



Teacher digital competence: Keys for an educational future through a systematic review

María de los Ángeles Domínguez-González ^{1*}

 0000-0002-9687-9325

Antonio Luque de la Rosa ²

 0000-0001-7981-029X

Carlos Hervás-Gómez ¹

 0000-0002-0904-9041

Pedro Román-Graván ¹

 0000-0002-1646-9247

¹ Universidad de Sevilla, Seville, SPAIN

² Universidad de Almería, Almería, SPAIN

* Corresponding author: mariaandg@us.es

Citation: Domínguez-González, M. Á., Luque de la Rosa, A., Hervás-Gómez, C., & Román-Graván, P. (2025). Teacher digital competence: Keys for an educational future through a systematic review. *Contemporary Educational Technology*, 17(2), ep577. <https://doi.org/10.30935/cedtech/16168>

ARTICLE INFO

Received: 20 Jun 2024

Accepted: 05 Feb 2025

ABSTRACT

Constant teacher training and up-dating is fundamental to provide quality teaching and learning. Digital competences are among the skills that teachers must acquire in order to improve the teaching and learning processes. The aim of the present study was to review the scientific production of the last five years regarding teacher digital competence (TDC). To this end, the preferred reporting items for systematic reviews and meta-analyses methodology was used, performing research in two relevant databases: Scopus and Web of Science. A total of 19 articles that met the pre-established criteria were ultimately selected and analyzed. The thorough analysis of the documents was conducted with ATLAS.ti software. To analyze the co-occurrence of keywords, VOSviewer was employed. The main results show that scientific production is increasing, and studies are mostly focused on exploring the level of TDC, which is usually low. The samples of the studies are mainly composed of secondary education teachers. This review concludes by highlighting the need to develop training programs for the improvement of TDC and to carry out further studies in this research line.

Keywords: teacher digital competence, education, ICT, innovation, teacher training

INTRODUCTION

Educational centers are in charge of preparing students for the future and for being active citizens who contribute to society. The attainment of this goal requires teachers who are competent in terms of digital transformation, effectively integrating technologies into their teaching (Maksimović & Dimić, 2016). In this sense, teachers face a double challenge: on the one hand, they must adapt their pedagogical practices to the current educational trends, including technologies (Biggs, 2023; Trujillos Torres et al., 2020; Valerio Neto et al., 2019) and, on the other hand, they must adapt these to the increasing diversity of the students (Yasar-Akyar et al., 2022).

In this respect, it is worth pointing out the concept of teacher digital competence (TDC), which goes beyond technical skills. Teachers must be able to make decisions on which resources they use and how they use them, depending on the work situation and context (Pongsakdi et al., 2021). However, the level of TDC is deficient in many cases, since teachers do not have the adequate training (Gallego Joya et al., 2025; Guillén-Gámez et al.,

2021; Larrañaga et al., 2023; Sánchez-Rivas et al., 2024). The recent COVID-19 pandemic has accentuated this problem, demonstrating the need to increase the level of TDC in order to transform the educational practices (Guillén-Gámez et al., 2021; Larrañaga et al., 2023). The crisis generated by the pandemic was a turning point in terms of the educational use of digital technologies. The unexpected closure of schools, as a response to the global health emergency, forced teachers around the world to adapt quickly and use digital tools, which became a fundamental pillar to continue the teaching-learning process. The pandemic provided a unique context, similar to a large-scale experiment, which made it possible to test the effectiveness of technologies in education and, at the same time, to identify weaknesses and opportunities for improvement in the traditional education system. In other words, what began as an urgent response to a health crisis was transformed into a process of deep reflection on the needs and technological advances essential for the future of education (Pozo et al., 2024). It is also important to underline the pressure that teachers endure in their attempt to adapt to technology, which is rapidly advancing and changing (Biggs, 2023).

The integration of technological resources in the classrooms depends on the capacities of centers, teachers and students. With respect to teachers, these are influenced by different factors that determine the use or non-use of digital resources, such as the lack of time due to administrative tasks, the constant need to communicate with the rest of the teachers and parents of the students, the limited availability of resources in the educational centers, and their own lack of training, as was previously mentioned (Gallardo Montes et al., 2023; Mazzotti et al., 2024; Starks et al., 2023).

