent categories, which led to the development of the following themes:

1. Pedagogical Framework and Strategies
2. Perception, Engagement and Motivation
3. Concerns Regarding GenAI in Education
4. Integration of GenAI in Education
5. Technical and Research Analysis.

1. Abdelghani, et. al., 2023	2.Aydin and Karaarslan, 2023	3.Baidoo-Anu and Owusu Ansah, 2023	4.Celik, et. al., 2022	5.Chan and Hu, 2023
6.Chen, et. al., 2023	7.Cheng, 2022	8.Daniel, 2015	9.Feffer, et. al., 2023	10.Fischer, et. al., 2020
11.Grindle, et. al., 2013	12.Harrer, 2023	13.Ilieva, et. al., 2023	14.Jančařík, et. al, 2023	15.Jovanović and Campbell, 2022
16.Khalil, et. al., 2023	17.Krumm et, al., 2018	18.Kumar and Raman, 2022	19.Lee, 2018	20.Niemi, 2021
21.Niemi, et. al., 2022	22.Pesek, et. al., 2021	23.Petersen, 2021	24.Rachha and Seyman, 2023	25.Richter, et. al., 2019
26.Roschelle, et. al., 2020	27.Slater, et. al., 2017	28.Stone, et. al., 2016	29.Suresh, et. al., 2019	30.Taranikanti and Davidson, 2023

FIGURE 2 30 Systematically selected articles.

An example of this grouping process can be seen in Figure 4 (the full record can be found in Appendix B) and Figure 5 details the unique codes that formed the above recurrent themes.

Across the literature systematically selected for analysis, 369 phrases were identified and documented as representing a key aspect of the literature examined. 35% (128) of these formed the 'Pedagogical Framework and Strategies' theme; 10% (36) made up the 'Perception, Engagement and Motivation' theme; 22% (82) formed the 'Integration of AI in education' theme; 14% (53) created the 'Concerns Regarding GenAI in Education' theme; and 19% (70) formed the 'Technical and Research Analysis' theme.

After these five themes had been formed, they were divided into frequently recurring sub-themes. An example of this is shown in Figure 6 and the full record can be found in Appendix C, which shows the full 46 sub-themes that were created as well as the coded phrases that constitute their formation.

The final step was to present these overarching themes and sub-themes in a singular graphic representation, or taxonomy. This is displayed in Figure 7. Following the precedent of previous taxonomies in the field of education research set by Bloom (1956) and the SOLO taxonomy (Biggs & Collis, 1982), the taxonomy presented in this paper is of hierarchical structure with the search term 'GenAI and education' that was used in the systematic selection of relevant literature acting as the overarching section. This is then divided into the five themes that were formulated based on the 369 coded phrases. The lowest layer of the taxonomy contains the sub-themes that make up each of the five main themes, with 46 sub-themes in total before 8 were removed due to repetition, leaving 38 sub-themes.

Article No.	Literature	Phrase	Code
1	Abdelghani et al. (2023)	1. Generative Artificial Intelligence (GAI) in education	1a
		2. Personalized and interactive pedagogical sequences	1b
		3. Students' intrinsic motivation	1c
		4. Active engagement in learning	1d
		5. Control over learning	1e
		6. Lack of uncertainty signaling in Large Language Models (LLMs)	1f
		7. Over-estimation of competencies	1g
		8. Passiveness in learning	1h
		9. Loss of curious and critical-thinking sense	1i
		10. Lack of pedagogical stance in GAI behaviors	1j
		11. Effects on students' active learning strategies	1k
		12. Metacognitive skills in education	1l
		13. Framework for introducing pedagogical transparency in GAI-based educational applications	1m
		14. Training methods for including pedagogical principles in AI models	1n
		15. Pedagogically-relevant interactions with GAI	1o
		16. Educational methods for acquiring skills to benefit from GAI	1p
		17. Meta-cognitive skills	1q
		18. GAI literacy in education	1r

FIGURE 3 Example of identified and documented literature phrases and unique codes.

Article No.	Literature	Phrase	Code
1	Abdelghani et al. (2023)	1. Generative Artificial Intelligence (GAI) in education	1a
		2. Personalized and interactive pedagogical sequences	1b
		3. Students' intrinsic motivation	1c
		4. Active engagement in learning	1d
		5. Control over learning	1e
		6. Lack of uncertainty signaling in Large Language Models (LLMs)	1f
		7. Over-estimation of competencies	1g
		8. Passiveness in learning	1h
		9. Loss of curious and critical-thinking sense	1i
		10. Lack of pedagogical stance in GAI behaviors	1j
		11. Effects on students' active learning strategies	1k
		12. Metacognitive skills in education	1l
		13. Framework for introducing pedagogical transparency in GAI-based educational applications	1m
		14. Training methods for including pedagogical principles in AI models	1n
		15. Pedagogically-relevant interactions with GAI	1o
		16. Educational methods for acquiring skills to benefit from GAI	1p
		17. Meta-cognitive skills	1q
		18. GAI literacy in education	1r

FIGURE 4 Example of coding grouping.

DISCUSSION

The literature analysed in this taxonomy has unearthed a disconnection within the literature itself. While all the individual literature has links to the ideas of others, the analysis revealed that two main foci are emerging within this fledging field of research that are not yet making secure enough connections between and across them. These two

Pedagogical Framework and Strategies												
1b	3c	5i	6l	8g	11h	13e	15h	21e	23f	26b	28d	30e
1e	3f	5j	6m	8h	11i	13g	15i	21f	23g	26c	28e	30f
1h	3g	5m	7k	8i	11j	13h	15j	21g	23h	26d	28f	30g
1l	3h	5o	7n	11a	11k	15a	18b	21h	23i	26e	28g	30h
1o	3m	5p	7p	11b	11l	15b	18j	21i	23j	26f	28h	30i
1q	3n	6a	7q	11c	11m	15c	20c	23a	23k	26g	28i	30j
1r	3p	6c	7t	11d	11n	15d	20d	23b	23l	26k	28j	30k
2a	4g	6d	7u	11e	11o	15e	20e	23c	23m	28a	28k	30l
2k	5b	6f	8a	11f	13c	15f	21a	23d	23n	28b	30a	
2l	5h	6k	8f	11g	13d	15g	21b	23e	26a	28c	30c	

Perception, Engagement and Motivation			
1c	5g	16d	22g
1d	5n	16i	22h
1i	5s	16k	25c
1k	6g	16l	29j
2d	6h	18f	30b
3e	6i	19d	30d
3o	13a	20b	
5a	13f	22d	
5d	16a	22e	
5e	16b	22f	

Integration of AI in Education								
1a	4h	7g	9i	10i	13b	22a	24k	29f
1j	4i	7h	9l	10j	14a	22b	24m	29i
1p	4j	7i	10a	10k	14f	22c	25e	
2b	4k	7j	10b	10l	14h	22i	25f	
2e	5q	7o	10c	10m	16c	22l	25g	
2h	7a	7v	10d	10n	16e	24b	25h	
4a	7b	9a	10e	10o	16j	24c	25i	
4b	7c	9c	10f	10p	18a	24f	25j	
4e	7d	9d	10g	10q	19a	24h	29a	
4f	7e	9g	10h	10r	20a	24i	29b	

Concerns Regarding AI in Education					
1f	5c	9e	19b	22k	26i
1g	5f	9f	19e	24a	26j
1m	5k	9h	19f	24d	26l
1n	5l	9j	20f	24e	
2f	5r	9m	20g	24g	
3d	6b	12d	20h	24j	
3i	6e	12e	20i	24l	
3j	6j	16f	21c	25b	
3k	6n	16g	21d	25d	
3l	9b	16h	22j	26h	

Technical and Research Analysis						
2c	7m	9p	14j	18d	27a	27k
2g	7r	12a	17a	18e	27b	27l
2i	7s	12b	17b	18g	27c	27m
2j	8b	12c	17c	18h	27d	27n
4c	8c	14b	17d	18i	27e	27o
4d	8d	14c	17e	18k	27f	29c
4l	8e	14d	17f	19c	27g	29d
4m	9k	14e	17g	22j	27h	29e
7f	9n	14g	17h	22k	27i	29g
7l	9o	14i	18c	25a	27j	29h

FIGURE 5 Code groupings to form assigned theme.

foci are: (1) GenAI technological innovation, development and challenges in an educational setting; and (2) pedagogical development and reimagining in an age of GenAI. The first strand—the technical strand—is primarily focused on how GenAI as a technological innovation will continue to develop and grow within educational settings (Aydin & Karaarslan, 2023; Chen et al., 2023). The second strand—the pedagogical strand—is primarily focused on how traditional or existing pedagogical practices will change/adapt/evolve in an age of GenAI (Baidoo-Anu & Owusu Ansah, 2023; Chen et al., 2023). Yet while there are connections within each of these strands, the analysis of this taxonomy unveiled that there is a distinct void between the two strands, meaning they have almost become 'siloed' areas of research (Celik et al., 2022; Ilieva et al., 2023) within an overarching or umbrella field of 'GenAI and education'.

