frontiers | Frontiers in Education

TYPE Systematic Review
PUBLISHED 13 October 2022
DOI 10.3389/feduc.2022.1005499

OPEN ACCESS

EDITED BY
María Beatriz de Ansó,
National University of Tres de Febrero, Argentina

REVIEWED BY
Delfín Ortega-Sánchez,
University of Burgos, Spain
Víctor Hugo Fernández-Bedoya,
Universidad César Vallejo, Peru
Taciana Pontual Falcão,
Universidade Federal Rural de Pernambuco, Brazil

*CORRESPONDENCE
María Rosa Fernández-Sánchez
rofersan@unex.es

SPECIALTY SECTION
This article was submitted to Digital Education, a section of the journal Frontiers in Education

RECEIVED 28 July 2022
ACCEPTED 12 September 2022
PUBLISHED 13 October 2022

CITATION
Fernández-Sánchez MR, Garrido-Arroyo MdC and Porras-Masero I (2022) Curricular integration of digital technologies in teaching processes. *Front. Educ.* 7:1005499. doi: 10.3389/feduc.2022.1005499

Curricular integration of digital technologies in teaching processes

María Rosa Fernández-Sánchez*,
María del Carmen Garrido-Arroyo and Isabel Porras-Masero

Department of Educational Sciences, Teacher Training College, University of Extremadura, Cáceres, Spain

The integration of digital technologies in the classroom is a complex and multidimensional process with different dynamics including, among others, those related to: the digital culture of the center, the competency of teachers and students, the support of families and innovation within educational programs. This paper presents a systematic literature review (SLR) to analyze how the curricular integration of educational technology in classroom practice has been developed at non-university levels in recent years. The PRISMA 2020 standards have been applied. For the selection of articles, the ERIC database was used, taking as a reference, key concepts from its Thesaurus, related to the objective of the research, performing a temporal search of scientific articles from 2018 up to the present day. After screening according to the inclusion criteria established by consensus among researchers, a total of 88 articles were obtained (n = 88). The main results point to several variables that should be strengthened to promote the integration of digital technologies in the classroom, among which teacher training stands out as a determining factor, with special emphasis on initial training. This opens a debate about the training that future teachers receive in relation to the integration of digital technologies in the teaching process.

Systematic review registration: [https://doi.org/10.5281/zenodo.6909261].

KEYWORDS

information and communication technologies, educational technology, teacher training, teaching practices, curriculum development, education, systematic review

Introduction

In the early years of the new millennium, the proliferation of information and communication technologies in educational environments began to blur the traditional boundaries between distance education and face-to-face educational practices, resulting in the emergence of what are considered to be "distributed learning environments" (Boshier et al., 2001). We must bear in mind that we live in a hyperconnected world in which technological artifacts and networks form a set of elements with which we

constantly interact, sometimes even unconsciously. The hybridity of contemporary life, what Bauman (2013) calls liquid reality, is already our reality. Feenberg (2019) insists that the digital is integrated and imbricated in everyday interactions. We live constantly crossing face-to-face with virtual spaces, even when we are teaching. Teaching today faces a pedagogical challenge in which we must integrate these digital transformations into knowledge construction. Digital technologies as mediating elements of teaching-learning processes, give teachers the possibility to break away from a traditional hierarchical model (Sorensen, 2009), forming frameworks and networks where students write, read, learn, interact, build collectively, and define their identities, according to what they experience in informal contexts. Teaching-learning processes are understood, in these environments, as processes of assembling and gathering people, digital technologies, curricula, work, study spaces, and assessment artifacts (Fendwich and Edwards, 2010).

Today's citizens live the experience of hyperconnectivity on a daily basis (Reig, 2013). This is something that, as a mediating element in the mutual relations between human beings and technology, constitutes, for some authors, a third evolutionary force of humanity (Nowak and Highfield, 2011). People's psychosocial schemes are continuously transformed (Ferrés, 2014) and this allows individuals and collectivities to use their oral, sound, and visual cultures to produce new citizen practices. One of the challenges facing education is to prepare people who are capable of exercising their rights as committed and participatory citizens in a society in which knowledge is a critical source of social and economic development.

Integration of digital technologies in classroom contexts

Some studies show a clear relationship between the integration of digital technologies and the success of 21st century students (Foster et al., 2011; Washbon, 2012). The integration of technologies in teaching-learning processes is a complex and multidimensional process that involves elements such as culture and management of the center, teachers, students, families, and educational programs, among others (Askar et al., 2006). It is difficult to find a clear definition of the concept (Akcil et al., 2021) due to the different models of technology integration identified in the learning theory adopted by researchers. The constant changes in the relationship between technology and education also has its effect.

As Spector (2015) says, today it is not possible to think about education without thinking about technologies that might support teaching-learning processes. The curricular integration of technologies is not something new in the field of educational technology research today. Internationally, research has shown that for more than two decades, the introduction of technologies in classrooms has not produced the expected results in terms of improving the quality of teaching-learning processes (Cuban et al., 2001; Zhao et al., 2002; Law et al., 2008; Vanderlinde et al., 2009; Alonso et al., 2010; Lugo and Kelly, 2011). The international commitment that drove the implementation of the 1:1 models (One Laptop Per Child, OLPC), whose purpose was to respond to the technological training needs of 21st century citizens, led to the search for theoretical and conceptual frameworks that describe the dimensions necessary to train digitally competent teachers and students. On the other hand, Area et al. (2020) emphasize that the hitherto research for the implementation of public policies, promoting the integration of technologies in education, is varied. It ranges from an institutional approach to the analysis of subjectivities and practices among educational agents. It is remarked that research developed along these lines has revealed increasingly evident issues such as: a failure to take into account the complexity and diversity of school cultures, the commercial orientation of programs, the sustainability of some initiatives and the lack of appropriation of educational policies with technologies at the center level, both by teachers and management teams. It has been almost 10 years since some authors pointed out that schools still have not reviewed their current model and vision, that data is not used for change and transformation and that many still have limited access to technology (Daniels et al., 2013).

In recent decades, several models and theories have been studied for the integration of technologies in the classroom with the purpose of supporting teachers with said integration. Mohebi (2021) reviews the theoretical models that have been most widely used in research that is focused on the integration of digital technologies in the classroom. The seven frameworks that, in some cases, are used in a complementary way are: The Teacher Thoughts and Action Process Model (TTAP), Theory of Planned Behavior (TPB), Expectancy-Value Theory of Achievement Motivation (EVTAM), Substitution Augmentation Modification Redefinition (SAMR), Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and Technological Pedagogical and Content Knowledge (TPACK).

Teacher training for the integration of technologies in the teaching process

One of the key elements in any model for the integration of digital technologies is teacher training for digital competence. If we turn to the research developed on this topic, current studies allude to the fact that teachers are not qualified for a true integration of digital technologies in the classroom (Fernández-Batanero et al., 2019; Pozo et al., 2020; Spiteri and Chang, 2020). Despite there being positive attitudes toward digital technologies and their use at the educational level,

training in their pedagogical use remains inadequate, both at the initial and ongoing training stages (George and Sanders, 2017). Teachers lack opportunities to observe, reflect, and experience how digital technologies can be used in teaching-learning activities in the classroom (Çebi and Reisoğlu, 2020). Following Valverde et al. (2021) there is evidence of: (a) a lack of knowledge, experience, demonstration, and observation of teaching practices in the use of digital technologies in the classroom; (b) lack of opportunities to reflect on the attitude toward technologies, on the teaching experience or on the role and challenges that technologies present to the educational world; (c) insufficient technical-pedagogical advice for the design and development of digital educational resources and for the use of media; (d) lack of collaborative work in the teaching profession; (e) lack of motivation, incentives, and time for the effective integration of technologies in the classroom; (f) need to assess the digital competence of teachers in order to design appropriate training for teachers. Moreover, in a very current study by Dikmen (2022), teachers with good pedagogical-technological competence are found to be more interested in educational technologies and we notice an increase in their expectations regarding results coming from the use of instrumental technologies. Furthermore, teachers end up perceiving themselves as more qualified.

One of the aspects to be assessed in the training actions being carried out and which are presented as a barrier to the proper integration of Digital Technologies (DT) in the classroom, is the marked instrumentalist nature of the training (Tilve and Álvarez, 2009; Tilve et al., 2009; Usun, 2009; Aguaded et al., 2010; Valverde et al., 2010; Fernández-Batanero and Bermejo, 2012). It does not offer adequate content to enhance the educational possibilities of digital tools, educational strategies or didactic models. Beneath the training plans, underlies the vision of the teacher as a technician who must have the necessary instrumental skills to use technological resources or it is indeed assumed that teachers have the ability to transform this knowledge into pedagogical application (Sanabria, 2006). As such, the innovative use of new technological applications is not promoted, resulting in uninteresting and decontextualized training (Valcke et al., 2007).

Teacher training for the integration of digital technologies therefore requires a rethinking of current approaches and practices, which are still practically oriented to technical-computer training (Valverde et al., 2010). It is important that in addition to developing digital skills and competencies in teachers, such skills are related to the content of each of the subjects taught (Brush et al., 2003; Usun, 2009). Since, as the TPACK model points out: for the integration of DTs to be fully effective, it is necessary to carry out, not only training in subject content (C), technology (T), and pedagogy (P) but training must also be focused on the relationship between all these elements (Koehler et al., 2014; Boschman et al., 2015; Rosenberg and Koehler, 2015). Of these three dimensions, the aspect most emphasized by research studies is the pedagogical one, in which it is necessary to reflect on new educational strategies, to uncover didactic methods suitable for developing educational experiences with digital technologies (DT), in addition to learning how to design and choose the appropriate technological didactic material for teaching and student assessment (Tejedor and García-Valcárcel, 2006; Mueller et al., 2008; Vanderlinde and van Braak, 2011).