Recent studies, such as that of Larrañaga et al. (2023), analyze the opinion of primary education teachers about the impact of information and communication technologies (ICT) and educational innovation. The main results show the need to include technological resources in teaching. Teachers state that the use of technology benefits the educational community, as it improves communication with the parents and allows for greater collaborative learning, among other advantages. Nevertheless, they also mention that students may use technology inadequately, associating, in most cases, digital tools with ludic activities, thereby misusing their educational potential. Therefore, teachers are aware of the educational opportunities offered by technologies, but they also require training, time and commitment to attain the effective digitization of educational centers.

The digital competence of teachers shows a significant increase after participation in training programs such as massive open online courses, webinars and other types of courses. These educational approaches provide teachers with the necessary tools and knowledge to improve their technological and pedagogical skills, thus favoring their adaptation to the new demands of the digital environment. However, the content of many of these programs often presents discrepancies with the real demands of teachers, who sometimes feel that the training offered does not fully meet their practical and contextual needs in the classroom. This disconnect between what is offered in the courses and what educators actually require could limit the impact of the training on their professional performance. Therefore, training should be conducted based on the real needs of teachers.

Similarly, there are more complex issues that are not only due to a lack of training or time. Ertmer (1999) identified two major barriers to the effective inclusion of technology in educational centers. On the one hand, this author underlined first-order extrinsic barriers, which are related to the lack of time due to planning and scheduling responsibilities, poor accessibility to digital tools, and limited human resources. On the other hand, Ertmer also pointed out second-order, intrinsic barriers, which are those associated with the personal beliefs of teachers and their educational practices, including their willingness to integrate technology into the classrooms and to try new and different pedagogical approaches.

In this regard, first-order barriers are easier to identify and solve compared to second-order barriers, since teachers usually have pre-established and strongly assimilated pedagogical practices. These barriers persist, despite the fact that, in the last years, different countries have improved their access to the Internet and the availability of digital resources in the educational scope (Hathaway et al., 2024).

Competence Frameworks

There are different competence frameworks that aim to help teachers to acquire TDC. The most recognized frameworks are the European framework for the digital competence of educators (DigCompEdu),

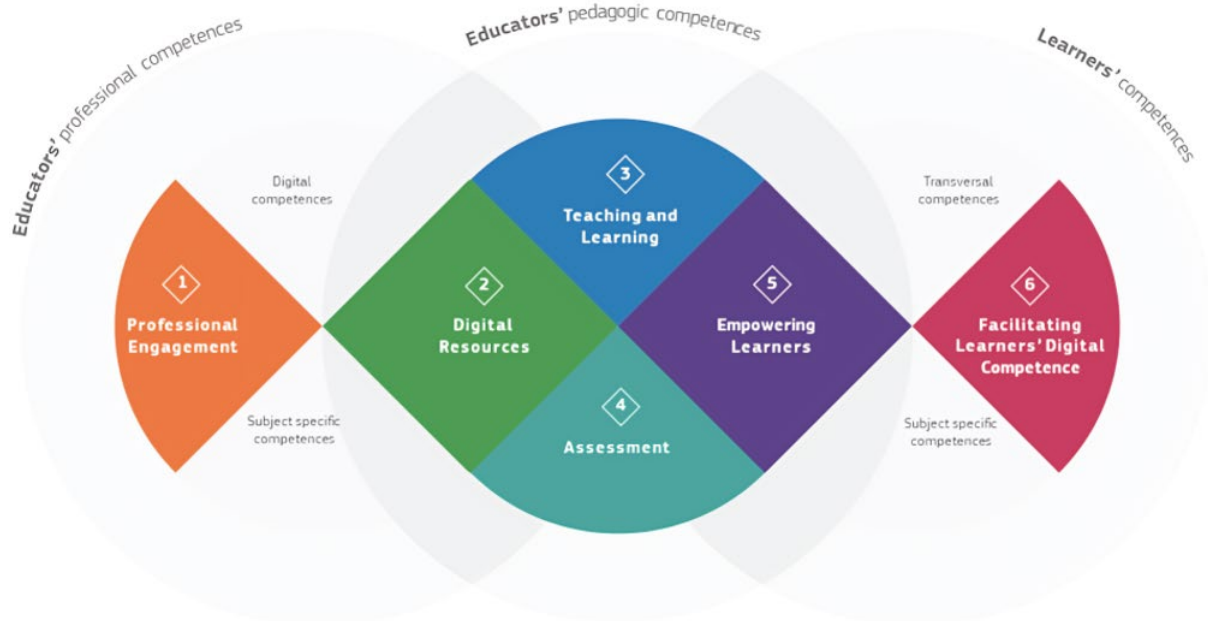


Figure 1. Digital competence framework for educators (adapted from Redecker, 2017)

the framework of the “International Society for Technology in Education”, UNESCO’s ICT competency framework for teachers, and the framework of the “Spanish Institute of Educational Technology and Teacher Training” (INTEF in Spanish).