This raises the critical question: How can we engage in meaningful discussions about GenAI in education without adequately addressing the pedagogical implications for educators? Without integrating a pedagogical lens, discussions surrounding GenAI remain abstract and disconnected from real-world applications. This means that the discussions about ethics (Harrer, 2023) cannot be truly held because they will lack nuance, since they will never incorporate all the necessary elements (Feffer et al., 2023) to form cohesive, universal conclusions. While discussion around GenAI tools in education rightly should be of a technically high calibre, the nuance divide between the technicalities of GenAI workings and pedagogical considerations will always act to undermine any

Theme	Sub-themes	Phrases and Codes
Pedagogical Framework and Strategies	**Personalisation and Interactivity**	Personalized and interactive pedagogical sequences (1b)
		Personalized and interactive learning (3f)
		Personalized learning support (5h)
		Tailoring GenAI technologies to address needs and concerns (5o)
		Promoting effective learning outcomes (5p)
		Personalized learning process (18b)
	Assessment and Feedback	Control over learning (1e)
		Formative assessment activities (3g)
		Ongoing feedback for teaching and learning (3h)
		Assessment through automated essay scoring (4g)
		Transforming pedagogical activities (13c)
		Effective assessment in education (23m)
	AI Integration in Education	Generative AI in education (2a)
		ChatGPT in higher education (5b)
		Recommendations for leveraging ChatGPT in education (3m)
		Use of ChatGPT in editing content (2k)
		Promises of Generative AI and large language models in education (2l)
		AI can be effectively used in teaching-learning process (18j)
	Collaboration and Integration	Collaboration between policy makers, researchers, educators, and technology experts (3n)
		Design and development of a new chatbot assistant for teaching AI concepts (6k)
		Providing educational resources through chatbots (6m)
		Unifying applications of intelligent chatbots in teaching-learning activities within universities (13h)
		AI-based intelligent tools and environments supporting human learning (21e)
		Contributions of AI to redesigning the future of education and learning (21i)
	Technological Advancements	Generative modeling in artificial intelligence (AI) (15a)
		Synthetic artifacts generation (15b)
		AI-based intelligent tools and environments supporting human learning (21e)
		New applications and consequences of AI in education (21g)
		Applications of AI in education (26f)
		Impact of AI on education (28h)
	Educational Development and Trends	Future directions (8g)
		Trends in AI development and changes required in education and working life contexts (21h)
		AI influences in education (28j)
		AI-related policy in education (28k)
		Challenges in education with AI (28i)
		AI influences in education (28j)
	Metacognitive or Thinking Skills	Metacognitive skills in education (1l)
		Meta-cognitive skills (1q)
		Metacognitive frameworks (30e)
		Critical thinking (30j)
		Skill development (30k)

FIGURE 6 Example of the formation of sub-themes.

conclusive statements that are drawn as they will fundamentally lack a cornerstone of the reality being examined.

The technical strand

This strand examines the underlying technologies and methodologies that drive GenAI, highlighting the implications for teaching and learning practices. The rapid advancements in AI technologies, such as natural language processing and machine learning, have paved the way for tools like ChatGPT to support educational objectives (Aydin & Karaarslan, 2023). The integration of AI in educational contexts presents both opportunities and challenges (Celik et al., 2022; Niemi et al., 2022), and this strand of literature emphasises the importance of understanding the mechanisms of AI systems to enhance their interpretability and usability (Jovanović & Campbell, 2022; Richter et al., 2019). By investigating these technical dimensions, the technical strand offers insights into how GenAI can be effectively harnessed to improve educational outcomes and adapt to the evolving needs of learners.

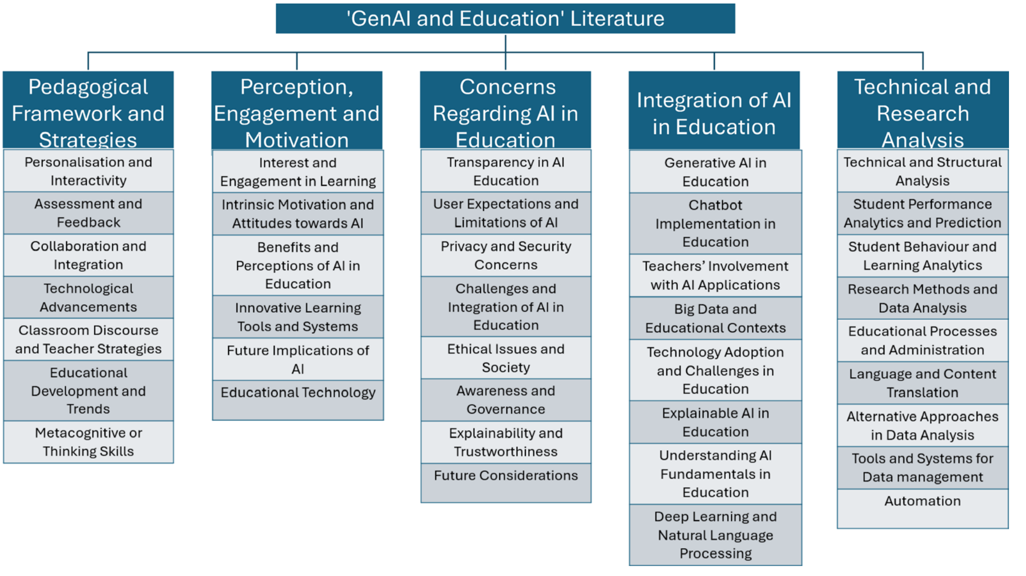

FIGURE 7 Taxonomy of themes within 'GenAI in education' literature.

Understanding AI mechanics

At the heart of the technical strand is a foundational knowledge of neural networks, natural language processing and machine learning algorithms (Jovanović & Campbell, 2022; Richter et al., 2019). Such an understanding is crucial for educators who wish to leverage GenAI effectively in their teaching practices. For instance, knowing how algorithms operate can help educators make informed decisions about which AI tools to adopt and how to integrate them into their instructional designs (Chan & Hu, 2023; Chen et al., 2023). Without this knowledge, educators may inadvertently adopt technologies that do not align with their pedagogical goals or that may even introduce biases into the learning environment (Aydin & Karaarslan, 2023; Celik et al., 2022). Therefore, professional development programmes must prioritise technical training for educators to ensure they are equipped to navigate the complexities of GenAI (Niemi et al., 2022).

Innovation and development

The technical advancements in GenAI have led to the development of a range of educational tools that hold great promise. From automated tutoring systems to intelligent content creation tools, these innovations can significantly enhance the learning experience (Baidoo-Anu & Owusu Ansah, 2023; Jančařík et al., 2023). For instance, AI-powered platforms can provide immediate feedback to students, allowing for personalised learning paths that cater to individual strengths and weaknesses (Ilieva et al., 2023; Taranikanti & Davidson, 2023). However, there is a risk that if educators prioritise the adoption of cutting-edge technologies without considering their educational value, they may inadvertently create learning experiences that are more about technology than meaningful engagement (Feffer et al., 2023; Suresh et al., 2019). This highlights the importance of ensuring that technical innovations are grounded in sound pedagogical practices, thus creating a balanced approach that enhances both the functionality of educational tools and the learning experience (Fischer et al., 2020; Roschelle et al., 2020).

The pedagogical strand

This strand encompasses a variety of studies examining the integration of AI tools in the classroom, with particular emphasis on their capabilities for enhancing teaching and learning processes (Chan & Hu, 2023; Rachha & Seyman, 2023). GenAI tools like ChatGPT can facilitate personalised learning experiences (Baidoo-Anu & Owusu Ansah, 2023), fostering greater engagement and understanding among students. This strand of literature discusses the potential of AI to support educators in developing innovative instructional strategies that leverage data analytics to tailor learning pathways (Grindle et al., 2013; Khalil et al., 2023). The technical developments in AI not only transform the methods of content delivery but also raise critical questions about the nature of learning itself (Ilieva et al., 2023). As educational institutions increasingly adopt these technologies, it becomes essential to analyse both their technical specifications and their pedagogical implications, ensuring that the integration of AI is aligned with educational goals and learner needs (Celik et al., 2022; Roschelle et al., 2020).

The role of educators

Educators play a critical role in shaping how GenAI is utilised within classrooms. Their insights and expertise are vital in determining how to integrate AI tools in ways that enhance learning rather than detract from it. This requires an understanding of both the capabilities of GenAI and the diverse needs of students (Baidoo-Anu & Owusu Ansah, 2023). Educators must be prepared to critically assess the tools available and select those that align with their instructional goals. The role of educators extends beyond mere facilitation. They must actively engage with GenAI technologies to create inclusive and equitable learning environments. This involves using AI to support differentiated instruction, ensuring that all students—regardless of their background or learning style—have access to tailored educational experiences. For instance, AI can help identify students who may be struggling and provide targeted interventions, thereby fostering an environment where every student can thrive (Chen et al., 2023; Ilieva et al., 2023).

