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Integrating AI into Education: Preparation Factors and Teachers' Digital Competencies

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Abstract

The ubiquity of artificial intelligence (AI) in education necessitates enhancing teachers' digital competencies. This review article synthesizes the pivotal factors that influence educators' pursuit of technological literacy. The objective was to identify the drivers and barriers affecting teachers' abilities to integrate technology and AI into their practice. Following the PRISMA methodology, a representative sample of 91 studies was analyzed through thematic analysis, categorizing factors into drivers, barriers, and generic elements across internal and external dimensions. Key drivers include pedagogical approaches highlighting technology value, accessible resources, communities of practice, and self-efficacy. Conversely, inadequate training, technophobia, outdated skills, and negative attitudes have emerged as significant barriers. Some reflections and AI inputs have been proposed to strengthen drivers and address barriers.

This review elucidates pathways for leveraging AI's potential of AI while adhering to pedagogical principles and ethical considerations. It informs educational leaders, policymakers, and researchers striving to empower educators as digitally competent professionals in the AI era..

Keywords

21st century education; artificial intelligence; teachers' technological competencies; literature review; innovation in education

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Integração da IA na educação: Fatores de preparação e competências digitais dos professores

Resumo

A onipresença da inteligência artificial (IA) na educação exige o aprimoramento das competências digitais dos professores. Este artigo de revisão sintetiza os fatores essenciais que influenciam a busca dos educadores pela alfabetização tecnológica. O objetivo era identificar os motivadores e as barreiras que afetam a capacidade dos professores de integrar a tecnologia e, por extensão, a inteligência artificial em sua prática profissional. Seguindo a metodologia PRISMA, uma amostra representativa de 91 estudos foi analisada por meio de análise temática, categorizando os fatores em motivadores, barreiras e elementos genéricos em dimensões internas e externas. Os principais motivadores incluíram abordagens pedagógicas que destacam o valor da tecnologia, recursos acessíveis, comunidades de prática e autoeficácia. Por outro lado, o treinamento inadequado, a tecnofobia, as habilidades desatualizadas e as atitudes negativas surgiram como barreiras significativas. Algumas reflexões e insumos de IA são propostos para fortalecer os motivadores e enfrentar as barreiras.

Esta análise elucida os caminhos para alavancar o potencial da IA e, ao mesmo tempo, aderir aos princípios pedagógicos e às considerações éticas. Ela informa líderes educacionais, formuladores de políticas e pesquisadores que se esforçam para capacitar os educadores como profissionais digitalmente competentes na era da IA.

Palavras-chave

educação do século xxi; inteligência artificial; competências tecnológicas dos docentes; revisão da literatura; inovação na educação

Integración de la IA en la educación: Factores de preparación y competencias digitales docentes

Resumen

La ubicuidad de la inteligencia artificial (IA) en la educación exige mejorar las competencias digitales de los profesores. Este artículo de revisión sintetiza los factores fundamentales que influyen en la alfabetización tecnológica de los educadores. El objetivo era identificar los impulsores y las barreras que afectan a la capacidad de los profesores para integrar la tecnología y, por extensión, la inteligencia artificial en su práctica profesional. Siguiendo la metodología PRISMA, se analizó una muestra representativa de 91 estudios mediante análisis temático, categorizando los factores en impulsores, barreras y elementos genéricos a través de dimensiones internas y externas. Entre los principales factores impulsores se incluyeron los enfoques pedagógicos que destacan el valor de la tecnología, los recursos accesibles, las comunidades de práctica y la autoeficacia. Por el contrario, la formación inadecuada, la tecnofobia, las destrezas obsoletas y las actitudes negativas surgieron como barreras significativas. Se proponen algunas reflexiones y aportaciones de la IA para reforzar los factores impulsores y hacer frente a los obstáculos.

Esta revisión aclara las vías para aprovechar el potencial de la IA respetando los principios pedagógicos y las consideraciones éticas. Sirve para informar a los responsables educativos, los responsables políticos y los investigadores que se esfuerzan por capacitar a los educadores como profesionales digitalmente competentes en la era de la IA.

Palabras clave

educación del siglo xxi; inteligencia artificial; competencias tecnológicas de los docentes; revisión de la literatura; innovación en la educación

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Introduction

The 21st century ushered in an age defined by exponential technological advancements that have radically transformed all realms of society (Wang & Siau, 2019). The pervasive digital revolution has disrupted the field of education, giving rise to a complex interplay between opportunities and challenges for teachers and educational institutions (Darma et al., 2020; Gabarda Méndez et al., 2021). This digital transformation of education is further catalyzed by groundbreaking developments in artificial intelligence (AI), which are opening new possibilities for teaching and learning (Ahmad et al., 2021; Bisen, 2021). However, effectively leveraging these emerging technologies requires teachers to possess digital skill sets aligned with the evolving landscape (Barana et al., 2020). Consequently, developing teachers' digital competency has become an urgent priority for enabling transformative yet human-centered educational AI innovation (König et al., 2020).