Therefore, it is necessary that teacher training, for the effective integration of technologies in the classroom, is oriented toward principles which standout in the educational research. For example: orientation toward curricular content; the use of active learning strategies, the involvement of teachers in collaboration, the use of models and/or modeling, facilitation of coaching and expert support, availability of time for feedback and reflection and sustained duration in the medium and long term (Darling-Hammond et al., 2017). Furthermore, some research considers it important that, for adequate teacher training with the goal of integrating digital technologies: (a) a constructivist and learner-centered model is developed (Ertmer and Ottenbreit-Leftwich, 2010; Losada et al., 2011); (b) the opportunity to reflect on one's own educational practice is afforded, in a joint and collaborative manner among faculty staff (Brush et al., 2003; Ertmer and Ottenbreit-Leftwich, 2010); (c) attitudes and beliefs toward technologies are taken into account and acknowledged (Mouza, 2009; Aguaded et al., 2010; Ertmer and Ottenbreit-Leftwich, 2010; Kopcha, 2012) by developing modeling with teachers, which is usually the most effective model for changing attitudes; (d) stress prevention strategies are developed and promoted, that will help teachers to face the difficulties that arise in the use of technologies (Al-Fudail and Mellar, 2008); and training should include the opportunity to disseminate good pedagogical practices developed by other teachers to help them visualize a real practice with technologies (Brush et al., 2003; Tejedor and García-Valcárcel, 2006; Al-Fudail and Mellar, 2008; Aguaded et al., 2010).

In order to open new lines of research and identify dimensions that need addressing for the effective integration of digital technologies in teaching processes, it is necessary to examine the results of the latest research. It is especially interesting to evaluate what has happened in the pre- and post-pandemic period, during which digital technologies have had a great impact in educational contexts.

Method

The study was approached from a systematic literature review (SLR) to analyze the curricular integration of educational technology in classroom practice at non-university levels. To conduct the SLR, the PRISMA 2020 standards have been applied, identifying eligibility criteria, information sources,

search strategy, selection process, data collection process, and data list (Page et al., 2021; Yepes-Nuñez et al., 2021).

Objectives and research questions

The main objective of the study is to analyze the curricular integration of technologies in current teaching practices. The research questions are organized around three areas (**Table 1**): (a) conceptual framework, analyzing the relationships between the key words identified in the literature on the analyzed topic (RQ1); (b) documentary characteristics, to identify journal impact indices, topics, geographical location, and research methodologies used in the identified documents (RQ2–RQ5); and (c) pedagogical dimension (RQ6–RQ9), to recognize the educational levels, areas of knowledge, pedagogical approaches, teaching practices, and didactic tools related to the curricular integration of technologies, which appear in the localized studies.

Eligibility criteria

The review included scientific articles published from 2018 to the present (January 2018–December 2021) that include in the title, abstract or keywords the concepts "technology integration" and "technology uses in education." The choice of this period is intended to provide an update to the latest research on the selected topic, gathering together that which has been carried out between a pre- and post-pandemic timeframe. Scientific articles (journal articles) that include theoretical and empirical studies with both quantitative and qualitative methodologies and mixed studies were strictly included. The exclusion criteria applied were articles that corresponded to higher levels of studies and documents that were reports, books, or opinion articles.

Information sources and search strategy

For the selection of articles, the ERIC database was used, taking as a search reference the concepts of its Thesaurus "technology integration" and "technology uses in education," in the temporal search established from 2018 to the present. The search syntaxes are included in the coding sheet available at the following link: https://bit.ly/3S4jBOD.

Selection process and data collection

The initial search resulted in 346 articles. The three researchers analyzed the articles on the basis of the title and abstract, according to the inclusion-exclusion criteria. After reaching consensus on the results, 241 articles were excluded. The remaining 105 were analyzed in full text in a second selection process independently by the researchers, resulting in the exclusion, by agreement, of 17 articles. This resulted in the final sample of documents for the systematic review (n = 88) (**Figure 1**).

The Zotero bibliographic manager was used for data organization. The synthesis of the information was performed

TABLE 1 Research questions and initial coding.

Scope	Research questions	Initial coding criteria
Conceptual framework	RQ1. What is the conceptual network around the terms "technology integration" and "technology uses in education," which is extracted from the literature?	Keyword co-occurrence map. Automatic coding and selection of nodes and subnodes.
Documentary characteristics	RQ2. What is the distribution of the articles according to the journal and their position in the database?	Quartile of the journal and year of publication of the article.
	RQ3. What are the topics of the articles according to the journal's category in the databases?	Thematic categorization of journals according to the database (ERIC).
	RQ4. What is the geographical distribution of the publications?	Country of residence of the first author of the article.
	RQ5. What research methodologies are used in the selected studies and if applicable, what is the size of their samples?	Theoretical studies/Instructional designs/Quantitative or qualitative research/Mixed.
Pedagogical dimension	RQ6. What educational levels are included in the research and what areas of knowledge are involved?	Infant/Primary/Secondary Areas of knowledge
	RQ7. What are the pedagogical approaches adopted in the literature regarding the curricular integration of technologies?	Technology curriculum integration models.
	RQ8. What kind of training is offered and/or should be offered to teachers for the integration of technology in the classroom?	Initial training Continuous training
	RQ9. What tools and applications are identified in the studies in relation to the curricular integration of educational technology?	Tools and applications used.

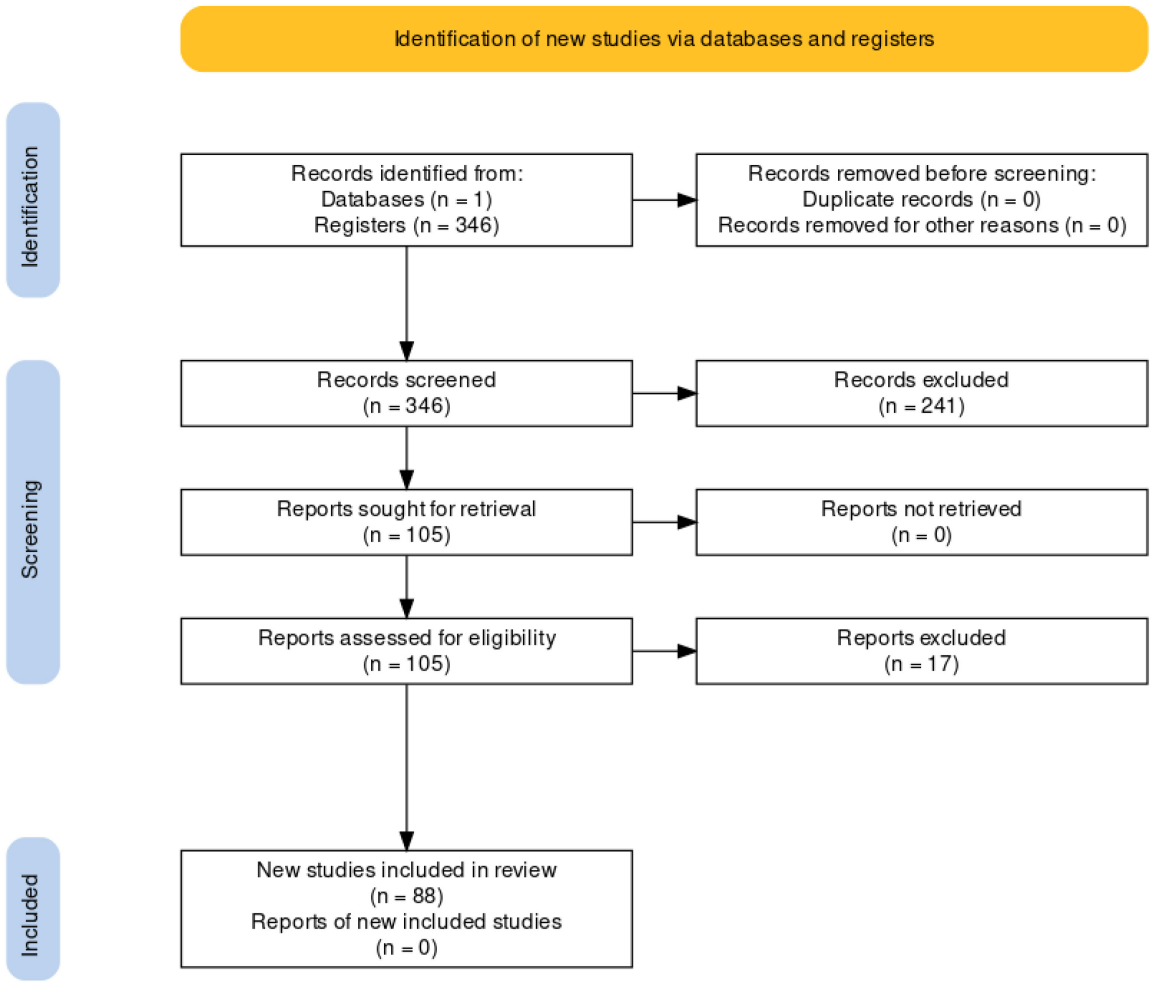


FIGURE 1
Study identification procedure (PRISMA).

using a coding sheet in Calc. The conceptual network was analyzed using VOSViewer. This software allows for the identification of clusters automatically by analyzing the keywords of the evaluated articles. The three researchers acted in a consensual manner in determining the preliminary and definitive inclusion criteria for this review. They also acted independently in the analysis of potential documents and later by consensus for the final sample of documents that form part of the review.