The DigCompEdu framework (Figure 1) was created in 2017 with the aim of improving the level of TDC, thereby advocating educational innovation. The competence tasks that are established in this European framework are professional commitment, digital contents, teaching and learning, evaluation and feedback, student empowerment, and the development of student digital competence. The framework establishes three blocks of levels that can be attained, from A1 to C2:

- Basic: A1 (beginner) and A2 (explorer).
- Intermediate: B1 (integrator) and B2 (expert).
- Advanced: C1 (leader) and C2 (pioneer).

The aim of this framework is to provide guidelines that helps teachers to effectively incorporate digital technologies into their teaching at any education level (Redecker, 2017).

For example, in Spain, a validated questionnaire based on the DigCompEdu framework is used to assess the level of CDT. In a recent study by Palacios-Rodríguez et al. (2025), the level of DCT of in-service teachers in Spain and Portugal was assessed. Using this questionnaire has benefits such as being able to assess digital competence by areas established in this framework, so that it is easy to visualize which areas the teacher needs to improve. The results of the study suggest the importance of implementing personalized training programs as well as fostering collaboration among teachers to achieve more effective learning for students.

Furthermore, there are different holistic approaches that focus on the importance of the pedagogical dimension with respect to the integration of technologies into teaching (Area & Adell, 2021). For instance, Esteve et al. (2018) proposed a model in which TDC consists of different functions that are linked to the teachers’ tasks. Likewise, it is also worth mentioning the technological pedagogical content knowledge model, which was developed by Mishra and Koehler (2006). In this model, teacher competences are grouped into three major, interrelated scopes: technological knowledge, pedagogical knowledge and curricular knowledge.

These competence frameworks are a reference for studies that aim to analyze the digital competence level of teachers.

Therefore, the main aim of this work was to review the scientific literature about TDC. To this end, the following research questions were proposed:

- Q1:** What is the state of the art of this topic in the last five years?
- Q2:** What is the most widely used methodology in literature?
- Q3:** Which countries stand out in this type of research?
- Q4:** What is the aim of these studies?
- Q5:** What type of professional profile is represented by the samples used in the studies related to this topic?

METHODOLOGY

Search Strategy

In order to respond to the study objectives, the preferred reporting items for systematic reviews and meta-analyses (PRISMA) declaration was used (Fernández-Batanero et al., 2021a; Page et al., 2021). The PRISMA statement is a 27-item checklist designed to ensure that a systematic review is rigorous and useful. Authors must prepare a clear, detailed and accurate report, explaining the reasons for the review, the process undertaken and the findings obtained (Page et al., 2021). The search and subsequent selection of articles were carried out in March and April 2024 by the authors in two databases: Scopus and Web of Science (WoS). Both tools were selected for being very complete databases that gather high-impact research, and they are considered to be potential tools for systematic reviews (Pranckutė, 2021).

With the aim of obtaining concise and relevant results, the following keywords were considered for the search strategy: digital competence, digital skills, training, education, schoolteacher, K-12, kindergartens, elementary schools, and primary schools. These words were combined with the Boolean operators “AND”, “OR” and “NOT” in the different searches conducted.

A total of 230 records were initially identified (116 in Scopus and 114 in WoS). After the first reading of the title and abstract of the documents, the researchers discarded duplicate records (98) and documents that were considered of little relevance or generated confusion (83). Systematic reviews (26) and documents that were not fully accessible (4) were also excluded, obtaining a final sample of 19 studies (**Figure 2**), whose content was exhaustively examined. To guarantee the validity and precision of this systematic review, this process was agreed upon and performed by the four authors of the study.

Inclusion and Exclusion Criteria

For an exhaustive article selection, the following inclusion criteria were established:

- C1:** Publications from the last five years (2020–2024).
- C2:** Type of document (article).
- C3:** Area of knowledge (social sciences).
- C4:** Accessible documents.
- C5:** Studies with active teachers as participants.

Thus, this work excluded systematic reviews, documents that were not fully accessible and other types of documents (e.g., book chapters, doctoral theses, and conferences), as well as articles that were not related to the scope of social sciences and those published before the year 2020.