The integration of technology into classroom environments is continuously increasing, resulting in digitally enriched pedagogies becoming the global norm rather than the exception. This proliferation is evident in the uptake of learning management systems, mobile devices, educational software, and interactive multimedia in schools and universities worldwide (Dhar et al., 2021; Li et al., 2021; Nada et al., 2022; Pettersson, 2017; Pulumbarit, 2021). In parallel, teachers also utilize technology for professional duties such as lesson planning, assessment, communication, and self-directed learning (König et al., 2020). However, the levels of effective technology adoption and digital literacy skills vary greatly among educators (Sánchez-Cruzado et al., 2021). This gap must be addressed, as teachers' digital competency is inextricably linked to successful educational outcomes in technology-pervasive classrooms (Barber & Mourshed, 2007; Gudmundsdottir & Hatlevik, 2018; Siddiq & Scherer, 2016).

In this context, the term Education 4.0 emerges, which can be defined as an educational model that incorporates advanced technologies and automation to address the challenges of the digital revolution. Education 4.0 can be defined as a new educational paradigm that promotes personalized learning experiences through experimentation. It emphasizes adaptive learning systems and encourages learners to individually explore various subjects. Technology, particularly artificial intelligence, is key to realizing Education 4.0. Learning models are revised and customized based on current learner profiles, with students taking on a more self-sufficient role (Almeida & Simoes, 2019). The goal is to transform education by developing

individualized learning and providing students with necessary skills in a dynamic technological environment (Ivanchenko et al., 2021).

Education 4.0 is widely regarded as a potent means of fostering social progress and economic development, particularly in developing economies (Caballero-Morales et al., 2020). This necessitates the integration of disruptive technologies and revision of conventional educational models (Misra & Moid, 2021). In this context, the role of educators in Education 4.0 shifts towards that of facilitators, while students assume an initiative-taking stance in their learning process. The overarching goal of this approach is to equip students with the requisite skills for the digital economy and to prepare them for future employment and life (Ivanchenko et al., 2021).

Artificial intelligence is not new, but its impact on education has been radically accelerated by the democratization of its use, particularly by OpenAI with ChatGPT (UNESCO, 2023). Several systematic reviews have demonstrated the relevance of AI in education (Bhutoria, 2022; Bozkurt et al., 2021; Chen et al., 2020; Chiu et al., 2023; Crompton & Burke, 2023; González-Calatayud et al., 2021; Okonkwo & Ade-Ibijola, 2021; Ouyang et al., 2022; Papadopoulos et al., 2020; Xu & Ouyang, 2022). The purpose of this article is to identify the factors that enable teachers to develop digital competencies, with artificial intelligence applied to education being a critical area within these competencies, given the advances and implications that AI has demonstrated.

Moreover, artificial intelligence has been presented as an extraordinary phenomenon with far-reaching global impact (Górriz et al., 2020). It is noteworthy that we are currently observing remarkable progress in the development of artificial intelligence, which has led to its increasing presence within educational systems (Chen et al., 2020; Zawacki-Richter et al., 2019). It is important to note that the term "artificial intelligence" encompasses a range of technologies and techniques designed to simulate human intelligence. As Popenici and Kerr (2017) mention, AI can be defined as “computing systems that are able to engage in human-like processes such as learning, adapting, synthesizing, self-correction, and the use of data for complex processing tasks" (p. 2).

AI capabilities in areas such as machine learning, natural language processing, computer vision, and affective computing have improved exponentially, and many AI applications have emerged to enhance and potentially transform learning (Crompton & Burke, 2023; Luckin & Holmes, 2016). These applications range from intelligent tutoring systems and virtual learning environments to AI-based assessment tools and student data analytics platforms (Yudelson et al., 2014). Realizing the potential of these

technologies in classrooms hinges on teachers skillfully using them in practice. However, studies have indicated that many teachers lack the digital literacy, training, and confidence required to meaningfully integrate AI into their pedagogical approaches (Altun, 2019; Heggart & Yoo, 2018; Sit et al., 2020). Addressing this competence gap is critical for materializing the promises of AI in education, while preserving humanistic values.

As the educational landscape continues to advance into the digital AI era, developing teachers' digital skills is an undeniable priority. However, barriers in teachers' attitudes, motivations, and institutional contexts hinder their engagement in effective technology-related professional development. A nuanced understanding of this skill gap is needed to cultivate policies and learning ecosystems that empower teachers to thrive as technology-enabled educators (Akayoğlu et al. 2020; Siddiq and Scherer 2016).

The concept of teacher digital competence has been theorized in several ways across different frameworks. Most interpretations characterize this as educators' fluency in meaningfully utilizing digital technology for both their professional practice and students' learning (Colás-Bravo-Bravo et al., 2019; Falloon, 2020; Padilla-Hernández et al., 2019; Tømte et al., 2015).