Results

Below, we present the results of the systematic review carried out, dividing the sections according to the research questions. Thus, at the beginning, we place the conceptual network on the integration of Educational Technology in teaching practices. A second block refers to the documentary characteristics and we finish with a third block that shows the results obtained from the objectives on the integration of digital technologies in educational practices.

Conceptual network on the integration of educational technology in teaching practices

For the analysis of the conceptual network, the clusters generated by the co-occurrence of the keywords of the articles selected in this review, are shown. The image shows (**Figure 2**) five clusters identified with five different colors: red ("educational technology"), green ("technological literacy"), blue ("teacher attitudes"), yellow ("barriers to integration"), and purple ("uses of technologies in education").

The clusters show a network of relationships that places the red cluster as the most relevant, encompassing concepts

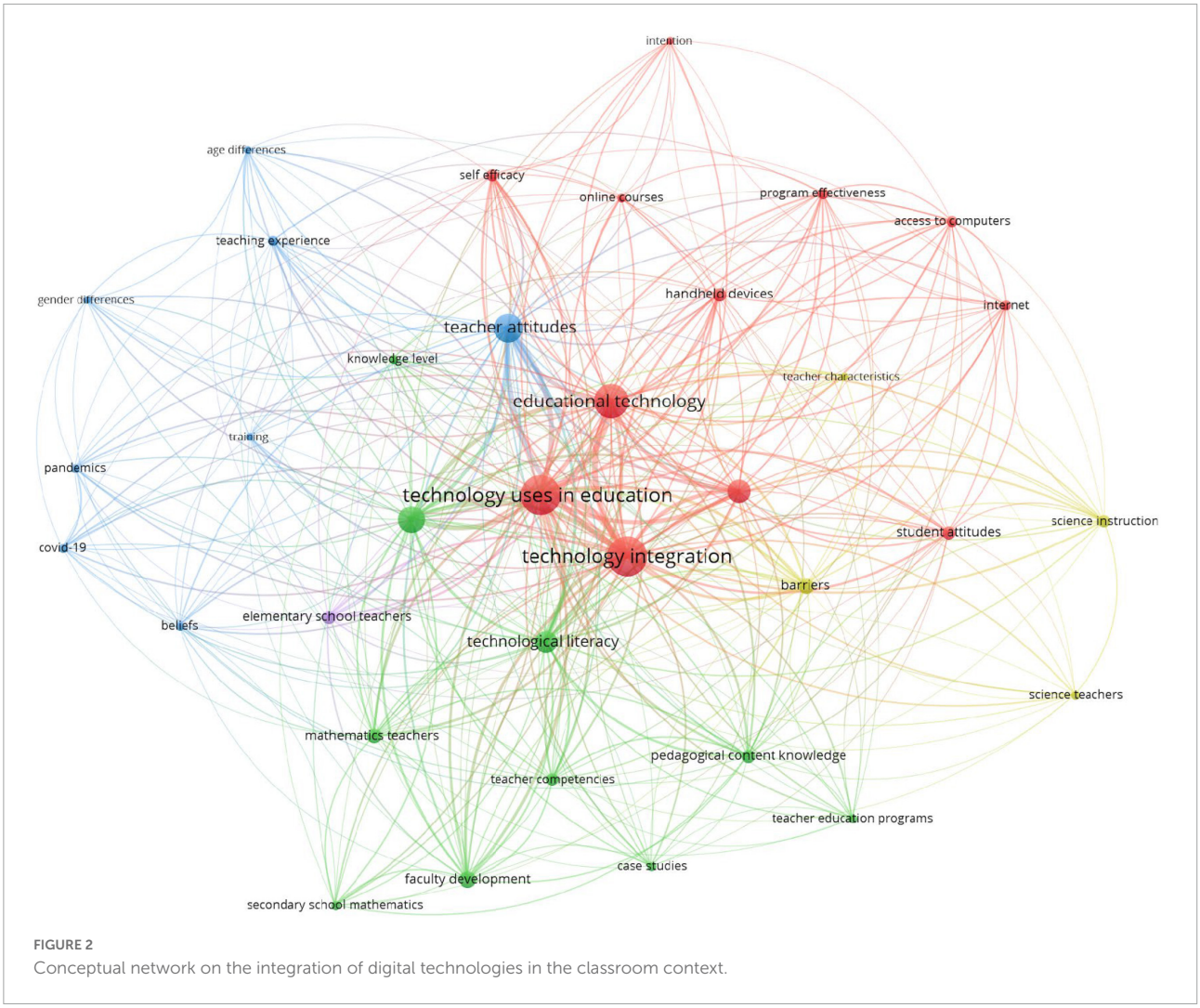


FIGURE 2
Conceptual network on the integration of digital technologies in the classroom context.

related to "educational technology." This cluster includes the term "technology integration," closely related to "uses of technologies in education" and "educational technology," together with the concepts "access to computers," "effectiveness of programs," "intentions," "self-efficacy," "students' attitudes," and "portable devices." The blue cluster identifies a key concept which is "teacher attitudes" and relates it to "teaching experience," "training," "gender and age differences," "beliefs" and concepts that allude to the "pandemic" or "COVID-19." The green cluster refers to "technological literacy," having as a referent the term "secondary education centers," which is related to the red cluster through the "use of technology in education." The most important relationship is with the term "technological competence" to which "teaching competence," "teacher training programs," "professional development," and "pedagogical content knowledge" are linked. In this cluster, "mathematics teachers" is identified as a related element. The yellow cluster starts from the concept of "barriers" and relates it to instruction, "teacher characteristics" and "science teachers." Finally, a small purple cluster is identified, which comes directly from the "uses of technologies in education" and relates it to "primary school teachers."

Documentary characteristics: Analysis and categorization

If we take into account the documentary characteristics of the selected articles, we can answer the research questions regarding the distribution of articles in journals, their position in databases, the main topics addressed in the articles, geographical distribution and research methodologies pertaining to the main samples.

Distribution of articles by journal and position in database

The selected research has been published in 60 international journals, all of them categorized in "Education," except for one

TABLE 2 Number of articles in the systematic literature review (SLR) by journals.

Journal	No. articles in the SLR
Education and Information Technologies	8
Technology, Pedagogy and Education	5
Journal of Science Education and Technology	3
Journal of Digital Learning in Teacher Education	3
Journal of Agricultural Education	3
International Journal of Research in Education and Science	3
International Journal of Education and Development using Information and Communication Technology	3
ZDM: Mathematics Education	2
Technology, Knowledge and Learning	2
Perspectives in Education	2
Education Sciences	2
Contemporary Issues in Technology and Teacher Education	2
Asian Journal of University Education	2

that appears in "Social Sciences." The journals with the largest number of studies are *Education and Information Technologies*, with 8 articles, and *Technology, Pedagogy and Education*, with 5 studies, as can be seen in Table 2.

Since 2018, the publication of studies on the subject matter addressed has remained stable, with an average of 22 articles per year (Graph 1). A slight decrease is identified in 2020, where publications drop below 20.

If we consider the impact of the journals in which the selected studies were published, we observe that they are all indexed in different databases. Of these, 54 appear in the Scopus indexes. The journals with an impact index that include the research in this review are mainly indexed in the first quartile (Graph 2).

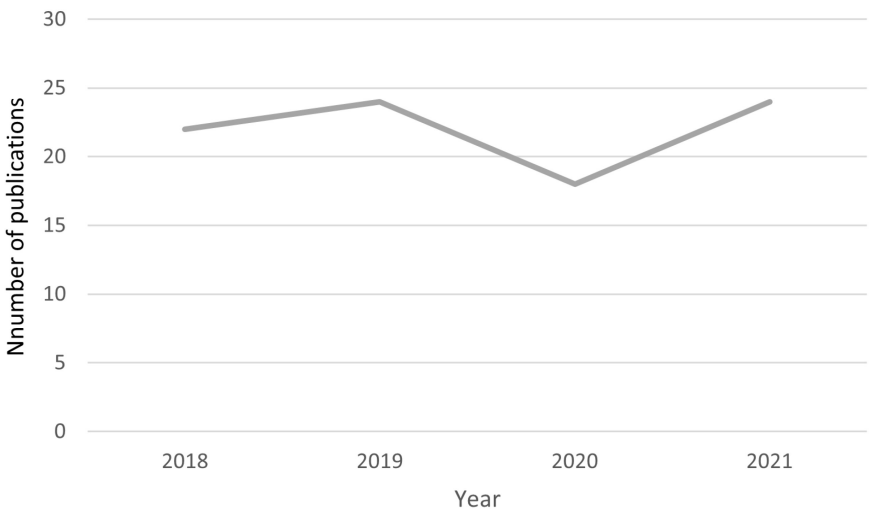
Main topics

Through an inductive content analysis of the selected articles, we have identified thirteen themes related to the Integration of Educational Technology in teaching practices.