To ensure the validity and reliability of the inclusion and exclusion criteria in the systematic review, a rigorous and transparent approach was adopted in their development and application. The criteria were established based on an exhaustive review of the relevant literature. The inclusion and exclusion criteria were clearly and specifically defined, and their application was supervised by all the authors of the present investigation, resolving any discrepancies by consensus. This approach minimized bias and ensured a rigorous and coherent selection of the studies included in the review.

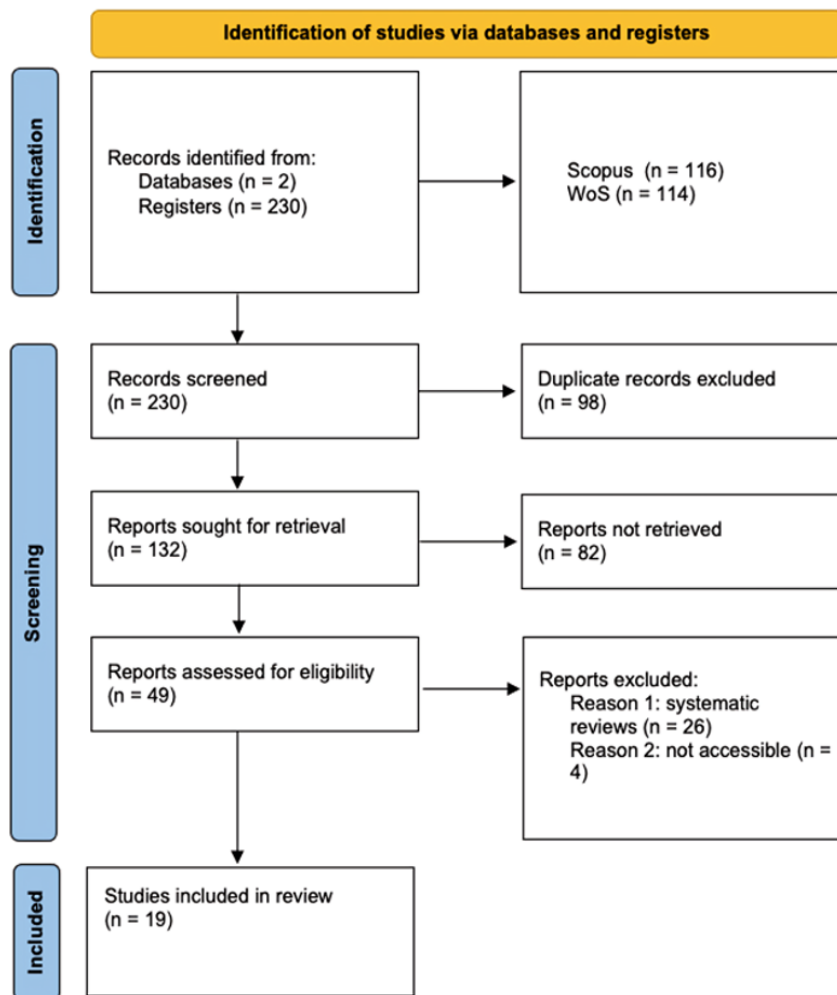


Figure 2. Flowchart of the article selection (adapted from Haddaway et al., 2021)

RESULTS

We presented the 19 studies that were selected for the review, alphabetically ordered according to their authors.

Studies Included in the Review

In this phase of the study, a thorough analysis of the obtained literature was carried out. To this end, a qualitative method was used, which examined the content of the selected articles (Table 1). This analysis was conducted using ATLAS.ti software v24.1.0. This tool allowed organising the information of the articles based on predefined codes, enabling the identification of relationships and patterns among the data.

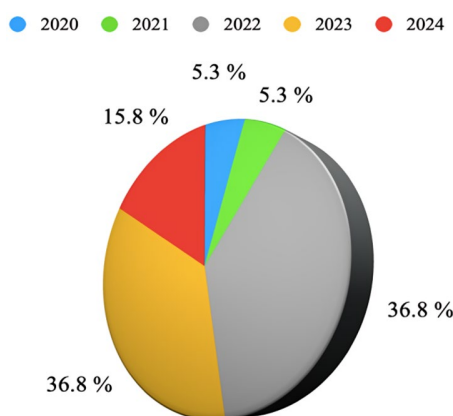
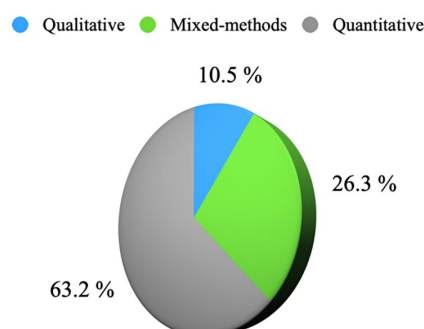
State of the Art in the Last Five Years

The analysis of the reviewed studies (Figure 3) shows that most of the articles are concentrated in the years 2022 and 2023 (36.8%), followed by the year 2024 (15.8%). On the other hand, very few studies were published in the years 2020 and 2021 (5.3%).