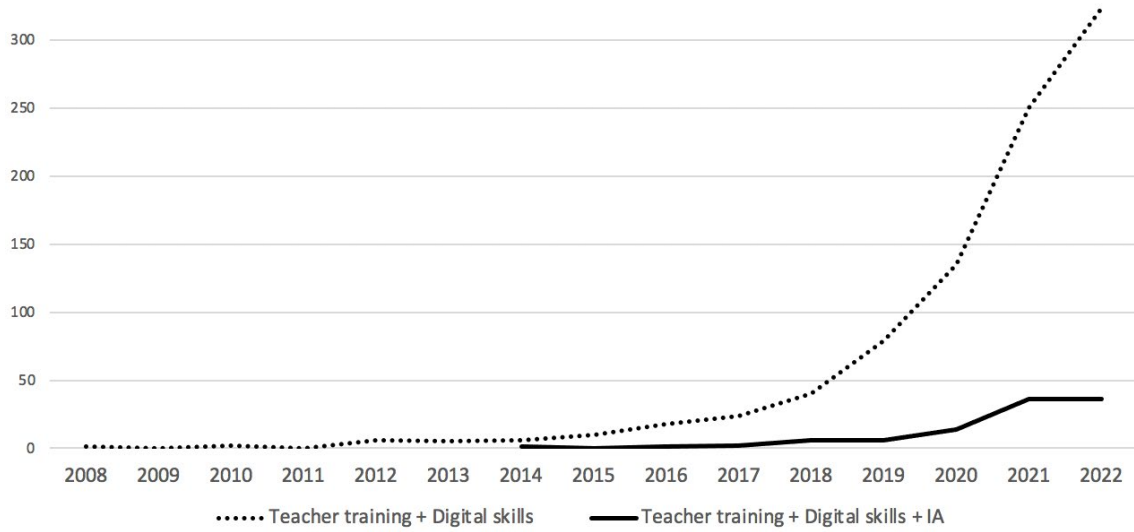
As AI becomes more ubiquitous in education, it encompasses the ability to evaluate, select, and integrate emerging technologies, such as intelligent tutoring systems, robotics, and virtual simulations, into pedagogical designs aligned with learning objectives and student needs (Crompton & Burke, 2023; Heitink et al., 2016). However, variations exist across countries and regions in how teachers' digital competence is formally conceptualized and assessed through certification requirements and professional standards (Uerz et al., 2018). This fluidity underscores the need for nuanced analysis.

Simultaneously, educational researchers have proposed many models of technological integration in teaching. These range from sequential stage-based models to open-ended frameworks, highlighting the interdependent factors shaping technology adoption (Davis, 1989; Ertmer, 1999; Mishra & Koehler, 2006; Puentedura, 2010). Although valuable, many established models predate the recent exponential growth in AI, limiting their transferability to integrating emergent technologies. Thus, new lenses are needed to understand the development of teachers' digital skills amid AI proliferation. The pressing need for a comprehensive literature review arises from the need to investigate the primary drivers and barriers that impact teachers' development of digital proficiency.

As mentioned above, from a research perspective, teacher training in the development of digital competencies, skills, and proficiencies has been growing steadily during the last decade, as shown in Figure 1. Although the

number of publications derived from this study was not excessively high, the trend was consistent, as shown in Figure 1. Something different happens when the earlier topic intersects with the use of Artificial Intelligence. In this regard, the history of publications in journals indexed in Scopus shows minimal production, which, considering the current relevance of the use of AI in education, seems to highlight the need to delve into both bibliographical and empirical research.

Figure 1. Research on Teacher training: Digital skills and AI.



Source: Scopus

Critically, despite strong research recognizing its benefits, the integration of technology into teaching practices remains constrained worldwide, indicating systemic gaps between technology availability and teacher readiness (Estrelle Rose A. Opeña, 2022; OECD, 2019; Önalan & Kurt, 2020; UNESCO, 2016). These discrepancies persist even as schools continue large-scale technology implementation, reflecting deeply rooted divides in teachers' digital literacy. Numerous internal and external obstacles contribute to this disparity and require extensive empirical research.

Within this complex landscape, this systematic literature review will critically investigate existing research on the key factors influencing teachers' digital skill development in the era of rising classroom AI. By synthesizing the knowledge of drivers and obstacles impacting technology integration competence, this review seeks to provide research-informed

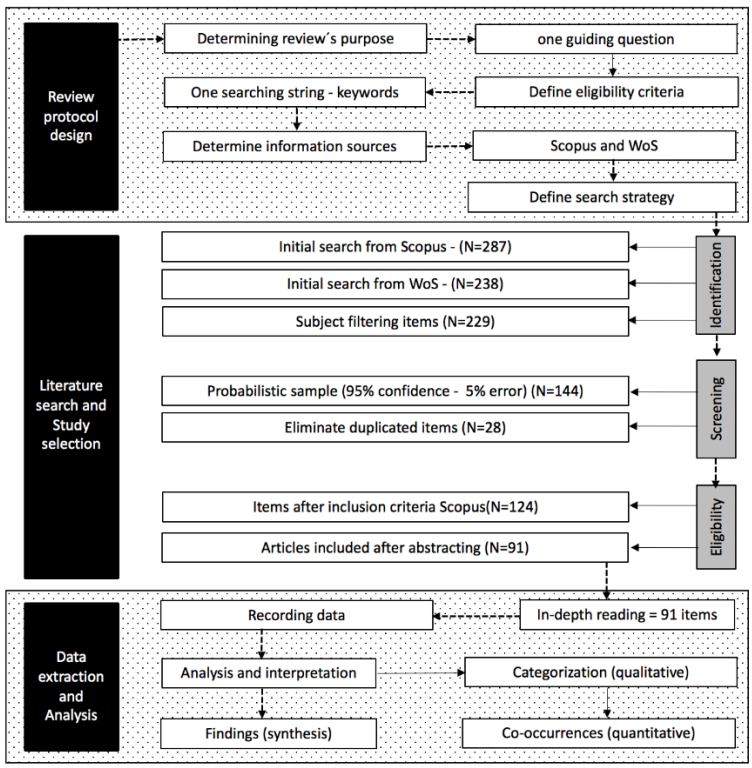
recommendations on how teachers' digital literacy can be strengthened in the age of AI (Caena & Redecker, 2019; Luan et al., 2020).