Ethical considerations

The integration of GenAI in education also raises important ethical considerations. Issues such as data privacy, algorithmic biases and the potential for exacerbating existing inequities must be critically examined (Celik et al., 2022). For example, AI systems often rely on large datasets, which may inadvertently perpetuate biases present in the data (Chan & Hu, 2023). While such systems remain in their infant phase, as currently, there is an inherent risk that the data they have been trained on are insufficient or of poor quality (Feffer et al., 2023), which further perpetuates biases. In 2018 a Tesla with an autopilot system, powered by AI, crashed into a stationary emergency vehicle (Lam, 2018), and similarly with a stationary roadwork vehicle in 2022 (Lam, 2022). Scatter Lab's AI chatbot has been reported as using offensive language towards LBTQ+ persons and people with disabilities (Perkins, 2020) and Meta systems, powered by AI, initially labelled videos of black men as primates (Dadkhahnikoo, 2020). Educators must therefore be vigilant in understanding these risks and advocate for the ethical use of AI technologies in their classrooms (Rachha & Seyman, 2023), ensuring that they give due consideration to the training data on which the AI tools they choose to engage with were built. These studies also underscore the necessity for ongoing dialogue and evaluation regarding AI's role in education, emphasising that successful implementation hinges on a deep understanding of both its capabilities and its limitations.

Contextualisation of GenAI

Not only this, but educators must also consider the diverse needs of students for effective integration of GenAI in educational settings. Each student possesses unique learning preferences, strengths and challenges, and GenAI can play a significant role in supporting differentiated instruction (Cheng, 2022). For example, AI-driven platforms can analyse student performance data to recommend personalised learning pathways, allowing educators to tailor their instruction to meet individual needs (Niemi et al., 2022). One such example is Carnegie Learning's MATHia software, which employs personalised mastery learning techniques based on research into the effectiveness of the mastery approach (Kulik et al., 1990), as well as employing the ACT-R theory of knowledge and performance (Anderson, 2007; Anderson et al., 2004). Small-scale research projects have concluded that MATHia software enabled learners to better articulate their mathematical reasoning (Aleven & Koedinger, 2002; Butcher & Aleven, 2008) compared to their peers who did not use MATHia. As well as enabling learners to reach a level of performance in 12% less time than peers who did not use MATHia (Cen et al., 2006), a large-scale study concluded that there was strong correlational evidence between use of MATHia software and elevated test outcomes (Fancsali et al., 2018). The personalised nature of MATHia software, when used by individual learners, has also been found to provide more accurate predictive data scores for three school years (Joshi et al., 2014; Ritter et al., 2013). MATHia software is therefore an example of success in integrating GenAI into education. When there is a clear focus on contextualising GenAI within the unique characteristics of their users, educators can ultimately not only boost learner test scores, but also provide them with impactful learning experiences (Roschelle et al., 2020).

Past attempts to integrate technology and pedagogy

Although various models, such as the Technology Acceptance Model/2 (TAM/2) (Davis, 1989; Venkatesh & Davis, 2000), Technological Pedagogical Content Knowledge (TPACK) framework (Koehler et al., 2013) and Substitution Augmentation Modification Redefinition (SAMR) model (Puentedura, 2006), have attempted to bridge the divide between pedagogical practices and technological innovations in education, significant developments in the fledgling field of Artificial Intelligence in Education (AIED) suggest that these frameworks, while valuable, may no longer accurately depict the current landscape of educational research. Since the introduction of the TPACK model in 2006, there has been a remarkable evolution in AIED, characterised by the rise of adaptive learning systems such as Oak National Academy's Aila, MagicSchool AI, Khanmingo, CoSchool and Century, all of which are AI software specifically developed for the education sector. These innovations enable personalised learning experiences that are tailored to individual student needs, thereby reshaping traditional pedagogical practices. For instance, platforms like DreamBox and Knewton have harnessed AI to adjust content in real time based on student performance, leading to a more individualised educational approach (Conkin, 2016).

The integration of predictive analytics now allows educators to identify at-risk students proactively, facilitating timely interventions that were not adequately addressed by earlier models (Siemens, 2013). Since 2019, many AI-driven learning management systems (LMS), such as Canvas and Moodle, have started integrating AI features to recommend resources, predict student success and automate administrative tasks. Post-2020, tools like Google Assistant and Microsoft Teams have begun implementing features to support educational environments, including answering student queries and scheduling. The emergence of AI-enhanced assessment tools further exemplifies this shift, as they streamline the grading process and provide immediate feedback, allowing for a more dynamic interaction between students and educators (Gnanaprakasam & Lourdusamy, 2024). While models like TPACK emphasise the interplay between technology, pedagogy and content knowledge, they may overlook the complexities of how these AI tools fundamentally change the roles of teachers and students in the learning process (Mishra et al., 2023).

In addition, ethical considerations surrounding AI in education have become increasingly prominent, highlighting the need for responsible implementation that considers equity and data privacy (Kimmons et al., 2020). The dialogue within the research community has begun to reflect a growing divide: on one side, researchers focus on the technological advancements of AIED, exploring how these tools can be leveraged for improved educational outcomes; on the other side, there are those investigating how existing pedagogical practices must adapt and evolve in response to these innovations. While traditional frameworks laid important groundwork, the current divide highlights the necessity for interdisciplinary collaboration that merges technological and pedagogical expertise (Beetham & Sharpe, 2013). Bridging this gap will be essential for maximising the potential of AI in education and ensuring that it complements, rather than complicates, effective teaching and learning practices (Al-Adwan et al., 2023). Thus, while models like TPACK remain relevant, they must evolve to reflect the complexities of the contemporary educational landscape shaped by AI.

The significance of an emerging technical versus pedagogical strand

The fact that analysis of this fledgling field of literature identified an emergence of a technical versus pedagogical strand, even as a theoretical issue, is significant. Even if the probability of the two emerging strands diverging and a void between them emerging is not absolute, it is still worth further exploration. Such a divergence will undermine the nuance of discussion within the wider field itself, and any assertion made by either strand on future recommendations for GenAI's integration into the educational domain will ultimately be flawed and lack ubiquitousness.

This flaw will stem from the fact that the rapidly evolving nature of GenAI technology necessitates a continuous revaluation of pedagogical practices (Mishra et al., 2023). As advancements in GenAI occur, they not only provide new functionalities but also introduce novel challenges and considerations in teaching. For instance, while GenAI tools can automate various educational processes, they also require educators to rethink assessment methods, student engagement strategies and the ethical implications of AI usage (Ertmer et al., 2012). This ongoing dialogue between technology and pedagogy is essential for developing comprehensive educational frameworks that can adapt to the dynamic landscape of AI. By framing the conversation around a dichotomy, we risk losing sight of the holistic understanding that educators need to navigate this complexity effectively (Ertmer et al., 2012).

This flaw of a technical versus pedagogical strand may inadvertently also marginalise the voices of educators who are attempting to bridge these two domains (Archambault & Barnett, 2010). Many teachers operate in a context where they must simultaneously grasp the intricacies of new technologies while adapting their teaching methods to meet the needs of diverse learners (Ning et al., 2024). This multifaceted approach reflects the reality of educational practice, where the boundaries between technology and pedagogy are often blurred (Wang, 2024). Instead of future research residing in these opposing camps, all education stakeholders should recognise the necessity for educators to possess both technological and pedagogical knowledge, as outlined in the TPACK framework. This model emphasises the interconnectedness of technological knowledge, pedagogical knowledge and content knowledge (Mishra & Koehler, 2006), suggesting that effective teaching in an era of GenAI requires a balanced integration of all these elements.

Bridging the divide: Integrating technical and pedagogical perspectives

The integration of GenAI into educational practices presents numerous benefits, yet educators face a variety of challenges in this endeavour. A primary obstacle is the insufficient training and support available for the effective implementation of new technologies. Many educators feel overwhelmed by the rapid advancements in technology and often lack the necessary resources to stay informed. This gap in knowledge can hinder the effective use of GenAI tools or lead to their misuse in ways that do not align with pedagogical objectives (Celik et al., 2022; Chan & Hu, 2023). Additionally, educators may encounter resistance from colleagues or administrators who doubt the efficacy of AI in educational contexts. To overcome this scepticism, it is essential to showcase the value of GenAI through evidence-based practices and success stories that demonstrate its positive impact on learning outcomes (Baidoo-Anu & Owusu Ansah, 2023). Recognising and incorporating students' voices and perceptions regarding GenAI is vital in mitigating resistance and fostering a more supportive environment (Chan & Hu, 2023).

To effectively bridge the gap between technical and pedagogical perspectives, educators require actionable frameworks and professional development opportunities. Educational institutions must prioritise ongoing training that addresses both the technical functionalities of GenAI and its pedagogical applications (Niemi, 2021). This training can take various forms, including workshops, collaborative learning communities and partnerships with technology providers, ensuring that educators are equipped to navigate the complexities of GenAI (Ilieva et al., 2023). Furthermore, educators should be encouraged to adopt reflective practices that allow them to assess the effectiveness of GenAI tools within their classrooms. Establishing a feedback loop where educators can share their experiences and insights will foster a culture of continuous improvement and innovation (Feffer et al., 2023; Taranikanti & Davidson, 2023). This collaborative approach can lead to the establishment of best practices that integrate GenAI in ways that are both technically robust and pedagogically sound.