The years 2020 and 2021 showed lower study production, which could be attributed to the impact of the COVID-19 pandemic, which significantly affected resources, funding, and the ability of investigators to conduct studies. This disruption slowed the pace of research in several areas. However, from 2022 onwards, there was a notable increase in scientific production, driven by the advancement of technologies and the growing need for continuous faculty training. This upturn continued in 2023. For 2024, an increase in production is anticipated due to the fact that this research was conducted between March and April of that year.

Table 1. Selected studies

No	Authors	Year	Country
1	Baytar et al.	2023	Morocco
2	Caneva et al.	2023	Switzerland
3	Cattaneo et al.	2022	Switzerland
4	Chiu et al.	2024	China
5	Dias-Trindade and Moreira	2020	Portugal
6	Diz-Otero et al.	2022	Spain
7	ElSayary	2023	United Arab Emirates
8	Guillén-Gámez et al.	2022	Spain
9	Hathaway et al.	2024	Norway and USA
10	Hurtado-Mazeyra et al.	2022	Peru
11	Jiang and Yu	2023	China
12	Kiriníc et al.	2023	Croatia
13	Lorenzo Martín et al.	2022	Spain
14	Mas García et al.	2024	Spain
15	Mørk Røkenes et al.	2022	Norway
16	Rahmawati et al.	2022	Indonesia
17	Rodríguez Muñoz and Ruiz-Domínguez	2021	Spain
18	Syahid et al.	2023	Indonesia
19	Tzafilkou et al.	2023	Greece

**Figure 3.** Proportion of studies per year of publication (the authors' own work)**Figure 4.** Methodology of studies (the authors' own work)

Type of Methodology Used in Studies

Regarding the methodology employed in the analyzed studies (Figure 4), the quantitative approach stands out (63.2%), followed by the mixed-methods approach (26.3%). Lastly, the qualitative methodology shows little representation (10.5%).

The prevalence of quantitative approaches implies that the results obtained tend to be more generalizable and objective, which may be an advantage in terms of replicability. However, this may limit the depth of interpretations on subjective or contextual aspects that would be better explored through a qualitative approach.

Main Countries

A considerable number of countries produced the analyzed articles, with Spain standing out (25%), followed by Indonesia, Norway and Switzerland (5%). The remaining 70% belonged to different countries: Morocco, China, Portugal, United Arab Emirates, USA, Peru, Croatia, and Greece.

Objectives of the Analyzed Studies

Regarding the objectives of the studies analyzed, most of the articles explored the level of TDC (57.9%), followed by the identification of the factors that could promote the level of TDC, as well as possible difficulties, strategies to design an action plan, and the development of an instrument to evaluate the level of TDC (10.5% in each of these objectives). Lastly, actions were carried out to improve the level of digital competence in the participating teachers (5.3%), analyzing their experiences after the implementation of the training program. Following the proposition of Syahid et al. (2023), it is fundamental that teachers develop their digital competences to ensure that the teaching and learning of the 21st century are adapted to the new challenges.

The COVID-19 pandemic not only brought an increase in the use of digital tools, but also a change in the methodologies employed in education (Lorenzo Martín et al., 2022). It is important to highlight that on-line teaching requires a set of knowledge and skills that comprise both pedagogical and technical aspects. These aspects encompass all the elements of the virtual learning environment, including the design of the content and activities, organization, communication, evaluation and teamwork (Hathaway et al., 2024).

In this sense, the results of the study of Diz-Otero et al. (2023) show a deficient training in digital competences among secondary education teachers, thus it is necessary to develop and evaluate in-service training plans adapted to the needs of teachers. The study of Tzafilkou et al. (2023) also reports a lack of digital competences in teachers.