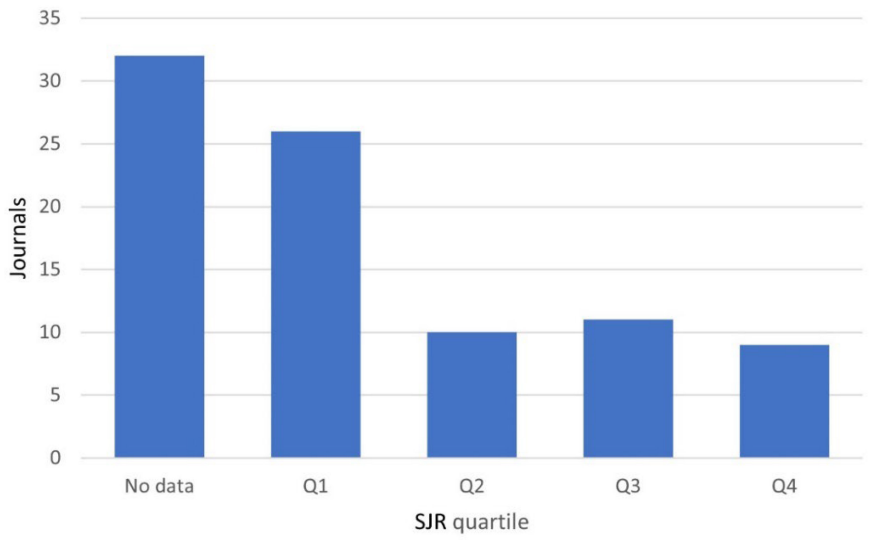
The predominant theme responds to the "integration of digital technologies in the classroom" (38%), followed by studies that focus on the "beliefs, attitudes, and perceptions of teachers" regarding the processes of integration of DT. Although in a smaller proportion, issues related to the barriers that teachers encounter in incorporating digital technologies in the classroom, are taken into account in the research, as well as the practices of "use of DT in classroom contexts," the "integration of hybrid learning" as a consequence of the pandemic and the processes of "integration of DT in educational centers." The graph shows (Graph 3) the topics identified in smaller proportions than those mentioned above but which also provide interesting data for this study.

Geographical distribution

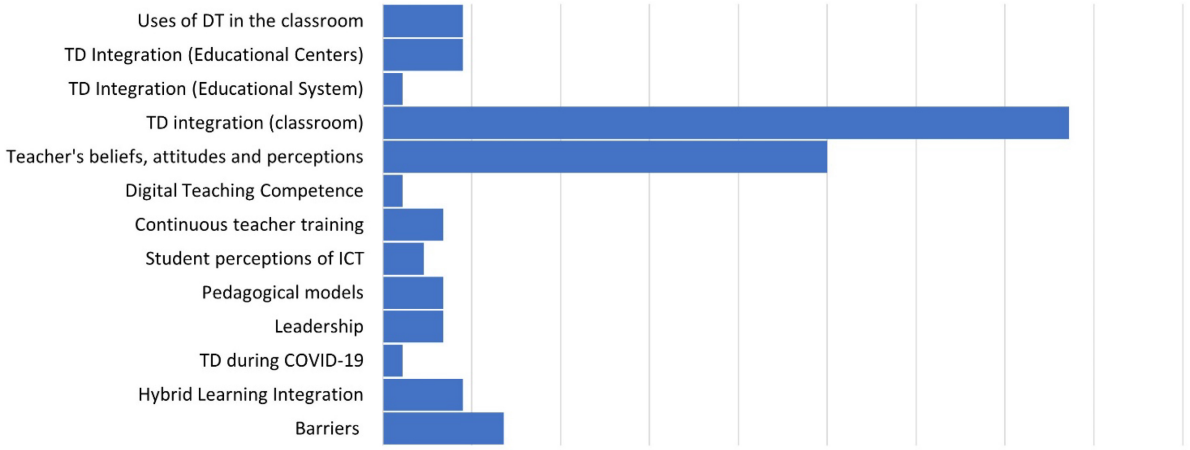
The geographical distribution of the publications has been analyzed taking into account the country of the primary author's research institution (affiliation), resulting in a variety of countries and a sample of studies that is broad and diverse. Figure 3 shows the worldwide distribution of the articles analyzed, with the consequent table (Table 3) showing the number of studies for each country indicated. The lack of studies from countries in South America and the northeastern part of



GRAPH 1
Evolution of publications in the selected years.



GRAPH 2
Scimago journal & country rank (SJR) impact index of the journals in which the articles were published.



GRAPH 3
Themes related to the integration of digital technologies in classrooms.

the continent is noteworthy. It is possible that the language of the selected database and the high cost of publication fees of some impact journals could explain the lack of studies in the indicated areas, although an in-depth analysis of these factors would be necessary.

Research methodologies and study subjects

The research methodologies identified are clearly qualitative in nature (**Figure 4**). Perhaps the complexity of analytical factors involved in the integration of digital technologies in the classroom explains the need for qualitative research approaches. This perspective is followed by quantitative and that which incorporates a mixture of quantitative and qualitative methodologies. The lowest proportion is found in theoretical studies, despite the need to find theoretical support for the practical application of Educational Technology.

As for the subjects of study (samples), the highest percentage of research studies refer to teachers, with more than 70% of the selected articles (**Graph 4**). The teacher is considered the key subject in the integration of digital technologies in the classroom, which explains the large proportion of studies that incorporate his or her perception or evaluation. The most numerous samples are those of teachers [1,335 in the study by Selwyn et al. (2020)] followed by those of students [1,174 in Dogan et al.'s (2021) research conducted].

FIGURE 3
Geographic distribution of publications.

Some single case studies are identified, being a teacher and his educational practice with digital technologies the object of study (Gómez, 2019; Trouche et al., 2020). Studies that stand out are those aimed at analyzing the integration of technology in the Educational System as the highest influential body in pedagogical use in classrooms (Williams, 2020) and of medium influence in Educational Centers (Skaftun et al., 2018; Lumagbas et al., 2019; Huang, 2021) or those addressed to the schools' Directorates (Thannimalai and Raman, 2018; Raman and Thannimalai, 2019; Ugur and Koç, 2019) to set strategies for the integration of technologies at the micro (classroom) level. We have also identified a study that analyses the effects of the pandemic on the competencies and experiences with digital technologies of teachers and also families in several dimensions (Öçal et al., 2021).

TABLE 3 No. of studies for country.

Country	No. of studies	Country	No. of studies
Saudi Arabia	2	Italy	1
Australia	2	Kazakhstan	1
Belgium	1	Malaysia	5
Canada	2	Nepal	2
China	1	Nigeria	1
Cyprus	1	No data	5
The United Kingdom	1	Norway	3
Spain	1	Portugal	1
The United States	20	Sri Lanka	2
Estonia	1	South Africa	6
The Philippines	4	Sudan	1
France	1	Sweden	2
Greece	2	Taiwan	2
Indonesia	1	Tanzania	2
Ireland	1	Turkey	10
Israel	1	Zimbabwe	2

Integration of digital technologies in educational practices

Educational levels and areas of knowledge

The educational levels of the selected studies show that the highest percentage corresponds to Secondary Education (75%), with 5.7% of the publications corresponding to Primary Education (**Graph 5**). In the rest of the publications, we find that the implementation of technologies has not been