By providing data-driven yet context-aware information on strengthening teacher ability in the digital AI era, this review aims to inform educational policies, leadership, and professional development ecosystems committed to ethical and human-centered educational innovation.

2. Method

A systematic approach was implemented to review and synthesize the literature. Drawing on the established guidelines, the process incorporates structured phases for search, screening, eligibility checks, data extraction, and synthesis. This review methodology integrates the key steps outlined by Okoli (2015) into the PRISMA framework. By adhering to these evidence-based procedures, this review enabled a comprehensive yet focused identification of relevant publications from a large volume of available literature. The methodical process undertaken is summarized visually in Figure 2, highlighting how the analysis aligned with the recommended best practices for a scholarly literature review.

Figure 2. Review method phases.



Source: Own elaboration

The categorization of the research was not linked to the nature of the research (qualitative, quantitative, or mixed). In the extraction and analysis phase, qualitative and quantitative analysis techniques were applied to make the analysis more in-depth, but it was not part of the purpose of the review to identify the methods used in the articles reviewed.

2.1 Review protocol design

The first step of this literature review was to demonstrate its purpose and goals. Specifically, this review seeks to identify the key factors that enable or hinder teachers from developing digital competence in Education 4.0. To focus on the synthesis, the following guiding review question was formulated.

What are the drivers and barriers affecting teachers' building of digital skills to integrate technology and AI into their practices?

With the research question defined, the next phase involved selecting appropriate sources for analysis. The selection of Scopus and Web of Science was based on their recognized breadth of content, rigorous peer review processes, and ability to offer a multidisciplinary perspective on the integration of technology and ai in teaching practices. These databases were chosen for their coverage of interconnected disciplines, such as education, technology, and educational psychology, as well as their ability to perform advanced searches and filter effectively according to specific inclusion and exclusion criteria aligned with the PRISMA methodology.

To determine the aspects to be included or excluded, we elaborate on the matrix.

Table 1. Pre-search inclusion and exclusion matrix

Criteria	Inclusion	Exclusion
Type of Study	Empirical articles, systematic reviews	Opinions, editorials, commentaries
Theme	Digital competencies, teacher training, integration of technology and AI in teaching	Studies outside the educational scope, such as business or health
Population	Basic education teachers	Studies focused on students or administrative personnel
Area of Publication	Social sciences, education, educational technology	Publications outside these areas, such as general literature or art
Year of Publication	From 2016 to present	Prior to 2016
Language	English, Spanish	Any language other than English or Spanish

Source: Own elaboration.

Targeted keyword search strings were applied to both databases to identify the relevant literature on this topic. The term 'teacher training' was considered because the focus was on in-service teachers that is, those who are active on the job. However, along with the previous condition, three terms were considered: 'digital skills",' 'digital competencies",' and 'artificial intelligence.'

They were searched in English to broaden their scope, although English and Spanish results were considered.

Although "digital skills" and "digital competences" seem synonymous, some authors use one or the other, so it was considered to include both. Regarding the term 'artificial intelligence,' there is no other synonym representative of what it implies; therefore, no variables were considered. The result was the search string shown below.

TITLE-ABS-KEY ("teacher training" AND ("digital skills" OR "digital competencies" OR "artificial intelligence")).

When a search is performed using this syntax, the first element is related to any of the following three. The purpose of using "OR" is not to exclude artificial intelligence, but to search for the relationship between "Teacher training" with the other concepts. Thus, "OR" adds elements. The Boolean "OR" generates results that include one or more terms. The linguistic "OR" is exclusive.

The sources were not categorized by the level of study or academic field (i.e., whether the research was related to primary, secondary, high school, or university), because this was not relevant to the review.

2.2 Literature Searching and Study Selection.

The time window chosen was based on the year of publication that emerged according to the formula applied. Prior to this, there were no relevant documents. In this review, it was decided to use SCOPUS as the main source of access to documents, considering its advantages in advanced search capabilities to find more accurate sources and its recognition in the research community for academic rigor and careful evaluation and validation processes by experts (Adriaanse & Rensleigh, 2013), as well as the wide coverage and quantity of high quality scientific sources it offers, along with data analysis tools that are very useful to visualize and make decisions regarding the review process (Pech & Delgado, 2020). Data screening was performed on a single participant. Together with this analysis, in-depth reading was complemented with an AI tool called Elicit, which contributed to the formation of the categories. To generate the categories, we took the ones offered by the systematic review itself through the

documents and added those derived from their interpretation. For this purpose, QDA Miner Lite® was used, and ideas or paragraphs were marked. The three main categories were generic factors, that is, those mentioned and whose absence or presence identified a relationship with the development of digital competencies; barriers, whose presence limited or slowed down teachers; and drivers, those elements that motivated or accelerated the development of digital competencies.

The identification, screening, and eligibility phases of the PRISMA method are applied during this stage. The first search yielded 525 documents (287 from Scopus and 238 from the WOS). After filtering for "social sciences" (Scopus, n=143) and "Education/educational research" (WOS, n=86), this produced a secondary set of 229 items. A probabilistic representative sample of 144 documents was calculated to ensure an adequate sample for further analysis, with a 95 % confidence level and 5 % margin of error, as shown in Table 2.