As the field of GenAI in education evolves, it is imperative to conduct longitudinal studies that evaluate the long-term impacts of these technologies on educational outcomes (Jovanović & Campbell, 2022). Research should concentrate on how GenAI affects student engagement, achievement and overall learning experiences over time (Chen et al., 2023). By collecting data and insights from real-world implementations, educators and researchers can refine their approaches and devise evidence-based strategies for effective integration. Ongoing research will also contribute to the formulation of ethical guidelines and policies governing the use of GenAI in education. As technology continues to advance, educators must remain attentive to the ethical implications, ensuring that GenAI functions as a tool for equity and inclusion rather than as a barrier to access (Rachha & Seyman, 2023). The comprehensive integration of GenAI into educational frameworks necessitates a balanced consideration of both technical capabilities and pedagogical aims, ultimately fostering enriched learning environments.

CONCLUSION

This taxonomy represents a crucial step towards a more interdisciplinary analysis of 'GenAI and education' through an interpretivist lens. It highlights two emerging research branches: one focusing on the technological mechanics of GenAI in educational settings and the other examining its transformative impact on teaching methodologies. This framework not only identifies these trajectories but also underscores the need for deeper exploration of GenAI's long-term implications for educational equity and access.

While current applications like personalised tutoring and administrative automation show promise, gaps remain in understanding their effects on academic integrity and critical thinking. Future research should prioritise longitudinal studies to evaluate GenAI tools' effectiveness across diverse educational contexts and develop strategies for ethical integration that foster student autonomy. As the field of 'GenAI and education' evolves, the divergence in research underscores the inadequacy of previous models in capturing its complexities. This bifurcation presents challenges for educators, who must balance AI integration with pedagogical concerns. Future research must bridge these strands, fostering collaboration that aligns technological advancements with effective teaching practices. This integrated approach is vital for maximising GenAI's potential to enhance educational outcomes, ensuring it enriches the learning experience for all students.

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The author declares no conflicts or competing interest.

DATA AVAILABILITY STATEMENT

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ETHICAL GUIDELINES

This paper does not involve research participants and is a review of other research findings. This paper was approved and completed under the author's PhD by Portfolio Supervisor Professor Lynn Revell at CCCU and ethical clearance was deemed not required.

CONSENT TO PUBLISH

All named authors consent to publish.

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APPENDIX A

Article No.	Literature	Phrase	Code
1	Abdelghani, et. al., 2023	1. Generative Artificial Intelligence (GAI) in education	1a
		2. Personalized and interactive pedagogical sequences	1b
		3. Students' intrinsic motivation	1c
		4. Active engagement in learning	1d
		5. Control over learning	1e
		6. Lack of uncertainty signaling in Large Language Models (LLMs)	1f
		7. Over-estimation of competencies	1g
		8. Passiveness in learning	1h
		9. Loss of curious and critical-thinking sense	1i
		10. Lack of pedagogical stance in GAI behaviors	1j
		11. Effects on students' active learning strategies	1k
		12. Metacognitive skills in education	1l
		13. Framework for introducing pedagogical transparency in GAI-based educational applications	1m
		14. Training methods for including pedagogical principles in AI models	1n
		15. Pedagogically-relevant interactions with GAI	1o
		16. Educational methods for acquiring skills to benefit from GAI	1p
		17. Meta-cognitive skills	1q
		18. GAI literacy in education	1r
2	Aydin and Karaarslan, 2023	1. Generative AI in education	2a
		2. Chatbot implementation in education	2b
		3. Public availability of ChatGPT	2c
		4. Interest from people of different fields, ages, and education	2d
		5. Trials with ChatGPT	2e
		6. User expectations of ChatGPT and Generative AI	2f
		7. Technical and structural fundamentals of ChatGPT and its competitors	2g
		8. Comparison with Google's Bard AI, Claude, Meta's Wit.ai, and Tencent's HunyuanAide	2h
		9. Analysis of early-stage due diligence and current situation	2i
		10. Examination of preprint papers and published articles	2j
		11. Use of ChatGPT in editing content	2k
		12. Promise of Generative AI and large language models in education	2l
3	Baidoo-Anu and Owusu Ansah, 2023	1. ChatGPT in education	3a
		2. Rapid subscriber growth after release	3b
		3. Capacity to carry out complex tasks	3c
		4. Impact on existing educational practices	3d
		5. Benefits of ChatGPT in teaching and learning	3e
		6. Personalized and interactive learning	3f
		7. Formative assessment activities	3g
		8. Ongoing feedback for teaching and learning	3h
		9. Limitations of ChatGPT	3i
		10. Generating wrong information	3j
		11. Biases in data training	3k
		12. Privacy issues	3l
		13. Recommendations for leveraging ChatGPT in education	3m
		14. Collaboration between policy makers, researchers, educators, and technology experts	3n
		15. Safe and constructive use of generative AI tools in education	3o
		16. Improving education and supporting students' learning with AI	3p
4	Celik, et. al., 2022	1. Teachers' use of artificial intelligence (AI) applications	4a
		2. Machine learning methods to analyze teachers' data	4b
		3. Opportunities for improved planning with AI	4c
		4. Defining students' needs through AI	4d
		5. Immediate feedback for teachers	4e
		6. Teacher intervention with AI	4f
		7. Assessment through automated essay scoring	4g
		8. Teachers' roles in the development of AI technology	4h
		9. Acting as models for training AI algorithms	4i
		10. Participating in AI development	4j
		11. Checking the accuracy of AI automated assessment systems	4k
		12. Challenges in AI implementation in teaching practice	4l
		13. Guidelines for developing the field of AI in education	4m

5	Chan and Hu, 2023	1. University students' perceptions of generative AI (GenAI) technologies	5a
		2. ChatGPT in higher education	5b
		3. Familiarity with GenAI	5c
		4. Willingness to engage with GenAI	5d
		5. Potential benefits of GenAI in teaching and learning	5e
		6. Challenges of integrating GenAI	5f
		7. Positive attitude towards GenAI in education	5g
		8. Personalized learning support	5h
		9. Writing and brainstorming assistance	5i
		10. Research and analysis capabilities	5j
		11. Concerns about accuracy, privacy, and ethical issues	5k
		12. Impact on personal development, career prospects, and societal values	5l
		13. John Biggs' 3P model	5m
		14. Influence of student perceptions on learning approaches and outcomes	5n
		15. Tailoring GenAI technologies to address needs and concerns	5o
		16. Promoting effective learning outcomes	5p
		17. Policy development for integrating GenAI in higher education	5q
		18. Responsible and effective implementation of GenAI tools	5r
		19. Enhancing teaching and learning experiences in higher education	5s
6	Chen, et. al., 2023	1. Low teacher-student ratios in higher education	6a
		2. Difficulty in receiving immediate and interactive help	6b
		3. Use of chatbots to help instructors meet student needs	6c
		4. Pedagogical chatbot efficacy in higher education	6d
		5. Opportunities, challenges, efficacy, and ethical concerns of using chatbots in education	6e
		6. Exploration of using chatbots as pedagogical tools in business education	6f
		7. Chatbot-guided interview with undergraduate students	6g
		8. Student attitudes towards chatbots as intelligent student assistants	6h
		9. Potential benefits of using chatbots in learning	6i
		10. Challenges of using chatbots in education	6j
		11. Design and development of a new chatbot assistant for teaching AI concepts	6k
		12. Engaging and responsive conversational learning tools	6l
		13. Providing educational resources through chatbots	6m
		14. Promising opportunities and ethical implications of using chatbots to support inclusive learning	6n

7	Cheng, 2022	1. Artificial intelligence	7a
		2. Semantic technologies	7b
		3. Education domain	7c
		4. Higher Education institutions (HEIs)	7d
		5. Students' academic performance	7e
		6. Early intervention for at-risk students	7f
		7. Curriculum	7g
		8. Machine learning models	7h
		9. Deep learning models	7i
		10. Semantic analysis	7j
		11. Computer Science curriculum	7k
		12. Predict students' performance	7l
		13. Genetic Algorithm	7m
		14. Long-Short Term Memory (LSTM)	7n
		15. Bidirectional Encoder Representation with Transformers (BERT)	7o
		16. Cosine similarity	7p
		17. Prerequisite identification	7q
		18. Dropout prediction	7r
		19. Similarity between courses	7s
		20. University programs	7t
		21. Student advisors	7u
		22. Recommendation systems	7v
8	Daniel, 2015	1. Institutions of higher education	8a
		2. Contemporary challenges	8b
		3. Big Data	8c
		4. Implementation of Big Data	8d
		5. Opportunities and challenges	8e
		6. Higher education	8f
		7. Future directions	8g
		8. Development and implementation	8h
		9. Institutional project on Big Data	8i
9	Feffer, et. al., 2023	1. AI ethics education	9a
		2. Awareness of AI harms	9b
		3. AI Incident Database (AIID)	9c
		4. Educational tool	9d
		5. Prevalence and severity of AI harms	9e
		6. Socially high-stakes domains	9f
		7. Classroom study	9g
		8. Societal and ethical considerations	9h
		9. AI and ML	9i
		10. Ethical and societal aspects	9j
		11. Educational gap	9k
		12. Database interaction	9l
		13. Governance and accountability mechanisms	9m
		14. Students' feedback	9n
		15. Actionable recommendations	9o
		16. AI ethics education improvement	9p