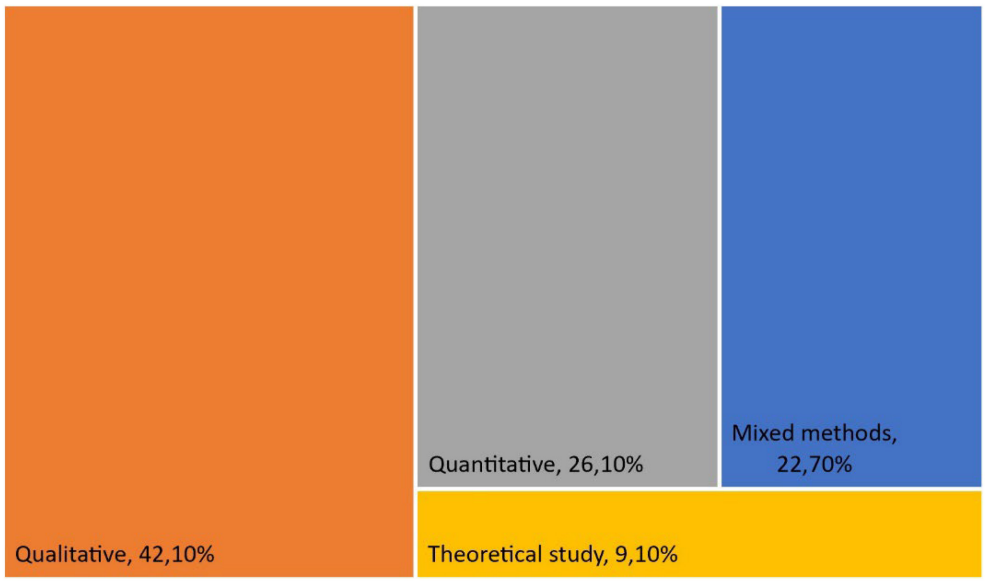
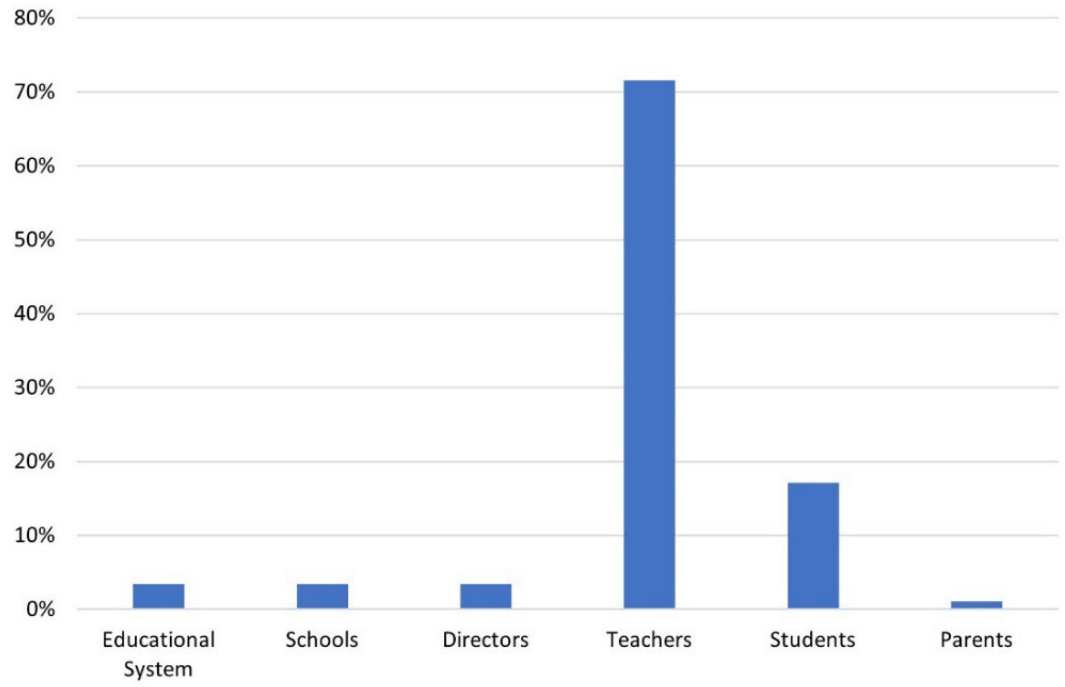
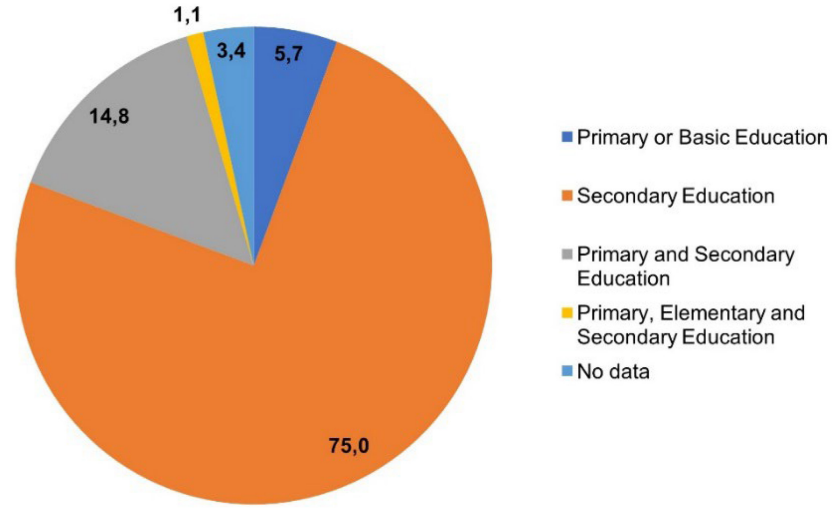


FIGURE 4
Research methodologies of the selected documents.



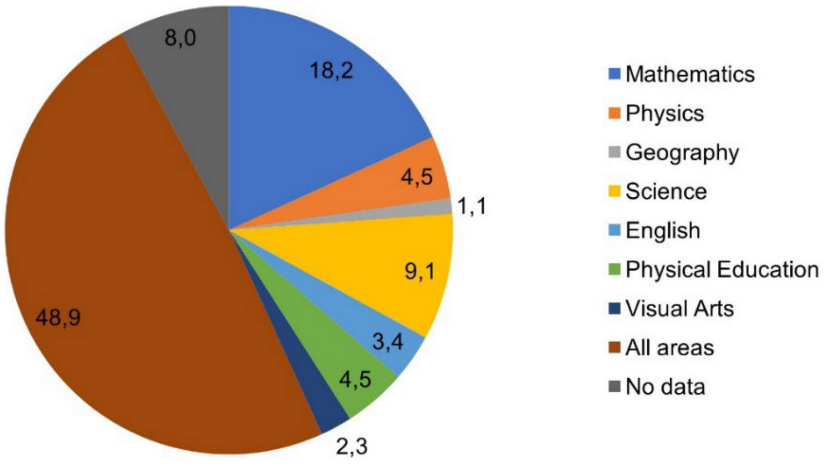
GRAPH 4
Subjects of studies in the selected publications.



GRAPH 5
Educational levels targeted by the research.

carried out at an exclusive educational level; thus, 14.8% of the research is related to Primary and Secondary Education levels and 1.1% to Infant, Primary, and Secondary Education levels. A total of 3.4% of the publications do not identify the educational level studied.

In relation to the areas of knowledge, 48.9% of the research has integrated technology in all areas of knowledge (Graph 6). The remaining publications show that integration has occurred in only one knowledge area, with mathematics standing out at 18.2%, followed by the area of science (9.1%); the areas of physical education and physics coincide with 4.5%; and it is the areas of English (3.4%), visual arts (2.3%), and geography (1.1%) that are the least present in the publications studied.



GRAPH 6
Knowledge areas of DT integration.

Pedagogical approaches in the curricular integration of educational technology

Research shows several theoretical models for curricular integration of educational technology in the classroom, some of which coincide with those described by Mohebi (2021).

One of the models used as a frame of reference is the Technological Pedagogical and Content Knowledge (TPACK) and we see the research of several authors reflected (Lai and Lin, 2018; Lisene and Jita, 2018; Yildirim and Sensoy, 2018; De Freitas and Spangenberg, 2019; Gómez, 2019; Li et al., 2019; Walan, 2020; Williams, 2020; Pamuk, 2022).

These investigations have analyzed the value of technology and technological pedagogical content knowledge in teachers, the factors, and barriers to integrate information and communication technologies (ICT), the levels of TPACK, as well as the beliefs of students and teachers. The results highlight the presence of factors that affect the effective use of technology in the classroom such as: (a) teachers' concerns (b) pedagogical beliefs and problems (c) teachers' attitudes toward the use of technology and (d) effectiveness of the training received. Several barriers to the integration of ICT in the classroom were identified: curriculum, technological infrastructure, ineffective professional development, impact of ICT on the teaching-learning process, teachers' pedagogical beliefs and leadership deficits. It should be noted that the results also show that the use of digital technology motivates students, facilitates their evaluation, and allows for more individualized teaching.

Another of the models present in the research is the TAM, which is taken as a reference in the research of Akar and Güzin (2019), Moodley et al. (2020), Firomumwe and Gamira (2021), Hamutoglu (2021). In these studies, the perception of usefulness, ease of use and the attitude of teachers toward technologies, have been evaluated. Also, we have identified the internal and external barriers that condition the acceptance or resistance to integrate technology in the classroom. We note that the study of Teo et al. (2019) focuses its attention on the student body and specifically, on the factors that drive them to use some technologies versus others.

The results focus on two key factors present in the TAM model for improving the acceptance of technology in the classroom: perceived usefulness and perceived ease of use. Among the findings, personal innovativeness is highlighted as an element that has a positive effect on perceived usefulness and perceived ease of use. Both are found to be significantly higher where teachers are significantly innovative than where staff lack innovation (Akar and Güzin, 2019). Equally noteworthy, are the results indicating that teachers show a positive attitude toward the use of technology derived from the two key factors outlined above, as well as the perception of ICT as a useful tool for the improvement of their effectiveness and performance (Firomumwe and Gamira, 2021). In addition to the two aforementioned factors, the results identified six sub-factors affecting ICT acceptance: anxiety, ability, attitude, facilitating conditions, subjective norm, and voluntariness (Moodley et al., 2020). The identification of these factors is relevant to help eliminate the presence of negative factors and instead foster those that facilitate the use and integration of ICT in the classroom by teachers.

Results suggest that training in the use of ICT is desirable (Firomumwe and Gamira, 2021) and that it is necessary to provide professional development, infrastructure, and additional resources for teachers in order for the use of technology to be successful.

Along with the above models, other theoretical models (23.9%) are referenced, such as Unified Theory of Acceptance and Use of Technology (UTAUT), Substitution Augmentation Modification Redefinition (SAMR), Digital Tokens, PhET Simulators, science, technology, engineering and mathematics (STEM), APOS Theory.

Type of formation

The selected publications show information related to the training of teachers for the integration of technologies: both training received and training they consider they should receive.

Initial training is present in research such as Gökmen et al. (2018), Agélii Genlott et al. (2019), Clark-Wilson and Hoyles (2019), Findley et al. (2019), Lumagbas et al. (2019), Moodley et al. (2020), Kilty and Burrows (2021), Morgado et al. (2021). The results show that the initial training received by teachers has been oriented to several aspects: (a) the integration of technologies in the learning process; (b): training for the use of mobile technology, tablet and App (c) professional development programs and in training received at the university stage (d) training for the use of specific resources (digital whiteboards, simulators).

In relation to continuous training, authors such as Gökmen et al. (2018), Herro et al. (2018), Kearney et al. (2018), Lai and Lin (2018), Akar and Güzin (2019), De Freitas and Spangenberg (2019), Ding et al. (2019), Lumagbas et al. (2019) reveal that teachers have received continuous and postgraduate training oriented to technological digital resources, pedagogy for the use of technology and computer science. Teachers also link continuous training with technical and pedagogical support and diverse ICT skills: participation in formal learning, in informal networks to share experiences, observation of other teachers' practices and exchange of didactic materials.