Study Samples

Regarding the samples of the studies, these consisted of active teachers from different education levels (Figure 5). Mainly, the articles were focused on the level of secondary education (52.6%). Some studies analyzed teachers from early childhood education (10.5%). Other articles employed samples of both early childhood and primary education (10.5%), or only primary education (10.5%). Lastly, some studies used samples of teachers from early childhood, primary and secondary education (5.3%), higher levels of vocational training (5.3%) or faculty members (5.3%).

Both teachers and students must learn to use different tools in digital environments. However, teachers play a fundamental role in this process, since they are in charge of designing and managing the learning environments (Dias-Trindade & Moreira, 2020). It is crucial to integrate TDC into all aspects of the professional development of teachers from initial teacher training (Chiu et al., 2024; Diz-Otero et al., 2023).

According to Jiang and Yu (2023), it is essential that secondary education teachers develop their digital skills, since these are necessary to guide and enhance the learning of the students. Secondary education teachers must reach a high level in these skills, in order to empower their students in the use of digital technologies for learning, communication and collaboration. In turn, this improves the quality of education and prepares students to face the academic and professional challenges of the future.

The study of Guillén-Gámez et al. (2021) reports a low level of TDC in early childhood education, which increases in higher education stages. This could be due to the fact that, at the earliest academic ages, teachers spend more time communicating with parents and pay more attention to the students. Moreover, early childhood students are less mature and autonomous for the use of digital resources. In some cases, teachers in this stage also advocate a little use of technological devices in schools, since children already make a daily and inadequate use of these resources at home. Therefore, it is necessary to attain an effective digital transformation in educational centers, which requires not only initial teacher training but also in-service teacher training (Caneva et al., 2023).

Figure 5 provides a clear view of the different educational levels from which the samples of the studies included in the review are drawn. However, it is important to reflect on how the representativeness of these samples may influence the results obtained. The concentration of research on a specific educational level may limit the generalization of findings to other contexts. For example, the pedagogical approaches and needs of

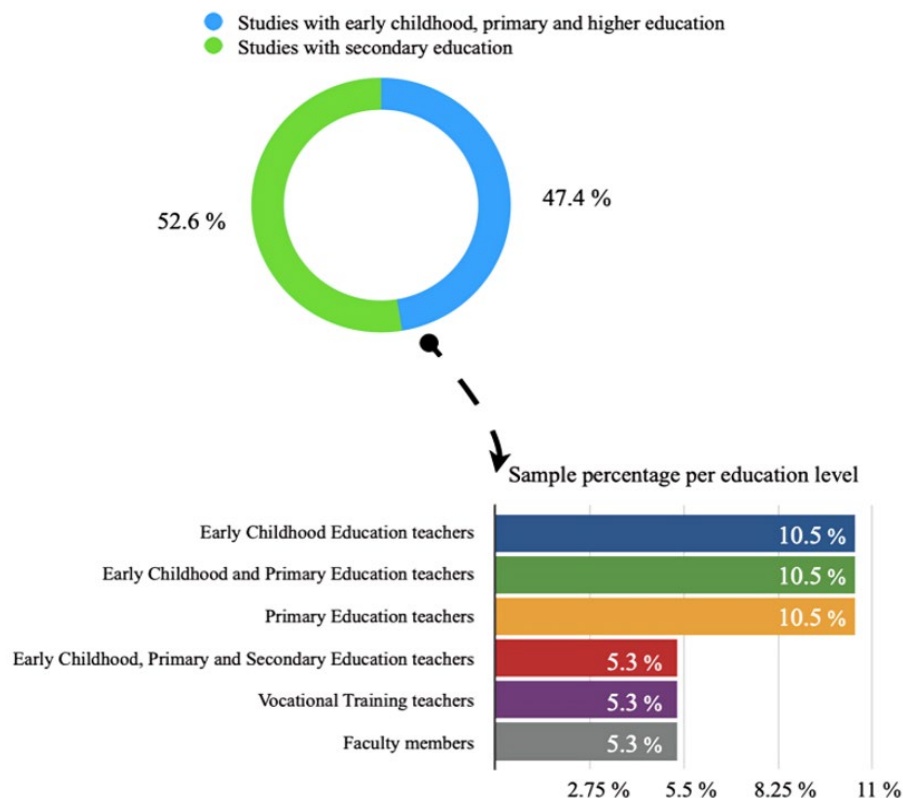


Figure 5. Study samples (the authors' own work)