10	Fischer, et. al., 2020	1. Big data in educational contexts	10a
		2. Data-driven approaches	10b
		3. Digital traces of student behavior	10c
		4. Scalable and finer-grained understanding	10d
		5. Learning processes	10e
		6. Clickstream data	10f
		7. Personalize and enhance instruction	10g
		8. Natural language processing techniques	10h
		9. Cognitive, social, behavioral, and affective processes	10i
		10. Institutional data	10j
		11. Course guidance systems	10k
		12. Early-warning systems	10l
		13. Challenges of accessing, analyzing, and using big data	10m
		14. Data privacy and protection	10n
		15. Data sharing and research	10o
		16. Educational data science methodologies	10p
		17. Explanation and prediction	10q
		18. Mining big data in education	10r
11	Grindle, et. al., 2013	1. Headsprout Early Reading (HER)	11a
		2. Online computer program	11b
		3. Teaching basic reading skills	11c
		4. Adult offenders with mild intellectual disabilities (IDs)	11d
		5. Secure hospital	11e
		6. Feasibility and effectiveness	11f
		7. Single subject pre-post-test design	11g
		8. Literacy tests	11h
		9. Reading self-concept	11i
		10. Treatment as usual (TAU) control participants	11j
		11. Improved reading skills	11k
		12. Self-concept scores	11l
		13. Typically developing children	11m
		14. Developmental disabilities	11n
		15. First study to evaluate this program with an adult population	11o
12	Harrer, 2023	1. knowledge retrieval and other cognitive processes	12a
		2. assistive tools for information management	12b
		3. transform data management workflows	12c
		4. proposes an ethical, technical, and cultural framework for responsible design, development, and deployment	12d
		5. incentivise users, developers, providers, and regulators	12e

13	Ilieva, et. al., 2023	1. Personalized learning experiences for students	13a
		2. Intelligent chatbots based on generative artificial intelligence (AI) technology	13b
		3. Transforming pedagogical activities	13c
		4. Guiding both students and instructors interactively	13d
		5. New theoretical framework for blended learning with intelligent chatbots integration	13e
		6. Comprehensive understanding of the transformative potential of AI chatbots in education	13f
		7. Holistic methodology to enhance the overall educational experience	13g
		8. Unifies the applications of intelligent chatbots in teaching-learning activities within universities	13h
14	Jančařík, et. al, 2023	1. Artificial intelligence chatbot for mathematics tutoring	14a
		2. Student behavior analysis	14b
		3. Approach to solving problems without external motivation	14c
		4. Course trajectory analysis	14d
		5. Intensive work in the lessons	14e
		6. Use of prepared help and instructional videos	14f
		7. Identification of different student groups based on solution time	14g
		8. Chat-bot format being close to learners	14h
		9. Analysis of solution time for analyzing learner behavior	14i
		10. Need for further analyses in this area	14j
15	Jovanović and Campbell, 2022	1. Generative modeling in artificial intelligence (AI)	15a
		2. Synthetic artifacts generation	15b
		3. Analyzing training examples	15c
		4. Learning patterns and distribution	15d
		5. Creating realistic facsimiles	15e
		6. Generative AI (GAI) using deep learning (DL) to produce diverse content	15f
		7. Utilizing existing media such as text, graphics, audio, and video	15g
		8. Practical opportunities and challenges of GAI	15h
		9. Various domains and everyday scenarios	15i
		10. Common techniques of generative AI	15j
16	Khalil, et. al., 2023	1. Artificial intelligence (AI) in education	16a
		2. Role of AI on education from a student-teacher perspective	16b
		3. Technology Acceptance Model (TAM)	16c
		4. Efficiency and convenience of implementing AI within education	16d
		5. Challenges faced by students and educators	16e
		6. Security and privacy issues as obstacles to the use of AI in education	16f
		7. Ethical aspects of AI tools and applications	16g
		8. Data privacy and security concerns	16h
		9. Support for self-dependent learning	16i
		10. Complexity of using AI without necessary skills and experience	16j
		11. Time consumption in collecting data	16k
		12. Methods to improve results and overcome challenges	16l

17	Krumm et, al., 2018	1. large numbers of learners	17a
		2. machine learning and artificial intelligence	17b
		3. analyzing educational big data	17c
		4. new forms of data and new analytical techniques	17d
		5. data-intensive research	17e
		6. research-practice partnerships	17f
		7. collaborative data-intensive improvement (CDI)	17g
		8. how data are used for research and improving practice	17h
18	Kumar and Raman, 2022	1. Artificial Intelligence (AI) in higher education	18a
		2. Teaching Learning process	18b
		3. Admission process	18c
		4. Placement process	18d
		5. Administrative process	18e
		6. student perceptions on AI usage	18f
		7. quantitative and qualitative response	18g
		8. statistical analysis	18h
		9. Ordination regression and correlation	18i
		10. AI can be effectively used in teaching-learning process	18j
		11. academic administration processes	18k
19	Lee, 2018	1. progress that China and the US are making in the field of AI	19a
		2. AI has become the powerful force	19b
		3. scientists well trained in the field of AI	19c
		4. AI will drastically change the nature of human labour	19d
		5. the consequences for our social systems	19e
		6. new paths will be taken, creating new jobs	19f
20	Niemi, 2021	1. AI for learning	20a
		2. supporting people in cognitive and non-cognitive task domains	20b
		3. agency, engagement, self-efficacy, and collaboration in learning	20c
		4. importance of social elements in learning	20d
		5. the teacher's role in digital pedagogy involving facilitating and coaching	20e
		6. limitations of AI in learning	20f
		7. ethical issues in AI, such as biases, privacy, transparency, and data ownership	20g
		8. explainability and explicability in the context of human learning	20h
		9. making AI more trustworthy for users in learning environments	20i
21	Niemi, et. al., 2022	1. Artificial intelligence (AI) in educational settings (AIED)	21a
		2. human learning and machine learning connected	21b
		3. consequences for education and working life	21c
		4. ethical issues with AI in education	21d
		5. AI-based intelligent tools and environments supporting human learning	21e
		6. potentialities of AI for education and learning	21f
		7. new applications and consequences of AI in education	21g
		8. trends in AI development and changes required in education and working life contexts	21h
		9. contributions of AI to redesigning the future of education and learning	21i
		10. AI's role in education globally	22j
		11. challenges in applying AI in learning and education.	22k
22	Pesek, et. al., 2021	1. Artificial intelligence adapting educational experiences	22a
		2. Intelligent Management Systems (IMS) in education	22b
		3. New impetus for AI in education	22c
		4. AI personalizing learning	22d
		5. Creating innovative learning content	22e
		6. Intelligent tutoring systems	22f
		7. Assisting pupils with special needs	22g
		8. Helping teachers assess	22h
		9. Providing students access to learning content	22i
		10. Translating educational content across languages	22j
		11. Removing language barriers in education	22k
		12. Exploring possibilities of using AI in education	22l
23	Petersen, 2021	1. Assessments in public education	23a
		2. Standards-based accountability	23b
		3. Capturing learning effectively	23c
		4. Tests in education	23d
		5. Information about student progress	23e
		6. Transformation in assessments	23f
		7. New forms of assessment	23g
		8. Improving teacher practice	23h
		9. Enhancing parent involvement	23i
		10. Increasing student learning	23j
		11. Assessments for learning	23k
		12. Assessment innovation in schools	23l
		13. Effective assessment in education	23m
		14. Teaching and learning in the 21st century	23n
24	Rachha and Seyman, 2023	1. Fairness, Accountability, Transparency, and Ethics (FATE) in educational interventions	24a
		2. Artificial Intelligence (AI) algorithms in education	24b
		3. eXplainable AI (XAI) in education	24c
		4. Trust in AI systems	24d
		5. Transparent explanations for AI decisions	24e
		6. XAI-ED framework for educational AI tools	24f
		7. Stakeholders in educational AI	24g
		8. Approaches for presenting explanations in education	24h
		9. Human-centered designs for AI interfaces	24i
		10. Potential pitfalls of providing explanations in education	24j
		11. Case studies applying XAI-ED in educational AI tools	24k
		12. Opportunities and challenges of incorporating XAI in education	24l
		13. Future research needs for XAI in education	24m
25	Richter, et. al., 2019	1. Artificial intelligence (AI) trend	25a
		2. Controversial discussions on AI	25b
		3. Potential to change the way people live and work	25c
		4. Consequences of misguided superintelligence	25d
		5. Prominent scientists and technology pioneers' opinions on AI	25e
		6. Drivers, advantages, disadvantages, and challenges of AI applications	25f
		7. Literature search on AI	25g
		8. Historical developments of AI	25h
		9. Common definitions of AI	25i
		10. Types and functionalities of AI	25j
26	Roschelle, et. al., 2020	1. Artificial intelligence (AI)	26a
		2. Machine learning	26b
		3. Educational robotics	26c
		4. Related technologies	26d
		5. Future of learning	26e
		6. Applications of AI in education	26f
		7. New innovations	26g
		8. Consequential applications of AI to education	26h
		9. Potential benefits and considerable risks	26i
		10. Scalable impacts	26j
		11. Educational planning	26k
		12. Long horizon to be effective	26l
27	Slater, et. al., 2017	1. Educational data mining (EDM)	27a
		2. Learning analytics (LA)	27b
		3. Alternatives to frequentist and Bayesian approaches	27c
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		5. Generalizable relationships and findings	27e
		6. Data mining as an area of methods	27f
		7. Exploratory data analysis	27g
		8. Analytics in other fields	27h
		9. Tools for research and practice in educational data mining	27i
		10. Tools used for educational data mining analyses	27j
		11. Structural equation models and multilevel models	27k
		12. Data management tools	27l
		13. Database management systems	27m
		14. Inclusion criteria for educational data mining tools	27n
		15. Core research groups and organizations in the field	27o
28	Stone, et. al., 2016	1. Artificial Intelligence (AI)	28a
		2. Machine learning	28b
		3. Deep learning	28c
		4. Natural Language Processing (NLP)	28d
		5. Education	28e
		6. Knowledge representation and reasoning	28f
		7. AI in education	28g
		8. Impact of AI on education	28h
		9. Challenges in education with AI	28i
		10. AI influences in education	28j
		11. AI-related policy in education	28k
29	Suresh, et. al., 2019	1. Deep learning	29a
		2. Natural language processing	29b
		3. Classroom discourse analysis	29c
		4. Teachers' discursive strategies	29d
		5. Automated analysis	29e
		6. Bidirectional long short-term memory (bi-LSTM) network	29f
		7. Annotation process automation	29g
		8. Teacher feedback	29h
		9. Deep learning approach	29i
		10. Educational technology	29j
30	Taranikanti and Davidson, 2023	1. Learning technologies	30a
		2. AI chatbots	30b
		3. Modern pedagogical techniques	30c
		4. AI technology	30d
		5. Metacognitive frameworks	30e
		6. Practical applications	30f
		7. Iterative and immediate feedback	30g
		8. Problem-based learning formats	30h
		9. Textual conversations	30i
		10. Critical thinking	30j
		11. Skill development	30k
		12. Lifelong learning process	30l