Table 2. Quantity of articles found per year and probabilistic sample

Year	# docs - Initial search	# docs - Subject filtering	# docs - Probabilistic sample
2012	2	1	1
2013	2	0	0
2014	3	0	0
2015	2	1	1
2016	14	10	6
2017	8	6	4
2018	25	15	9
2019	49	25	16
2020	70	32	20
2021	112	55	35
2022	133	84	52
Total	420	229	144

Source: Own elaboration.

A statistically sound sampling approach aligned with the PRISMA guidelines was used to support the credibility and generalizability of the analysis. This rigorous sampling introduced rigor by reducing the potential bias and allowing a more accurate synthesis from the literature.

Duplicate references were eliminated by comparing the exported Scopus and Web of Science lists in PDF format using Claude.ai; 28 duplicates were identified. The representative literature sample provides a focused yet sufficiently comprehensive corpus for an in-depth review.

Adhering to PRISMA's structured eligibility and sampling procedures lends credibility to the findings. As part of the eligibility assessment, an abstracting process was followed by applying the following inclusion/exclusion criteria: (1) selecting the most cited articles for each year proportionally to the publication curve of the initial set, and (2) selecting articles addressing the topic from an educational perspective with empirical findings.

The documents that met the criteria included a final set of 91 articles subjected to close reading and systematic data extraction. Overall, the methodological approach enhanced the rigor of the literature synthesis and strengthened the insights generated.

2.3 Data extraction and analysis

The data extraction phase involved closely reading each selected article and systematically recording relevant information in a documentation matrix. The data were categorized according to a rigorous process aligned with the parameters of Thematic Analysis methodology.

The final phase involves synthesizing, interpreting, and compiling results into a coherent narrative. The findings were structured according to the IMRaD format (Introduction, Method, Results, and Discussion) to facilitate comprehensive and logical understanding. Qualitative and quantitative analyses were performed to examine the accuracy and relevance of the data thoroughly. Key insights and trends were extracted through a meticulous analysis.

Subsequently, the synthesized findings were interpreted to derive deeper meanings from participants. Finally, the results were organized into a cohesive manuscript that presented the methodology, findings, and discussions in a structured manner. Overall, following established conventions for compiling academic research, rigor was introduced to culminate in interpretation and reporting processes.

3. Results

The elements identified in the literature are classified into three categories: generic factors, drivers, and barriers. The latter refers to the ideas of the authors where elements to consider when developing digital competences are mentioned, but they are not explicitly described as a barrier or driver but can tend to one side or the other according to the presence or absence of these factors. Barriers or drivers can be matched; however, it is preferable to preserve them

separately to support the original text. To simplify the reference, these three elements (drivers, barriers, and generic factors) are referred to as the factors.

The identified texts were labeled descriptively, resulting in fifty-six varied factors. These factors were analyzed and synthesized using two categorization processes. Different areas. Table 3 describes the categories used in the first categorization process.

Table 3. Categories used in the second categorization process

Category	Description
Attitudinal	It refers to statements linked to the belief of people regarding their self-valuation, their personal statements or elements linked to the subject itself.
Generational	It refers to texts where age appears as an element co-related with digital competences
Institutional	It refers to policies, decisions, strategies, or actions that are usually outside the personal sphere and in the field of decisions of the institutions to which the subjects are linked.
Pedagogical	It refers to decisions related to the design, execution, or evaluation of teaching-learning processes
Related to resources	It refers to texts where physical resources linked to the development of digital skills are explicitly mentioned.
Relational	It refers to a point of convergence between attitudinal (of the person) and institutional elements. They differ from them because it is assumed that the relationship between the subjects does not depend exclusively on the will of one of the parties, but on the convergence of both
Scarce results	It refers to texts where the difficulties and limited results in developing digital competences are made explicit.

Source: Own elaboration.

In a complementary way, a second categorization was applied based on Ertmer´s research (Ertmer, 1999), so two main additional categories were determined: external and internal factors. The review results are presented in three tables: generic factors, drivers, and barriers. Each was characterized by considering the two groups of categories mentioned above.

3.1 Generic factors

Table 4. Characterization and frequency of generic factors

Factor	Category group 1	Category group 2	%
Importance of teacher training	Institutional	External	15%
Generational group	Generational	Internal	15%
Training design	Institutional	External	10%

Investment in resources	Institutional	External	8%
Contents of teacher training	Institutional	External	8%
Complexity of digital competences	Pedagogical	External	5%
Perception of teaching quality - Motivation	Attitudinal	Internal	5%
Training resources	Related to resources	External	5%
Characteristics of each person	Attitudinal	Internal	5%
Learning - emotion - attention	Attitudinal	Internal	5%
Willingness to change	Attitudinal	Internal	3%
Attitudes and beliefs	Attitudinal	Internal	3%
Teaching experience	Institutional	External	3%
Evidence of the Competences acquired	Institutional	External	3%
Level for which the teacher studies	Pedagogical	External	3%
Perception of the practicality and usefulness of technology	Attitudinal	Internal	3%
Level of digital competence	Attitudinal	External	3%
Perception of practicality and usefulness of technology	Attitudinal	Internal	3%

Source: Own elaboration.

Sometimes seeming a little obvious, the factor that most frequently appeared was the training of teachers (Cateriano-Chavez et al., 2021; Hollenstein et al., 2022; Ruiz-Cabezas et al., 2020b; Vásquez et al., 2021), It is interesting to note that most of the next ones; generational group, training design, investment in resources, and training content are external factors, which highlights the importance of the environment and the context in the development of desired digital competencies.