The research shows that not all teachers have received training, either initial or continuous, for the use and integration of ICT in the classroom, which is an aspect to be considered for the reflection and development of training programs and actions.

Technological tools and applications

The educational practices described in the research point toward a wide variety of technological tools and applications being used by teachers. In the results of research such as that by Macauda (2018), Kearney et al. (2018), Cementina (2019), Ding et al. (2019), Gómez (2019), Walan (2020), Cooper et al. (2021), among others, there is mention of those tools and applications that teachers have reported using in their classrooms. The review of the studies shows that educational platforms and educational software are the most commonly used tools. Google Classroom, Moodle and Canva stand out; all of them allow for the creation of content, activities and information exchange between the members of the educational community. This result is especially relevant in the global context of the pandemic where the use of platforms has been a fundamental element in the teaching-learning process. Other studies show that teachers use tools that are not specifically educational but can be implemented in classrooms. This is the case with office automation packages (word processing, spreadsheets, databases, or presentations) or Google Earth; a software tool that is applied for teaching purposes in primary and secondary classrooms and which facilitates active learning and the development of both digital and research skills and collaborative work. The use of mobile and tablet devices in classrooms also appears, for Internet access, navigating social networks, blogging, and video creation. Some studies have been identified where technological tools were linked to specific areas of knowledge; this is the case of Cabri, GeoGebra, or Geometer's Sketchpad for the teaching-learning of mathematics.

The results of the studies highlight that teachers have diversified technological tools and applications (Kearney et al., 2018). Integration in classrooms is perceived as beneficial, both pedagogically and organizationally which propels their use.

Discussion

Our results provide insight into the variables that should be strengthened to promote the integration of digital technologies by teachers in their classroom practices. It is essential to understand in depth, the factors that lead teachers to make the decision to use or not to use technologies and seek better training, that is more pedagogical in nature and which prepares teachers for an adequate integration into their teaching process. Of course, it must also be taken into account that technology integration should be driven by pedagogical objectives and not by technological pressures (Christopoulos and Sprangers, 2021).

The research analyzed highlights a conceptual relationship between: educational technology, technological literacy, teacher attitudes, barriers to the integration of technologies and the use of technology in education. An average of 22 articles per year with impact in international databases and using diverse research methodologies are identified, with the exception of the year 2020, when this figure dropped, only to rise again in 2021. Perhaps the impact of the pandemic and the development of research at that time is the reason for the variability of publications in that year. As for the main topics, those which stand out are: the integration of technologies in the classroom and research related to teachers' beliefs, attitudes and perceptions about this integration. All these topics are mainly focused on Secondary Education and all subject areas. The main theoretical-methodological approaches to the integration of technologies in teaching processes are TPACK and TAM, with little incidence of other well-known reference models such as UTAUT or SAMR, among others.

In terms of training, there is an orientation toward more pedagogical content in the use of digital technologies in classroom contexts, both in initial and continuing education. In a current study, conducted with teachers in their initial training, they admit feeling digitally competent but do not feel capable of integrating digital technologies in the classroom despite knowing the didactic possibilities they offer (Tadeu, 2020). This research establishes a positive relationship between the valuation of DTs in teaching, their effects on learning, knowledge of

their use for didactic purposes and how to include them in teaching practices. Other research such as Gómez-Trigueros et al. (2019) and Ortega-Sánchez and Gómez-Trigueros (2020) analyses new training strategies, aimed at future teachers, to develop competencies linked to the TPACK model through MOOCs (Massive Open Online Courses) and NOOCs (Nano Open Online Courses). Therefore, initial teacher training in educational technology continues to be essential, without forgetting that it should be complemented by continuous training that allows teachers to advance and update their skills.

It is evident that the pedagogical relationship has changed and that teachers must create spaces for students to develop their full potential. It is necessary not only to possess pedagogical tools and practices but also to be able to transfer this knowledge to the classroom. Technology changes teaching and using technology well in the classroom means that today we have to rethink the definition of the classroom and of teaching itself (Bayne et al., 2020). In this sense, we should also rethink the pedagogical usefulness of time in face-to-face teaching and adopt a pedagogical approach to move toward the transformation of education. The identification of pedagogical models is essential to analyze educational practices with technologies and avoid the "dispersion" of models that make it difficult to understand what happens in classrooms when educational practices with technologies are implemented.

We note that there is a shift in approaches toward technology integration around the world due to the impact of the pandemic. The exact details of the actual levels of integration of technologies in this period remain unknown. In addition to a thorough investigation of this issue, there is a need for the development of frameworks and approaches that encourage hybrid models, providing a pedagogical frame of reference, providing easy-to-implement technologies in blended teaching and learning processes and promoting teachers' digital competence through training that extracts real utility from technologies and which demonstrates the effectiveness of hybrid models.

The analysis of the results related to teacher training gives rise to the need for greater and deeper investigation and training for teachers, a determining factor for the integration of technologies in the classroom.

The main limitations of the study can be related to the unification of criteria to a single database, applying the established filters. In future work we intend to broaden the selection criteria, extending the sample to other educational levels such as higher education. We also considered the possibility of performing inferential statistical analyses on associations of some of the variables that articulate the research questions. At the same time, we have considered the integration of digital technologies in the classroom context, excluding articles that worked on specific technologies. Perhaps it would be interesting to investigate the latter context, expanding the research that can lead us to open new avenues of study. On the other hand, the research review leaves some questions unanswered with relation to the integration of technologies in educational practices, especially in a post-pandemic context in which the data and results of previous research have probably changed. The analysis of teaching practices, technological tools, and applications, as well as the study of teachers' attitudes toward the integration of technology are topics that may offer interesting data in this new context.

Data availability statement

The datasets analyzed in this study can be found in the Database of Systematic review of the literature. Curricular integration, Digital technologies & Teaching processes. This data can be found here: doi: 10.5281/zenodo.6909261.

Author contributions

MRF-S, MCG-A, and IP-M contributed to conception and design of the study, selected the articles, organized the database, and read and categorized the data. MRF-S and MCG-A performed the statistical analysis, wrote the first draft of the manuscript, and wrote sections of the manuscript. MRF-S reviewed and organized the references. All authors contributed to manuscript revision, read, and approved the submitted version.

Funding

This publication was made possible thanks to funding granted by the Consejería de Economía, Ciencia y Agenda Digital from Junta de Extremadura, and by the European Regional Development Fund of the European Union through the reference grant ref: IB18088.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Agélii Genlott, A., Grönlund, Å, and Viberg, O. (2019). Disseminating digital innovation in school – leading second-order educational change. *Educ. Inform. Technol.* 24, 3021–3039. doi: 10.1007/s10639-019-09908-0

Aguaded, J. I., Pérez, M. A., and Monescillo, M. (2010). Hacia una integración curricular de las TIC en los Centros educativos andaluces de Primaria y Secundaria. *Bordón* 62, 7–23.

Akar, M., and Güzin, S. (2019). Does it matter being innovative: Teachers' technology acceptance. *Educ. Inform. Technol.* 24, 3415–3432. doi: 10.1007/s10639-019-09933-z

Akcil, U., Uzunboylu, H., and Kinik, E. (2021). Integration of technology to learning-teaching processes and google workspace tools: A literature review. *Sustainability* 13:5018. doi: 10.3390/su13095018

Al-Fudail, M., and Mellar, H. (2008). Investigating teacher stress when using technology. *Comput. Educ.* 51, 1103–1110. doi: 10.1016/j.compedu.2007.11.004

Alonso, C., Casablancas, S., Domingo, L., Guitert, M., Moltó, O., Sánchez, J. A., et al. (2010). De las propuestas de la Administración a las prácticas del aula. *Rev. Educ.* 352, 53–76.

Area, M., Miño, R., Rivera, P., and Alonso, C. (2020). "Investigación sobre tecnologías educativas: más allá de los artefactos," in *Caminos y derivas para otra investigación educativa y social*, eds J. Sancho, F. Hernández, L. Montero, J. De Pablos, J. I. Rivas, and A. Ocaña (Barcelona: Octaedro), 223–236.

Askar, P., Usluel, Y. K., and Mumcu, F. K. (2006). logistic regression modeling for predicting task-related ICT use in teaching. *Educ. Technol. Soc.* 9, 141–151.

Bauman, Z. (2013). *Sobre la educación en un mundo líquido*. Buenos Aires: Paidós.