APPENDIX B

Article No.	Literature	Phrase	Code
1	Abdelghani, et. al., 2023	1. Generative Artificial Intelligence (GAI) in education	1a
		2. Personalized and interactive pedagogical sequences	1b
		3. Students' intrinsic motivation	1c
		4. Active engagement in learning	1d
		5. Control over learning	1e
		6. Lack of uncertainty signaling in Large Language Models (LLMs)	1f
		7. Over-estimation of competencies	1g
		8. Passiveness in learning	1h
		9. Loss of curious and critical-thinking sense	1i
		10. Lack of pedagogical stance in GAI behaviors	1j
		11. Effects on students' active learning strategies	1k
		12. Metacognitive skills in education	1l
		13. Framework for introducing pedagogical transparency in GAI-based educational applications	1m
		14. Training methods for including pedagogical principles in AI models	1n
		15. Pedagogically-relevant interactions with GAI	1o
		16. Educational methods for acquiring skills to benefit from GAI	1p
		17. Meta-cognitive skills	1q
		18. GAI literacy in education	1r
2	Aydin and Karaarslan, 2023	1. Generative AI in education	2a
		2. Chatbot implementation in education	2b
		3. Public availability of ChatGPT	2c
		4. Interest from people of different fields, ages, and education	2d
		5. Trials with ChatGPT	2e
		6. User expectations of ChatGPT and Generative AI	2f
		7. Technical and structural fundamentals of ChatGPT and its competitors	2g
		8. Comparison with Google's Bard AI, Claude, Meta's Wit.ai, and Tencent's HunyuanAide	2h
		9. Analysis of early-stage due diligence and current situation	2i
		10. Examination of preprint papers and published articles	2j
		11. Use of ChatGPT in editing content	2k
		12. Promise of Generative AI and large language models in education	2l
3	Baidoo-Anu and Owusu Ansah, 2023	1. ChatGPT in education	3a
		2. Rapid subscriber growth after release	3b
		3. Capacity to carry out complex tasks	3c
		4. Impact on existing educational practices	3d
		5. Benefits of ChatGPT in teaching and learning	3e
		6. Personalized and interactive learning	3f
		7. Formative assessment activities	3g
		8. Ongoing feedback for teaching and learning	3h
		9. Limitations of ChatGPT	3i
		10. Generating wrong information	3j
		11. Biases in data training	3k
		12. Privacy issues	3l
		13. Recommendations for leveraging ChatGPT in education	3m
		14. Collaboration between policy makers, researchers, educators, and technology experts	3n
		15. Safe and constructive use of generative AI tools in education	3o
		16. Improving education and supporting students' learning with AI	3p
4	Celik, et. al., 2022	1. Teachers' use of artificial intelligence (AI) applications	4a
		2. Machine learning methods to analyze teachers' data	4b
		3. Opportunities for improved planning with AI	4c
		4. Defining students' needs through AI	4d
		5. Immediate feedback for teachers	4e
		6. Teacher intervention with AI	4f
		7. Assessment through automated essay scoring	4g
		8. Teachers' roles in the development of AI technology	4h
		9. Acting as models for training AI algorithms	4i
		10. Participating in AI development	4j
		11. Checking the accuracy of AI automated assessment systems	4k
		12. Challenges in AI implementation in teaching practice	4l
		13. Guidelines for developing the field of AI in education	4m
5	Chan and Hu, 2023	1. University students' perceptions of generative AI (GenAI) technologies	5a
		2. ChatGPT in higher education	5b
		3. Familiarity with GenAI	5c
		4. Willingness to engage with GenAI	5d
		5. Potential benefits of GenAI in teaching and learning	5e
		6. Challenges of integrating GenAI	5f
		7. Positive attitude towards GenAI in education	5g
		8. Personalized learning support	5h
		9. Writing and brainstorming assistance	5i
		10. Research and analysis capabilities	5j
		11. Concerns about accuracy, privacy, and ethical issues	5k
		12. Impact on personal development, career prospects, and societal values	5l
		13. John Biggs' 3P model	5m
		14. Influence of student perceptions on learning approaches and outcomes	5n
		15. Tailoring GenAI technologies to address needs and concerns	5o
		16. Promoting effective learning outcomes	5p
		17. Policy development for integrating GenAI in higher education	5q
		18. Responsible and effective implementation of GenAI tools	5r
		19. Enhancing teaching and learning experiences in higher education	5s
6	Chen, et. al., 2023	1. Low teacher-student ratios in higher education	6a
		2. Difficulty in receiving immediate and interactive help	6b
		3. Use of chatbots to help instructors meet student needs	6c
		4. Pedagogical chatbot efficacy in higher education	6d
		5. Opportunities, challenges, efficacy, and ethical concerns of using chatbots in education	6e
		6. Exploration of using chatbots as pedagogical tools in business education	6f
		7. Chatbot-guided interview with undergraduate students	6g
		8. Student attitudes towards chatbots as intelligent student assistants	6h
		9. Potential benefits of using chatbots in learning	6i
		10. Challenges of using chatbots in education	6j
		11. Design and development of a new chatbot assistant for teaching AI concepts	6k
		12. Engaging and responsive conversational learning tools	6l
		13. Providing educational resources through chatbots	6m
		14. Promising opportunities and ethical implications of using chatbots to support inclusive learning	6n
7	Cheng, 2022	1. Artificial intelligence	7a
		2. Semantic technologies	7b
		3. Education domain	7c
		4. Higher Education institutions (HEIs)	7d
		5. Students' academic performance	7e
		6. Early intervention for at-risk students	7f
		7. Curriculum	7g
		8. Machine learning models	7h
		9. Deep learning models	7i
		10. Semantic analysis	7j
		11. Computer Science curriculum	7k
		12. Predict students' performance	7l
		13. Genetic Algorithm	7m
		14. Long-Short Term Memory (LSTM)	7n
		15. Bidirectional Encoder Representation with Transformers (BERT)	7o
		16. Cosine similarity	7p
		17. Prerequisite identification	7q
		18. Dropout prediction	7r
		19. Similarity between courses	7s
		20. University programs	7t
		21. Student advisors	7u
		22. Recommendation systems	7v
8	Daniel, 2015	1. Institutions of higher education	8a
		2. Contemporary challenges	8b
		3. Big Data	8c
		4. Implementation of Big Data	8d
		5. Opportunities and challenges	8e
		6. Higher education	8f
		7. Future directions	8g
		8. Development and implementation	8h
		9. Institutional project on Big Data	8i
9	Feffer, et. al., 2023	1. AI ethics education	9a
		2. Awareness of AI harms	9b
		3. AI Incident Database (AIID)	9c
		4. Educational tool	9d
		5. Prevalence and severity of AI harms	9e
		6. Socially high-stakes domains	9f
		7. Classroom study	9g
		8. Societal and ethical considerations	9h
		9. AI and ML	9i
		10. Ethical and societal aspects	9j
		11. Educational gap	9k
		12. Database interaction	9l
		13. Governance and accountability mechanisms	9m
		14. Students' feedback	9n
		15. Actionable recommendations	9o
		16. AI ethics education improvement	9p