It should be noted that when the authors refer to generational groups, the keyword is age, and this is linked to how younger people tend to develop some digital skills more easily than adults (Basilotta-Gómez-Pablos et al., 2022; Jorge-Vázquez et al., 2021), although it is a non-causal correlational factor. By contrast, the design of training, content, and resources are factors whose main responsibilities are institutions (Jorge-Vázquez et al. 2021; Ruiz-Cabezas et al. 2020b; Velázquez et al. 2020).

Other factors are quantitatively less representative but should be highlighted to clarify them and give rise to future research. Examples include the perception of complex digital competencies (Ruiz-Cabezas et al., 2020), motivation to learn (Paetsch & Drechsel, 2021), the characteristics of each person (Basilotta-Gómez-Pablos et al., 2022; Gómez-Gómez, 2021), their willingness to change (Cateriano-Chavez et al., 2021), and their attitudes and beliefs, particularly regarding their teaching experiences (López et al., 2021). Additionally, they perceive the practicality and usefulness of technology, their

level of digital competence, and their perception of the practicality and usefulness of technology (Paetsch & Drechsel, 2021).

Category Group 1 showed the following distribution of factors: institutional, 45%; attitudinal, 28%; generational, 15%; pedagogical, 8%; and resource-related, 5%. To conclude, it is convenient to examine the number of Category Group 2 internal factors in relation to external factors because external factors predominate, although the difference is small. This speaks of the tasks to be performed by institutions and those seeking to support them. Thus, 60% of the factors were external and 40% were internal.

3.2 Drivers

The identified drivers were diverse, which is also a sign of the complexity of the process of developing digital competencies. The most frequent driver is an adequate pedagogical approach (García et al., 2022; Ruiz-Cabezas et al., 2020; Velázquez et al., 2020), which consists of a clear formative intention to go beyond techniques or processes to repeat, but to provide teachers with a reason to use technology. Subsequently, in this way, teachers have knowledge of the benefits of technology usage (García et al., 2022, 2022; Velázquez et al., 2020) and engage students as self-trainers (García et al., 2022) with the elements that report greater significance. The first is particularly important because the vision we have about technology opens or closes doors for teachers to use Information and Communication Technologies (ICT) or seek to continue training on that topic. On the other hand, the second is a valuable element to consider because along the way, students can enhance their self-esteem by providing evidence of what they can do for others.

This and all other elements that stand out can and should be embedded in the pedagogical vision to enhance the results. Later, accompaniment (García et al., 2022) stood out, which was related to the opportunity to have space and time for practice (García et al., 2022). During these processes, teachers are not alone; that is why being part of a learning community becomes motivational, which is related to accessibility to resources and creates a positive attitude towards technology (García et al., 2022; Gómez-Gómez, 2021; Jorge-Vázquez et al., 2021; Paetsch & Drechsel, 2021).

In this regard, there are other factors that, although they appear less frequently, stand out, among them: exemplification by trainers or colleagues, positive perception and practice of technology, meaningful learning experiences with technology, principal's role, willingness to change, desire to self-train (Basilotta-Gómez-Pablos et al., 2022), frequent offer of training, feedback for improvement, clear and applicable frameworks, good

working environment, and the availability of financial resources (García et al., 2022).

When reviewing the data considering Category Group #1, this distribution emerged as follows: pedagogical, 36 %; attitudinal, 24 %; relational, 17 %; institutional, 11 %; and resource-related, 11%. When focusing on Category Group #2, will notice that 75 % were external and 25 % were external, which reinforces the idea that even when teachers have the will and understand ICT as an ally, with training, accompaniment, and resources, it is possible not to achieve the expected digital competencies, at least at no to a high level.

Table 5. Characterization and frequency of drivers

Factor	Category group 1	Category group 2	%
Adequate pedagogical approach	Pedagogical	External	20%
Engaging learners as trainers	Pedagogical	External	10%
Have knowledge of the benefits of technology	Attitudinal	Internal	7%
Accompaniment	Relational	External	7%
Adequate training	Institucional	External	6%
Be part of a learning community	Relational	External	6%
Accessibility to resources	Related to resources	External	6%
Have space and time for practice	Related to resources	External	5%
Motivation	Attitudinal	Internal	5%
Positive attitude towards technology	Attitudinal	Internal	5%
Positive perception and practice of technology	Attitudinal	Internal	3%
Meaningful learning experiences with technology	Institucional	External	3%
Willingness to change	Attitudinal	Internal	3%
Principal's role	Relational	External	3%
Exemplification by trainers or colleagues	Pedagogical	External	3%
Desire to self-train	Attitudinal	Internal	1%
Desire to self-train	Institucional	External	1%
Feedback for improvement	Pedagogical	External	1%
Clear and applicable frameworks	Pedagogical	External	1%
Have economic resources	Related to resources	Internal	1%
Good working environment	Relational	External	1%
Frequent offer of training	Institucional	External	1%

Source: Own elaboration.