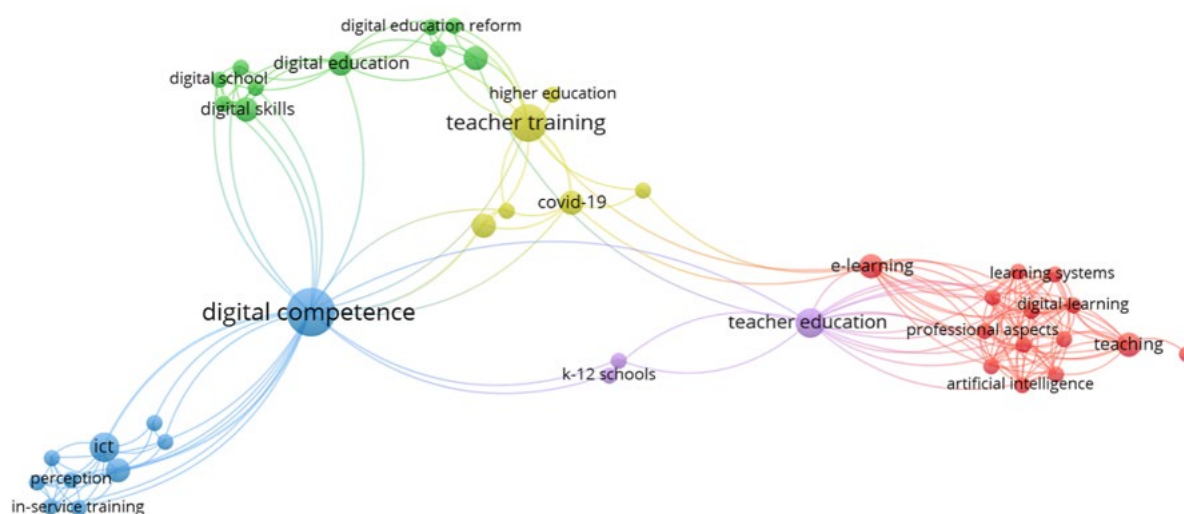


Figure 6. Map of thematic nodes or clusters (the authors' own work)

teachers in early childhood education may differ significantly from those of teachers in higher education, which could generate different results that are not easily transferable between educational levels. It is important that future studies consider a balanced representation of educational levels to ensure that the results adequately reflect the needs and characteristics of teachers as a whole.

Keyword Co-Occurrence Analysis

The keyword co-occurrence analysis of the selected studies was performed automatically using VOSviewer software. Through this software it is possible to build and visualize bibliometric networks. **Figure 6** shows the thematic nodes, or clusters, with the main keywords employed in the studies. The size, color and distance of the nodes indicate the frequency of the words, as well as their relationships.

- **Cluster 1:** The first cluster consists of 14 items, and it is represented in red. This group of keywords mainly refers to digital resources. These keywords are artificial intelligence (AI), AI competence, digital learning policy, digital-learning, e-learning, ICT, learning cultures, learning policy, learning systems, satisfaction of needs, professional aspects, self-determination theory, TDC, and teaching.
- **Cluster 2:** The second cluster includes 10 items represented in green, which refer to technologies in the educational scope. This group encompasses the following keywords: digital education, digital education reform, digital school, digital skills, digital teaching, information literacy, instructional coaching, professional development, teachers' professional training, and technology coaching.
- **Cluster 3:** The third cluster gathers 10 items, which are shown in blue. They mainly refer to digital competence. The keywords included in this cluster are digital competence, ICT, in-service training, initial training, perception, research methods, secondary education, teachers, technology, and tutoring action.
- **Cluster 4:** The fourth cluster consists of 6 items, represented in yellow, with the following keywords: COVID-19, higher education, new technologies, science education, secondary school teachers, and teacher training.
- **Cluster 5:** The fifth and last cluster only includes 3 items, shown in purple. The following keywords are included in this cluster: K-12 schools, online teaching, and teacher education.

DISCUSSION AND CONCLUSIONS

The aim of this systematic review was to analyze the studies related to TDC. Considering the thoroughly analyzed studies and the research questions proposed at the beginning of this work, it can be asserted that the scientific production in this topic has increased over the years, and it is expected to continue growing due to the obtained results (**Q1**). With regard to the type of methodology used in the studies (**Q2**), the quantitative approach stands out, as well as Spain as the country with the largest number of publications in this field (**Q3**). Moreover, the studies were focused on analyzing the level of TDC (**Q4**) in teachers of different education levels, with most studies using samples of secondary education teachers (**Q5**).