10	Fischer, et. al., 2020	1. Big data in educational contexts	10a
		2. Data-driven approaches	10b
		3. Digital traces of student behavior	10c
		4. Scalable and finer-grained understanding	10d
		5. Learning processes	10e
		6. Clickstream data	10f
		7. Personalize and enhance instruction	10g
		8. Natural language processing techniques	10h
		9. Cognitive, social, behavioral, and affective processes	10i
		10. Institutional data	10j
		11. Course guidance systems	10k
		12. Early-warning systems	10l
		13. Challenges of accessing, analyzing, and using big data	10m
		14. Data privacy and protection	10n
		15. Data sharing and research	10o
		16. Educational data science methodologies	10p
		17. Explanation and prediction	10q
		18. Mining big data in education	10r
11	Grindle, et. al., 2013	1. Headsprout Early Reading (HER)	11a
		2. Online computer program	11b
		3. Teaching basic reading skills	11c
		4. Adult offenders with mild intellectual disabilities (IDs)	11d
		5. Secure hospital	11e
		6. Feasibility and effectiveness	11f
		7. Single subject pre-post-test design	11g
		8. Literacy tests	11h
		9. Reading self-concept	11i
		10. Treatment as usual (TAU) control participants	11j
		11. Improved reading skills	11k
		12. Self-concept scores	11l
		13. Typically developing children	11m
		14. Developmental disabilities	11n
		15. First study to evaluate this program with an adult population	11o
12	Harrer, 2023	1. knowledge retrieval and other cognitive processes	12a
		2. assistive tools for information management	12b
		3. transform data management workflows	12c
		4. proposes an ethical, technical, and cultural framework for responsible design, development, and deployment	12d
		5. incentivise users, developers, providers, and regulators	12e

13	Ilieva, et. al., 2023	1. Personalized learning experiences for students	13a
		2. Intelligent chatbots based on generative artificial intelligence (AI) technology	13b
		3. Transforming pedagogical activities	13c
		4. Guiding both students and instructors interactively	13d
		5. New theoretical framework for blended learning with intelligent chatbots integration	13e
		6. Comprehensive understanding of the transformative potential of AI chatbots in education	13f
		7. Holistic methodology to enhance the overall educational experience	13g
		8. Unifies the applications of intelligent chatbots in teaching-learning activities within universities	13h
14	Jančařík, et. al, 2023	1. Artificial intelligence chatbot for mathematics tutoring	14a
		2. Student behavior analysis	14b
		3. Approach to solving problems without external motivation	14c
		4. Course trajectory analysis	14d
		5. Intensive work in the lessons	14e
		6. Use of prepared help and instructional videos	14f
		7. Identification of different student groups based on solution time	14g
		8. Chat-bot format being close to learners	14h
		9. Analysis of solution time for analyzing learner behavior	14i
		10. Need for further analyses in this area	14j
15	Jovanović and Campbell, 2022	1. Generative modeling in artificial intelligence (AI)	15a
		2. Synthetic artifacts generation	15b
		3. Analyzing training examples	15c
		4. Learning patterns and distribution	15d
		5. Creating realistic facsimiles	15e
		6. Generative AI (GAI) using deep learning (DL) to produce diverse content	15f
		7. Utilizing existing media such as text, graphics, audio, and video	15g
		8. Practical opportunities and challenges of GAI	15h
		9. Various domains and everyday scenarios	15i
		10. Common techniques of generative AI	15j
16	Khalil, et. al., 2023	1. Artificial intelligence (AI) in education	16a
		2. Role of AI on education from a student-teacher perspective	16b
		3. Technology Acceptance Model (TAM)	16c
		4. Efficiency and convenience of implementing AI within education	16d
		5. Challenges faced by students and educators	16e
		6. Security and privacy issues as obstacles to the use of AI in education	16f
		7. Ethical aspects of AI tools and applications	16g
		8. Data privacy and security concerns	16h
		9. Support for self-dependent learning	16i
		10. Complexity of using AI without necessary skills and experience	16j
		11. Time consumption in collecting data	16k
		12. Methods to improve results and overcome challenges	16l

17	Krumm et, al., 2018	1. large numbers of learners	17a
		2. machine learning and artificial intelligence	17b
		3. analyzing educational big data	17c
		4. new forms of data and new analytical techniques	17d
		5. data-intensive research	17e
		6. research-practice partnerships	17f
		7. collaborative data-intensive improvement (CDI)	17g
		8. how data are used for research and improving practice	17h
18	Kumar and Raman, 2022	1. Artificial Intelligence (AI) in higher education	18a
		2. Teaching Learning process	18b
		3. Admission process	18c
		4. Placement process	18d
		5. Administrative process	18e
		6. student perceptions on AI usage	18f
		7. quantitative and qualitative response	18g
		8. statistical analysis	18h
		9. Ordination regression and correlation	18i
		10. AI can be effectively used in teaching-learning process	18j
		11. academic administration processes	18k
19	Lee, 2018	1. progress that China and the US are making in the field of AI	19a
		2. AI has become the powerful force	19b
		3. scientists well trained in the field of AI	19c
		4. AI will drastically change the nature of human labour	19d
		5. the consequences for our social systems	19e
		6. new paths will be taken, creating new jobs	19f
20	Niemi, 2021	1. AI for learning	20a
		2. supporting people in cognitive and non-cognitive task domains	20b
		3. agency, engagement, self-efficacy, and collaboration in learning	20c
		4. importance of social elements in learning	20d
		5. the teacher's role in digital pedagogy involving facilitating and coaching	20e
		6. limitations of AI in learning	20f
		7. ethical issues in AI, such as biases, privacy, transparency, and data ownership	20g
		8. explainability and explicability in the context of human learning	20h
		9. making AI more trustworthy for users in learning environments	20i
21	Niemi, et. al., 2022	1. Artificial intelligence (AI) in educational settings (AIED)	21a
		2. human learning and machine learning connected	21b
		3. consequences for education and working life	21c
		4. ethical issues with AI in education	21d
		5. AI-based intelligent tools and environments supporting human learning	21e
		6. potentialities of AI for education and learning	21f
		7. new applications and consequences of AI in education	21g
		8. trends in AI development and changes required in education and working life contexts	21h
		9. contributions of AI to redesigning the future of education and learning	21i
		10. AI's role in education globally	22j
		11. challenges in applying AI in learning and education.	22k

22	Pesek, et. al., 2021	1. Artificial intelligence adapting educational experiences	22a
		2. Intelligent Management Systems (IMS) in education	22b
		3. New impetus for AI in education	22c
		4. AI personalizing learning	22d
		5. Creating innovative learning content	22e
		6. Intelligent tutoring systems	22f
		7. Assisting pupils with special needs	22g
		8. Helping teachers assess	22h
		9. Providing students access to learning content	22i
		10. Translating educational content across languages	22j
		11. Removing language barriers in education	22k
		12. Exploring possibilities of using AI in education	22l
23	Petersen, 2021	1. Assessments in public education	23a
		2. Standards-based accountability	23b
		3. Capturing learning effectively	23c
		4. Tests in education	23d
		5. Information about student progress	23e
		6. Transformation in assessments	23f
		7. New forms of assessment	23g
		8. Improving teacher practice	23h
		9. Enhancing parent involvement	23i
		10. Increasing student learning	23j
		11. Assessments for learning	23k
		12. Assessment innovation in schools	23l
		13. Effective assessment in education	23m
		14. Teaching and learning in the 21st century	23n
24	Rachha and Seyman, 2023	1. Fairness, Accountability, Transparency, and Ethics (FATE) in educational interventions	24a
		2. Artificial Intelligence (AI) algorithms in education	24b
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		10. Potential pitfalls of providing explanations in education	24j
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		12. Opportunities and challenges of incorporating XAI in education	24l
		13. Future research needs for XAI in education	24m

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30	Taranikanti and Davidson, 2023	1. Learning technologies	30a
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		11. Skill development	30k
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APPENDIX C

Theme	Sub-themes	Phrases and Codes
Pedagogical Framework and Strategies	Personalisation and Interactivity	Personalized and interactive pedagogical sequences (1b)
		Personalized and interactive learning (3f)
		Personalized learning support (5h)
		Tailoring GenAI technologies to address needs and concerns (5o)
		Promoting effective learning outcomes (5p)
		Personalized learning process (18b)
	Assessment and Feedback	Control over learning (1e)
		Formative assessment activities (3g)
		Ongoing feedback for teaching and learning (3h)
		Assessment through automated essay scoring (4g)
		Transforming pedagogical activities (13c)
		Effective assessment in education (23m)
	AI Integration in Education	Generative AI in education (2a)
		ChatGPT in higher education (5b)
		Recommendations for leveraging ChatGPT in education (3m)
		Use of ChatGPT in editing content (2k)
		Promises of Generative AI and large language models in education (2l)
		AI can be effectively used in teaching-learning process (18j)
	Collaboration and Integration	Collaboration between policy makers, researchers, educators, and technology experts (3n)
		Design and development of a new chatbot assistant for teaching AI concepts (6k)
		Providing educational resources through chatbots (6m)
		Unifying applications of intelligent chatbots in teaching-learning activities within universities (13h)
		AI-based intelligent tools and environments supporting human learning (21e)
		Contributions of AI to redesigning the future of education and learning (21i)
	Technological Advancements	Generative modeling in artificial intelligence (AI) (15a)
		Synthetic artifacts generation (15b)
		AI-based intelligent tools and environments supporting human learning (21e)
		New applications and consequences of AI in education (21g)
		Applications of AI in education (26f)
		Impact of AI on education (28h)
	Educational Development and Trends	Future directions (8g)
		Trends in AI development and changes required in education and working life contexts (21h)
		AI influences in education (28j)
		AI-related policy in education (28k)
		Challenges in education with AI (28i)
		AI influences in education (28j)
	Metacognitive or Thinking Skills	Metacognitive skills in education (1l)
		Meta-cognitive skills (1q)
		Metacognitive frameworks (30e)
		Critical thinking (30j)
		Skill development (30k)