3.3 Barriers

Although these barriers were less prevalent in the review, they remain important. First, there is a lack of training (Basilotta-Gómez-Pablos et al., 2022; García et al., 2022; Hollenstein et al., 2022; Jorge-Vázquez et al., 2021), which is related to the fear of using technology (García et al., 2022; Jorge-Vázquez et al., 2021; Ruiz-Cabezas et al., 2020), and it is reinforced by a negative mindset about technology (García et al., 2022; Jorge-Vázquez et al., 2021), which is derived

from a lack of practice (García et al., 2022; Paetsch & Drechsel, 2021; Ruiz-Cabezas et al., 2020).

Difficulties in keeping pace with changing technology (García et al., 2022) and lack of access to devices (García et al., 2022; Jorge-Vázquez et al., 2021) make it even more difficult for teachers who have not developed attitudes and do not seek tools, such as those described in the driver section.

Other factors to consider are the rejection of the pedagogical use of technology, which implies that the vision of technology in education is eminently negative, although it may have multiple causes, one of which is a lack of connectivity (López et al., 2021) and low self-perception of digital competencies (Hollenstein et al., 2022). This is exacerbated when there is a lack of accompaniment (García et al., 2022) and recognition (Basilotta-Gómez-Pablos et al., 2022) and the importance of teacher training is not understood.

From the perspective of categories, in Group #1, the following elements emerged: attitudinal (42%), institutional (47%), resource (9%), and relational (2%). When considering Group 2, although external predominates, it has the narrowest distribution within the compared categories: external, 58% and internal, 42%.

Table 6. Characterization and frequency of barriers

Factor	Category group 1	Category group 2	%
Lack of training	Institutional	External	33%
Fear of using technology	Attitudinal	Internal	18%
Negative mindset about technology	Attitudinal	Internal	9%
Lack of practice	Institutional	External	9%
Difficulties in keeping pace with changing technology	Attitudinal	Internal	7%
Lack of access to devices	Related to resources	External	7%
Rejection of the pedagogical use of technology	Attitudinal	Internal	4%
Lack of connectivity	Related to resources	External	2%
Low self-perception of their digital competences	Attitudinal	Internal	2%
Non-existent teaching vocation	Attitudinal	Internal	2%
Lack of accompaniment	Relational	External	2%
Lack of recognition	Institutional	External	2%
Importance of teacher training	Institutional	External	2%

Source: Own elaboration.

4. Discussion

In this comprehensive review, we distilled a nuanced understanding of the multifaceted factors that either facilitate or impede educators' pursuit of digital competencies. These factors have been categorized into drivers, barriers, and generic elements, revealing the intricate interplay between the external and

internal dimensions that mold the integration of technology into teaching (Al-Mamary et al., 2022). Although significant obstacles undoubtedly exist, this review highlights several promising drivers, particularly those that can be harnessed through the emerging capabilities of artificial intelligence (ai) to bolster the development of educators' digital literacy.

4.1 Generic factors do not mean generic answers

The information previously presented in Table 4 emphasizes the significance of training in both its importance and its relevance to design. It is within this context that the role of age ranges becomes evident.

It is crucial not only that training is provided, but that it is structured in a manner that enables teachers to connect it with their responsibilities and duties, as well as their challenges and concerns. This is comparable to contextualizing a problem for students to comprehend its usefulness and practical applications in life. Similarly, it is essential for teachers to have a clear understanding of the relationship between training and their profession.

In regard to age, rather than serving as a cause of drivers or barriers, it can be correlated with digital skills since younger teachers are more likely to have had greater exposure to technology in their daily lives. However, this does not automatically place them at an advantage over other groups. Additional factors that are explored in the barriers and drivers will be presented below.

4.2 Enhancing Drivers with AI

One of the primary drivers was the adoption of pedagogical approaches that offered clear and contextually relevant reasons for using technology in education. As Dong and Li (2022) mention, AI has the potential to shine by dynamically generating personalized recommendations that highlight how specific technologies align with curriculum objectives, student needs, and lesson goals, thereby facilitating purposeful integration. Furthermore, AI-powered adaptive learning systems can effectively demonstrate the advantages of personalized technology utilization (Hou & Fidopiastis, 2017).

Additionally, AI can serve as a mentor for educators, providing tailored guidance, resources, and feedback as they develop technology-related skills (Dhinagaran et al., 2022). These AI-guided interactions can boost educators' self-efficacy by recognizing and celebrating their progress. Moreover, as Huizing et al. (2021) indicated, virtual coaching powered by AI can exemplify effective teaching practices, strengthening key drivers, such as motivation, self-improvement, guidance, and communities of practice.

Furthermore, AI-enabled learning analytics dashboards that visualize the positive impacts of technology integration can reinforce educators' beliefs regarding the value of technology in education. By aggregating data across various classrooms and presenting insights, AI can objectively demonstrate enhanced engagement, creativity, or learning outcomes resulting from technology integration (Dhar et al., 2021). Finally, accompaniment is mentioned as a relevant driver. Although this, at first glance is something eminently human, and it is, it is also possible to add AI tools that make this possible, such as tailored chatbots to resolve doubts, remember processes, policies, or steps to follow so that although each educational institution can provide a human structure for it, it can reinforce it with the possibilities offered by personalized chatbots with AI.

4.3 Overcoming Barriers with AI

Our review highlights training gaps as the most significant barrier to teachers' digital literacy. According to Xiao and Bai (2022), interactive AI tutors tailored to individual educators' knowledge levels can offer scalable and self-paced technological skills development. In this sense, it is interesting to consider that the 24/7 availability of AI may provide on-demand support, adaptability allows a focus on areas needing improvement, and virtual simulations offer a low-pressure environment for practice. Chat-based dialogue offers a means for immediate inquiry.