Bayne, S., Evans, P., Ewins, R., Knox, J., Lamb, J., Mcleod, H., et al. (2020). *The manifesto for teaching online*. Cambridge, MA: MIT Press. doi: 10.7551/mitpress/11840.001.0001

Boschman, F., McKenney, S., and Voogt, J. (2015). Exploring teachers' use of TPACK in design talk: The collaborative design of technology-rich early literacy activities. *Comput. Educ.* 82, 250–262. doi: 10.1016/j.compedu.2014.11.010

Boshier, R., Brand, S., Dabiri, A., Fujitsuka, T., and Tsai, C. Y. J. (2001). Virtual universities revealed: More than just a pretty interface? *Distance Educ.* 22, 212–231. doi: 10.1080/0158791010220203

Brush, T., Glazewski, K., Rutowski, K., Berg, K., Stromfors, C., Van-Nest, M. H., et al. (2003). Integrating technology in a field-based teacher training program: The PT3@ASU projects. *Educ. Technol. Res. Dev.* 51, 57–72. doi: 10.1007/BF02504518

Çebi, A., and Reisoğlu, I. (2020). Digital competence: A study from the perspective of pre-service teachers in Turkey. *J. N. Approach. Educ. Res.* 9:2. doi: 10.7821/naer.2020.7.583

Cementina, S. (2019). Language teachers' digital mindsets: Links between everyday use and professional use of technology. *TESL Can. J.* 36, 31–54. doi: 10.18806/tesl.v36i3.1320

Christopoulos, A., and Sprangers, P. (2021). lntegration of educational technology during the Covid-19 pandemic: An analysis of teacher and student receptions. *Cogent Educ.* 8:1. doi: 10.1080/2331186X.2021.1964690

Clark-Wilson, A., and Hoyles, C. (2019). A research-informed web-based professional development toolkit to support technology-enhanced mathematics teaching at scale. *Educ. Stud. Math.* 102, 343–359. doi: 10.1007/s10649-018-9836-1

Cooper, A., Timmons, K., and MacGregor, S. (2021). Exploring how ontario teachers adapted to learn-at-home initiatives during COVID-19: Blending technological and pedagogical expertise in a time of growing inequities. *J. Teach. Learn.* 15, 91–101. doi: 10.22329/jtl.v15i2.6726

Cuban, L., Kirkpatrick, H., and Peck, C. (2001). High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *Am. Educ. Res. J.* 38, 813–834. doi: 10.3102/00028312038004813

Daniels, J., Jacobsen, M., Varnhagen, S., and Friesen, S. (2013). Barriers to systemic, effective, and sustainable technology use in high school classrooms. *Can. J. Learn. Technol.* 39, 1–14. doi: 10.21432/T2SG67

Darling-Hammond, L., Hyler, M. E., and Gardner, M. (2017). *Effective teacher professional development*. Palo Alto, CA: Learning Policy Institute. doi: 10.54300/122.311

De Freitas, G., and Spangenberg, E. D. (2019). Mathematics teachers' levels of technological pedagogical content knowledge and information and communication technology integration barriers. *Pythagoras* 40, 1–13. doi: 10.4102/pythagoras.v40i1.431

Dikmen, C. H. (2022). The role of technological pedagogical content knowledge and social cognitive variables in teachers' technology integration behaviors. *Particip. Educ. Res.* 9, 98–415. doi: 10.17275/per.22.46.9.2

Ding, A.-C. E., Ottenbreit-Leftwich, A., Lu, Y.-H., and Glazewski, K. (2019). EFL teachers' pedagogical beliefs and practices with regard to using technology. *J. Digit. Learn. Teach. Educ.* 35, 20–39. doi: 10.1080/21532974.2018.1537816

Dogan, N. A., Dawson, K., and Ritzhaupt, A. D. (2021). Do school levels matter? How elementary, middle, and high school teachers differ in their perceptions and use of technology. *J. Educ. Technol. Syst.* 49, 432–460. doi: 10.1177/0047239520961339

Ertmer, P. A., and Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, beliefs, and culture intersect. *J. Res. Technol. Educ.* 42, 255–284. doi: 10.1080/15391523.2010.10782551

Feenberg, A. (2019). The internet as network, world, co-construction, and mode of governance. *Inform. Soc.* 35, 229–243. doi: 10.1080/01972243.2019.1617211

Fendwich, T., and Edwards, R. (2010). *Actor-network theory in education*. London: Routledge. doi: 10.4324/9780203849088

Fernández-Batanero, J. M., and Bermejo, B. (2012). Actitudes docentes hacia las tic en centros de buenas prácticas educativas con orientación inclusiva. *Enseñanza Teach.* 30, 45–61.

Fernández-Batanero, J. M., Sañudo, B., Montenegro-Rueda, M., and García-Martínez, I. (2019). Physical education teachers and their ICT training applied to students with disabilities, The Case of Spain. *Sustainability* 11:2559. doi: 10.3390/su11092559

Ferrés, J. (2014). *Las pantallas y el cerebro emocional*. Barcelona: Gedisa.

Findley, K., Whitacre, I., Schellinger, J., and Hensberry, K. (2019). Orchestrating mathematics lessons with interactive simulations: Exploring roles in the classroom. *J. Technol. Teach. Educ.* 27, 37–62.

Firomumwe, T., and Gamira, D. (2021). Evaluating technology acceptance in teaching of advanced level geography in Zimbabwean secondary schools. *Pak. J. Distance Online Learn.* 7, 1–14.

Foster, J., Kelley, P., Pritz, S., and Hodes, C. (2011). CTE's focus on continuous improvement. *Techniques* 86, 28–31.

George, A., and Sanders, M. (2017). Evaluating the potential of teacher-designed technology- based tasks for meaningful learning: Identifying needs for professional development. *Educ. Inform. Technol.* 24, 2871–2895. doi: 10.1007/s10639-017-9609-y

Gökmen, ÖF., Duman, I., Akgün, and Öe. (2018). Teachers' Views about the Use of Tablet Computers Distributed in Schools as Part of the Fatih Project. *Malays. Online J. Educ. Technol.* 6, 20–34. doi: 10.17220/mojet.2018.04.002

Gómez, M. (2019). Exploring 1:1 pedagogy through the lens of a veteran middle school teacher: The case of Ms. Goodman. *Middle Sch. J.* 50, 32–43. doi: 10.1080/00940771.2019.1674769

Gómez-Trigueros, I. M., Ruiz-Bañuls, M., and Ortega-Sánchez, D. (2019). Digital literacy of teachers in training: Moving from ICTs (information and communication technologies) to LKTs (learning and knowledge technologies). *Educ. Sci.* 9:4. doi: 10.3390/educsci9040274

Hamutoglu, N. B. (2021). Testing the effects of technological barriers on high school teachers' role in technology integration. *Asian J. Dist. Educ.* 16, 74–89.

Herro, D., Quigley, C., and Jacques, L. A. (2018). Examining technology integration in middle school STEAM Units. *Technol. Pedagogy Educ.* 27, 485–498. doi: 10.1080/1475939X.2018.1514322

Huang, J. (2021). Using information technology to improve the quality of education in areas lacking educational resources: Taking southwestern Guizhou prefecture in Guizhou, China as a sample. *Sci. Insights Educ. Front.* 9, 1199–1212. doi: 10.15354/sief.21.re039

Kearney, M., Schuck, S., Aubusson, P., and Burke, P. F. (2018). Teachers' Technology adoption and practices: Lessons learned from the IWB phenomenon. *Teach. Dev.* 22, 481–496. doi: 10.1080/13664530.2017.1363083

Kilty, T. J., and Burrows, A. C. (2021). Secondary science preservice teachers: Technology integration in methods and residency. *J. Sci. Teach. Educ.* 32, 578–600. doi: 10.1080/1046560X.2021.1907514

Koehler, M., Mishra, P., Kereluik, K., Shin, T. S., and Graham, C. R. (2014). "The technological pedagogical content knowledge framework," in *Handbook of research on educational communications and technology*, 4th Edn, eds M. Spector, M. D. Merrill, J. Elen, and M. J. Bishop (New York, NY: Springer-Verlag), 101–111. doi: 10.1007/978-1-4614-3185-5_9

Kopcha, T. J. (2012). Teachers' perceptions of the barriers to technology integration and practices with technology under situated professional development. *Comput. Educ.* 59, 1109–1121. doi: 10.1016/j.compedu.2012.05.014

Lai, T-l, and Lin, H.-F. (2018). An investigation of the relationship of beliefs, values and technological pedagogical content knowledge among teachers. *Technol. Pedagogy Educ.* 27, 445–458. doi: 10.1080/1475939X.2018.1496137

Law, N., Pelgrum, W. J., and Plomp, T. (Eds). (2008). *Pedagogy and ICT use*. Dordrecht: Springer. doi: 10.1007/978-1-4020-8928-2

Li, Y., Garza, V., Keicher, A., and Popov, V. (2019). Predicting high school teacher use of technology: Pedagogical beliefs, technological beliefs and attitudes, and teacher training. *Technol. Knowl. Learn.* 24, 501–518. doi: 10.1007/s10758-018-9355-2

Lisene, L. N., and Jita, T. (2018). Exploring the integration of modern technologies in the teaching of physical science in Lesotho. *Perspect. Educ.* 36, 111–127. doi: 10.18820/2519593X/pie.v36i1.8

Losada, D., Karrera, I., and Correa, J. M. (2011). Políticas sobre la integración de las TIC en la escuela de la Comunidad Autonoma del País Vasco. *RELATEC Rev. Latinoam. Tecnol. Educ.* 10, 21–35.

Lugo, M. T., and Kelly, V. (2011). *El modelo 1 a 1. Un compromiso por la calidad y la igualdad educativas. La gestión de las TIC en la escuela secundaria: Nuevos formatos institucionales*. Paris: UNESCO.