Theme	Sub-themes	Phrases and Codes
Perception, Engagement and Motivation	Interest and Engagement in Learning	Active engagement in learning (1d)
		Effects on students' active learning strategies (1k)
	Intrinsic Motivation and Attitudes towards AI	Students' intrinsic motivation (1c)
		Loss of curious and critical-thinking sense (1i)
		Positive attitude towards GenAI in education (5g)
		Student attitudes towards chatbots as intelligent student assistants (6h)
	Benefits and Perceptions of AI in Education	Benefits of ChatGPT in teaching and learning (3e)
		Potential benefits of GenAI in teaching and learning (5e)
		Influence of student perceptions on learning approaches and outcomes (5n)
		Enhancing teaching and learning experiences in higher education (5s)
		Potential benefits of using chatbots in learning (6i)
		AI personalizing learning (22d)
	Use of AI in Education	Safe and constructive use of generative AI tools in education (3o)
		Comprehensive understanding of the transformative potential of AI chatbots in education (13f)
		Artificial intelligence (AI) in education (16a)
		Role of AI on education from a student-teacher perspective (16b)
		Efficiency and convenience of implementing AI within education (16d)
		Support for self-dependent learning (16i)
		Methods to improve results and overcome challenges (16l)
	Innovative Learning Tools and Systems	Chatbot-guided interview with undergraduate students (6g)
		Personalized learning experiences for students (13a)
		AI chatbots (30b)
		AI technology (30d)
		Intelligent tutoring systems (22f)
		Assisting pupils with special needs (22g)
		Helping teachers assess (22h)
	Future Implications of AI	AI will drastically change the nature of human labor (19d)
		Potential to change the way people live and work (25c)
	Educational Technology	Educational technology (29j)
		Creating innovative learning content (22e)

Theme	Sub-themes	Phrases and Codes
Concerns Regarding AI in Education	Pedagogical Transparency in AI Education	Framework for introducing pedagogical transparency in GAI-based educational applications - 1m
		Training methods for including pedagogical principles in AI models - 1n
	User Expectations and Limitations of AI	User expectations of ChatGPT and Generative AI - 2f
		Limitations of ChatGPT - 3i
	Privacy and Security Concerns	Privacy issues - 3l
		Security and privacy issues as obstacles to the use of AI in education - 16f
		Data privacy and security concerns - 16h
	Challenges and Integration of AI in Education	Challenges of integrating GenAI - 5f
		Challenges of using chatbots in education - 6j
		Challenges of using chatbots in education - 6j
		Challenges of integrating GenAI - 5f
	Ethical Issues and Society	Concerns about accuracy, privacy, and ethical issues - 5k
		Ethical and societal aspects - 9j
		Ethical aspects of AI tools and applications - 16g
		Ethical issues in AI, such as biases, privacy, transparency, and data ownership - 20g
	Awareness and Governance	Awareness of AI harms - 9b
		Governance and accountability mechanisms - 9m
	AI Impacts on Education and Society	Impact on existing educational practices - 3d
		Impact on personal development, career prospects, and societal values - 5l
		Consequences for education and working life - 21c
		AI's role in education globally - 22j
		Challenges in applying AI in learning and education - 22k
	Explainability and Trustworthiness	Transparent explanations for AI decisions - 24e
		Trust in AI systems - 24d
		Making AI more trustworthy for users in learning environments - 20i
	Future Considerations	New paths will be taken, creating new jobs - 19f
		Long horizon to be effective - 26l
		Scalable impacts - 26j

Theme	Sub-themes	Phrases and Codes
Integration of AI in Education	Generative Artificial Intelligence (GAI) in Education	1. Generative Artificial Intelligence (GAI) in education (1a)
		2. Lack of pedagogical stance in GAI behaviors (1j)
		3. Educational methods for acquiring skills to benefit from GAI (1p)
	Chatbot Implementation in Education	1. Chatbot implementation in education (2b)
		2. Trials with ChatGPT (2e)
	Teachers' Involvement with Artificial Intelligence (AI) Applications	1. Teachers' use of artificial intelligence (AI) applications (4a)
		2. Machine learning methods to analyze teachers' data (4b)
		3. Immediate feedback for teachers (4e)
		4. Teacher intervention with AI (4f)
		5. Teachers' roles in the development of AI technology (4h)
		6. Acting as models for training AI algorithms (4i)
		7. Participating in AI development (4j)
		8. Checking the accuracy of AI automated assessment systems (4k)
	AI Ethics and Education	1. AI ethics education (9a)
		2. AI Incident Database (AIID) (9c)
		3. Educational tool (9d)
		4. Classroom study (9g)
		5. AI and ML (9i)
		6. Database interaction (9l)
	Big Data and Educational Contexts	1. Big data in educational contexts (10a)
		2. Data-driven approaches (10b)
		3. Digital traces of student behavior (10c)
		4. Scalable and finer-grained understanding (10d)
		5. Learning processes (10e)
		6. Clickstream data (10f)
		7. Personalize and enhance instruction (10g)
		8. Natural language processing techniques (10h)
		9. Cognitive, social, behavioral, and affective processes (10i)
		10. Institutional data (10j)
		11. Course guidance systems (10k)
		12. Early-warning systems (10l)
		13. Challenges of accessing, analyzing, and using big data (10m)
		14. Data privacy and protection (10n)
		15. Data sharing and research (10o)
		16. Educational data science methodologies (10p)
		17. Explanation and prediction (10q)
		18. Mining big data in education (10r)
	Technology Adoption and Challenges in Education	1. Technology Acceptance Model (TAM) (16c)
		2. Challenges faced by students and educators (16e)
		3. Complexity of using AI without necessary skills and experience (16j)
	AI Applications and Innovations in Education	1. Artificial Intelligence (AI) in higher education (18a)
		2. AI for learning (20a)
		3. Artificial intelligence adapting educational experiences (22a)
		4. Intelligent Management Systems (IMS) in education (22b)
		5. New impetus for AI in education (22c)
		6. Providing students access to learning content (22i)
		7. Exploring possibilities of using AI in education (22l)
	Explainable AI (XAI) in Education	1. Artificial Intelligence (AI) algorithms in education (24b)
		2. eXplainable AI (XAI) in education (24c)
		3. XAI-ED framework for educational AI tools (24f)
		4. Approaches for presenting explanations in education (24h)
		5. Human-centered designs for AI interfaces (24i)
		6. Case studies applying XAI-ED in educational AI tools (24k)
		7. Future research needs for XAI in education (24m)
	Understanding AI Fundamentals in Education	1. Prominent scientists and technology pioneers' opinions on AI (25e)
		2. Drivers, advantages, disadvantages, and challenges of AI applications (25f)
		3. Literature search on AI (25g)
		4. Historical developments of AI (25h)
		5. Common definitions of AI (25i)
		6. Types and functionalities of AI (25j)
	Deep Learning and Natural Language Processing in Education	1. Deep learning (29a)
		2. Natural language processing (29b)
		3. Bidirectional long short-term memory (bi-LSTM) network (29f)
		4. Deep learning approach (29i)

Theme	Sub-themes	Phrases and Codes
Technical and Research Analysis	**Technical and Structural Analysis of AI in Education**	Public availability of ChatGPT - 2c
		Technical and structural fundamentals of ChatGPT and its competitors - 2g
	AI Implementation Challenges in Education	Challenges in AI implementation in teaching practice - 4l
		Guidelines for developing the field of AI in education - 4m
	Student Performance Analysis and Prediction	Predict students' performance - 7l
		Dropout prediction - 7r
		Early intervention for at-risk students - 7f
	Big Data and Educational Data Mining	Big Data - 8c
		Implementation of Big Data - 8d
		Analyzing educational big data - 17c
		Educational data mining (EDM) - 27a
	Student Behaviour Analysis and Learning Analytics	Student behaviour analysis - 14b
		Learning analytics (LA) - 27b
	Research Methods and Data Analysis	Machine learning and artificial intelligence - 17b
		Generalizable relationships and findings - 27e
		Statistical analysis - 18h
	Educational Processes and Administration	Admission process - 18c
		Placement process - 18d
		Administrative process - 18e
	Language and Content Translation in Education	Translating educational content across languages - 22j
		Removing language barriers in education - 22k
	Classroom Discourse and Teacher Strategies	Classroom discourse analysis - 29c
		Teachers' discursive strategies - 29d
	AI Trends and Ethical Education	Artificial intelligence (AI) trend - 25a
		AI ethics education improvement - 9p
	Alternative Approaches in Data Analysis	Alternatives to frequentist and Bayesian approaches - 27c
		Exploratory data analysis - 27g
	Tools and Systems for Data Management	Data management tools - 27l
		Database management systems - 27m
	Automated Analysis and Annotation	Automated analysis - 29e
		Annotation process automation - 29g