Regarding technology-related anxiety, AI tutors can provide non-judgmental environments, allowing the assessment of educators' fear levels and responding with affirmation and encouragement, thereby promoting a growth mindset (Horigome et al., 2023). Similarly, Huizing et al. (2021) stated that virtual practice is guided by the confidence levels of AI scaffold-built educators. Additionally, conversational AI agents make complex technological interactions more intuitive, allowing AI to play a crucial role in overcoming psychological barriers (Zhu & Van Brummelen, 2021).

Regarding the above, challenges in updating teachers' skills to keep up with rapidly evolving technologies may also be addressed by using AI. For example, AI tutors designed for lifelong learning can continually assess competence and introduce educators to emerging tools, helping them to stay current. Related to this, Taupiac et al. (2018) considered that AI can also curate relevant external training resources and help overcome connectivity barriers while AI applications transition to offline modes.

Regarding other critical insights, although human support must remain irreplaceable (Rizzo et al., 2011), AI assistance can significantly augment

educators' skill-building journeys, amplify drivers, and circumvent barriers. However, it is essential that the integration of AI aligns with sound pedagogical principles, avoids overly automated approaches, and maintains necessary human support structures. With prudence, AI and education can collaboratively scale teachers' digital literacy development.

4.4 Ethical Considerations and the Path Forward

The final key consideration for IA use in enhancing the development of teachers' digital competencies is related to ethical issues. Therefore, this review synthesizes promising evidence on how artificial intelligence, as an exponential technology, can accelerate the development of educators' digital skills, a clear and pressing priority. However, we must be vigilant in mitigating the ethical risks associated with over automation and dehumanization. The wise integration of AI should aim to enhance, rather than replace, human-centered educational experiences (Cai et al., 2019; Luan et al., 2020; Shneiderman, 2020).

Crucially, teachers' openness to adopting AI, institutional prioritization of these technologies, and a clear pedagogical vision are central to realizing AI's transformative potential of AI. A growth mindset must be cultivated at both the organizational and policy levels to leverage AI in the face of enduring challenges such as limited budgets. Additionally, it is crucial to shift the perception of technology from merely a cost to an investment in capacity building.

Further empirical research is required to explore AI implementation in the context of teachers' professional development. Although emerging evidence has highlighted these benefits, large-scale studies in diverse settings are lacking. It is essential to rigorously compare the efficacy of various AI functionalities for teacher skill development and qualitatively capture learners' experiences.

Developing educators' digital literacy must be an initiative-taking priority and not an afterthought. Through deliberate adoption, AI can help educators gain competence in navigating the ever-evolving landscape of educational technology. However, it is paramount to avoid associated risks such as dehumanization, privacy breaches, and over-automation. Wisdom, ethics, and the pursuit of human purposes must guide these potentially transformative integrations to empower educators to thrive as digital professionals.

5. Conclusions

In this age of AI and educational transformation, development of teachers' digital competencies is of utmost importance. However, there is a significant disparity between the availability of technology and teachers' readiness to effectively utilize it.

Multiple factors influence teachers' pursuit of digital literacy skills, including pedagogical approaches that highlight the value of technology, learning communities, accessible resources and self-efficacy. However, insufficient training, technophobia, outdated skills, and negative attitudes are the major obstacles. AI has the potential to amplify drivers and overcome barriers in developing teachers' digital competencies.

Hence, there is an urgent need to design relevant, pertinent, and meaningful learning and training experiences so that teachers can integrate technology to maximize its benefits and reduce difficulties. For example, thinking about Edgar's contribution that AI offers, AI tutors can provide personalized and scalable training, practice environments, and skill updates. Nevertheless, human support is essential and more empirical research is needed to implement AI in teachers' professional development across diverse settings. Impact studies should compare AI functionalities and capture user experiences.

The integration of AI in education must adhere to sound pedagogical principles, avoid the risk of dehumanization, and enhance human-centered experiences. Teachers' openness, institutional prioritization of AI, and ethical considerations are critical. However, it is vital to recognize and emphasize that AI or digital competencies are not the goal but the path. What is sought is improvement in the educational experience, but certainly in the 21st century, they are realities that go hand in hand.

In summary, despite the obstacles, artificial intelligence has the potential to expedite the worldwide advancement of teachers' digital literacy. Nevertheless, it is essential to enhance digital competencies before increasing the utilization of AI. Identifying the significance of this relationship can empower us to make informed decisions that mitigate barriers and strengthen the drivers that promote this process.

Limitations and future research

Artificial intelligence constitutes a rapidly evolving phenomenon, particularly given that advancements can no longer be measured in years, but rather in months or even days. Hence, the focus in education is not on providing technical

knowledge of the tools, but a holistic understanding of what they are, what they imply, what they challenge, and what should be considered. Hence, a limitation of this study is the nature of the technology.

However, this opens up new avenues for research and reflection. Even though the factors linked to the development of digital competencies have been identified, the reality may present nuances by educational level, nature of the educational center (public or private), years of teaching practice, or age range of teachers. Hence, this phenomenon offers many new paths to follow, but with clearer frames of reference, whether these or others, to achieve the goal of improving education and educational experience to enhance the talent of not only students but also the teachers themselves.

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