Lumagbas, J. J., Smith, W., Care, E., and Scoular, C. (2019). Tablet computers in philippine public schools: School-level factors that influence technology management and use. *Technol. Pedagogy Educ.* 28, 73–89. doi: 10.1080/1475939X.2019.1572535

Macauda, A. (2018). Augmented reality environments for teaching innovation. *Res. Educ. Media* 10, 17–25. doi: 10.1515/rem-2018-0011

Mohebi, L. (2021). Theoretical models of integration of interactive learning technologies into teaching: A systematic literature review. *Int. J. Learn. Teach. Educ. Res.* 20, 232–254. doi: 10.26803/ijlter.20.12.14

Moodley, K., Callaghan, P., Fraser, W. J., and Graham, M. A. (2020). Factors enhancing mobile technology acceptance: A case study of 15 teachers in a pretoria secondary school. *South Afr. J. Educ.* 40, 1–16. doi: 10.15700/saje.v40ns2a1791

Morgado, J. C., Lencastre, J. A., Freires, T., and Bento, M. (2021). Smart education as empowerment: Outlining veteran teachers' training to promote digital migration. *Technol. Knowl. Learn.* 26, 897–916. doi: 10.1007/s10758-021-09494-6

Mouza, C. (2009). Does research-based professional development make a difference? A longitudinal investigation of teacher learning in technology integration. *Teach. Coll. Rec.* 111, 1195–1241. doi: 10.1177/016146810911100502

Mueller, J., Wood, E., Willoughby, T., Ross, C., and Specht, J. (2008). Identifying discriminating variables between teachers who fully integrate computers and teachers with limited integration. *Comput. Educ.* 51, 1523–1537. doi: 10.1016/j.compedu.2008.02.003

Nowak, M. A., and Highfield, R. (2011). *SuperCooperators: Altruism, evolution, and why we need each other to succeed*. New York, NY: Free Press.

Öçal, T., Halmatov, M., and Ata, S. (2021). Distance education in COVID-19 pandemic: An evaluation of parent's, child's and teacher's competences. *Educ. Inform. Technol.* 26, 6901–6921. doi: 10.1007/s10639-021-10551-x

Ortega-Sánchez, D., and Gómez-Trigueros, I. M. (2020). MOOCs and NOOCs in the training of future geography and history teachers: A comparative cross-sectional study based on the TPACK model. *IEEE Access* 8, 4035–4042. doi: 10.1109/ACCESS.2019.2963314

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ* 372:160. doi: 10.1136/bmj.n160

Pamuk, S. (2022). Investigation of teachers' reflections on countrywide tablet PC and interactive white board initiative in Turkish schools. *Participat. Educ. Res.* 9, 22–40. doi: 10.17275/per.22.2.9.1

Pozo, S., López-Belmonte, J., Fernández-Cruz, M., and López-Núñez, J. A. (2020). Análisis correlacional de los factores incidentes en el nivel de competencia digital del profesorado. *Rev. Electrón. Interuniv.. Formación Profesorado* 23, 143–159. doi: 10.6018/reifop.396741

Raman, A., and Thannimalai, R. (2019). Importance of technology leadership for technology integration: Gender and professional development perspective. *SAGE Open* 9. doi: 10.1177/2158244019893707

Reig, D. (2013). "Describiendo al hiperindividuo, el nuevo individuo conectado," in *Los jóvenes en la era de la hiperconectividad: Tendencias, claves y miradas*, eds D. Reig and L. F. Vílchez (Madrid: Fundación Telefónica/Fundación Encuentro), 21–90.

Rosenberg, J. M., and Koehler, M. J. (2015). Context and technological pedagogical content knowledge (TPACK): A systematic review. *J. Res. Technol. Educ.* 47, 186–210. doi: 10.1080/15391523.2015.1052663

Sanabria, A. (2006). Las TIC en el sistema escolar de Canarias: Los programas institucionales de innovación educativa para la integración curricular de las Tecnologías de la Información y Comunicación. *RELATEC Rev. Latinoam. Tecnol. Educ.* 5, 191–202.

Selwyn, N., Nemorin, S., Bulfin, S., and Johnson, N. F. (2020). The'obvious' stuff: Exploring the mundane realities of students' digital technology use in school. *Digital Educ. Rev.* 37, 1–14. doi: 10.1344/der.2020.37.1-14

Skaftun, A., Igland, M.-A., Husebø, D., Nome, S., and Nygard, A. O. (2018). Glimpses of dialogue: Transitional practices in digitalised classrooms. *Learn. Media Technol.* 43, 42–55. doi: 10.1080/17439884.2017.1369106

Sorensen, E. (2009). *The materiality of learning: Technology and knowledge in educational practice*. Cambridge: Cambridge University Press.

Spector, M. J. (2015). *Foundations of educational technology: Integrative approaches and interdisciplinary perspectives (interdisciplinary approaches to educational technology)*. London: Routledge. doi: 10.4324/9781315764269

Spiteri, M., and Chang, S. N. (2020). Literature review on the factors affecting primary teachers' use of digital technology. *Technol. Knowl. Learn.* 25, 115–128. doi: 10.1007/s10758-018-9376-x

Tadeu, P. (2020). La competencia científico-tecnológica en la formación del futuro docente: Algunos aspectos de la autopercepción con respeto a la integración de las TIC en el aula. *Educ. Siglo XXI* 38, 37–54. doi: 10.6018/educatio.413821

Tejedor, F. J., and García-Valcárcel, A. (2006). Competencias de los profesores para el uso de las TIC en la enseñanza. Análisis de sus conocimientos y actitudes. *Rev. Española Pedagogía* 64, 21–43.

Teo, T., Doleck, T., Bazelais, P., and Lemay, D. J. (2019). Exploring the drivers of technology acceptance: A study of Nepali school students. *Educ. Technol. Res. Dev.* 67, 495–517. doi: 10.1007/s11423-019-09654-7

Thannimalai, R., and Raman, A. (2018). The influence of principals' technology leadership and professional development on teachers' technology integration in secondary schools. *Malays. J. Learn. Instruct.* 15, 203–228 doi: 10.32890/mjli2018.15.1.8

Tilve, M. D., and Álvarez, Q. (2009). Un estudio de caso sobre un proyecto de innovación con TIC en un centro educativo de Galicia: ¿Acción o reflexión? *Bordón* 61, 95–108.

Tilve, M. D., Gewerc, A., and Álvarez, Q. (2009). Proyectos de innovación curricular mediados por TIC: Un estudio de caso. *RELATEC Rev. Latinoam. Tecnol. Educ.* 8, 65–81.

Trouche, L., Rocha, K., Gueudet, G., and Pepin, B. (2020). Transition to digital resources as a critical process in teachers' trajectories: The case of Anna's documentation work. *ZDM Math. Educ.* 52, 1243–1257. doi: 10.1007/s11858-020-01164-8

Ugur, N. G., and Koç, T. (2019). Leading and teaching with technology: School principals' perspective. *Int. J. Educ. Leadersh. Manag.* 7, 42–71. doi: 10.17583/ijelm.2019.3758

Usun, S. (2009). Information and communication technologies (ICT) in teacher education (ITE) program in the world and Turkey. *Procedia Soc. Behav. Sci.* 1, 331–334. doi: 10.1016/j.sbspro.2009.01.062

Valcke, M., Rots, I., Verbeke, M., and van Braak, J. (2007). ICT teacher training: Evaluation of the curriculum and training approach in Flanders. *Teach. Teach. Educ.* 23, 795–808. doi: 10.1016/j.tate.2007.02.004

Valverde, B. J., Fernández-Sánchez, M. R., Revuelta Dominguez, F. I., and Sosa-Díaz, M. J. (2021). The educational integration of digital technologies preCovid-19: Lessons for teacher education. *PLoS One* 16:8. doi: 10.1371/journal.pone.0256283

Valverde, B. J., Garrido-Arroyo, M. C., and Fernández-Sánchez, M. R. (2010). Enseñar y aprender con tecnologías: Un modelo teórico para las buenas prácticas educativas con TIC. *Rev. Electrón. Teoría Educ.* 11, 203–229. doi: 10.14201/eks.5840

Vanderlinde, R., and van Braak, J. (2011). A new ICT curriculum for primary education in flanders: Defining and predicting teachers' perceptions of innovation attributes. *Educ. Technol. Soc.* 14, 124–135.

Vanderlinde, R., Van Braak, J., and Hermans, R. (2009). Educational technology on a turning point: Curriculum implementation in Flanders and challenges for schools. *Educ. Technol. Res. Dev.* 57, 573–584. doi: 10.1007/s11423-009-9126-9

Walan, S. (2020). Embracing digital technology in science classrooms–secondary school teachers' enacted teaching and reflections on practice. *J. Sci. Educ. Technol.* 29, 431–441. doi: 10.1007/s10956-020-09828-6

Washbon, J. L. (2012). Learning and the new workplace: Impacts of technology change on postsecondary career and technical education. *New Direct. Commun. Coll.* 157, 43–52. doi: 10.1002/cc.20005

Williams, K. M. (2020). Point, read, think, click: Expanding new literacies in Kazakhstan and Mongolia. *Int. J. Educ. Dev. Using Inform. Commun. Technol.* 16, 16–34.

Yepes-Nuñez, J. J., Urrútia, G., Romero-García, M., and Alonso-Fernández, S. (2021). Declaración PRISMA 2020: Una guía actualizada para la publicación de revisiones sistemáticas. *Rev. Española Cardiol.* 74, 790–799. doi: 10.1016/j.recesp.2021.06.016

Yildirim, H. I., and Sensoy, O. (2018). Effect of science teaching enriched with technological practices on attitudes of secondary school 7th grade students towards science course. *Univ. J. Educ. Res.* 6, 947–959. doi: 10.13189/ujer.2018.060516

Zhao, Y., Pugh, K., Sheldon, S., and Byers, J. (2002). Conditions for classroom technology innovations. *Teach. Coll. Rec.* 104, 482–515. doi: 10.1111/1467-9620.00170