In the current situation, digital competence should be a fundamental skill of all teachers (Chiu et al., 2024). Different studies state that it is essential that teachers have a solid digital competence in order to create different learning environments and make the most of the potential of technology in enriching the educational processes (Baytar et al., 2023; Mas García et al., 2024; Rahmawati et al., 2022).

The COVID-19 pandemic and the advance of AI has generated greater awareness about the need for a better understanding of the digital world (Chiu et al., 2024; ElSayary, 2023; Hathaway et al., 2024). This situation brought two issues that were not considered a priority in the field of education until the present time: on the one hand, the urgency of responding to the use of technologies to minimize the effects of on-line education and increasing digitization; and, on the other hand, the deficient response capacity of teachers at the formative level, whose mastery of digital competences is far from sufficient to meet the double objective of facilitating the learning of contents for the students and enabling training in the management and use of technologies in the different areas of knowledge (Diz-Otero et al., 2023).

Nevertheless, a large number of active teachers lack digital competence, including both basic competences for teaching and learning, and knowledge of emerging technologies such as AI (Chiu et al., 2024). Most active teachers have not received enough training, thus they are less qualified and do not have the necessary confidence to implement technologies effectively. This includes legal and ethical aspects, as well as the protection of data privacy and safety (Chiu et al., 2024). In the field of education, ethics goes beyond simple interactions between people; it becomes a fundamental means for the transmission of values, playing a key role in the professionalism of teachers. Although there is research that has addressed ethical issues related to the use of technologies in education, most studies focus on how these tools are used, without delving into the pedagogical practices that should guide their implementation in the classroom. This aspect is not minor, as teachers must take responsibility for the ethical challenges that arise from the use of advanced technologies, such as facial recognition, learning based on big data, AI, and other technological innovations in teaching. Current competency frameworks address ethical issues in a general way, but it would be necessary

to include more specific strategies and models that incorporate a clear ethical perspective in teacher education (Gómez-Trigueros, 2025).

Since digital competence is an essential skill for 21st century teachers, it is important to take specific actions to identify practical strategies that strengthen the skills of teachers in the integration of technology into the learning process (Syahid et al., 2023). For many teachers, the use of technologies in educational contexts requires dedicating more time to solving technical problems and less time to pedagogical planning (Caneva et al., 2023); moreover, it may also cause stress and anxiety (Fernández-Batanero et al., 2021b). It is thus necessary to implement training programs for the development of digital competence in teachers (Hurtado-Mazeyra et al., 2022), addressing both pedagogical and technological aspects in the training and improvement of active teachers (ElSayary, 2023).

It is fundamental to thoroughly review, or at least question, the in-service training and up-dating programs in matters of teaching methodologies and the integration of technologies, since, despite having this type of training, teachers consider that it is insufficient and limited in this sense (Rodríguez Muñoz & Ruiz-Domínguez, 2021).

In this respect, Kirinić et al. (2023) propose two possible ways to increase the level of TDC and attain digital transformation. On the one hand, they refer to infrastructural and organizational support, and, on the other hand, they mention the personal dimension, underlining the importance of considering beliefs and specific values when planning the processes for the implementation of digital transformation, considering that both teachers and students need digital competences to actively participate in digital transformation (Tzafilkou et al., 2023).

Caneva et al. (2023) also propose the role of the teacher as an instructional tutor or coach with enough training and experience to promote a digital culture in schools, given the fact that the counsellors and support units of educational centers usually help more with technical matters than with pedagogical issues (Røkenes et al., 2022).

In conclusion, teachers who develop their digital competence have the necessary skills to effectively integrate technology in their educational practices, which promotes the commitment of the students toward their own learning. Therefore, it is crucial to advocate the development of TDC (ElSayary, 2023). However, research on digital competence in education continues to be scarce (Cattaneo et al., 2022).

Future Directions

This study has some limitations. It is recommended that future studies include more databases in their article search strategies and replicate this review periodically, in order to compare the results.

In addition, it would be valuable to expand this study into areas of research that have not been addressed in the scope of this review, but which are essential for a deeper understanding of teachers' digital competence. In particular, it is recommended to explore the analysis of regional gaps in TDC training, considering the differences in access to technological resources, educational infrastructure and teacher training policies in different parts of the world. This approach could provide crucial information on how socioeconomic and geographic inequalities affect the development of digital competencies in teachers. Furthermore, the implications of these gaps on educational quality could be investigated, contributing significantly to the design of inclusive policies and training strategies that address the specific needs of teachers in different regions. Addressing these areas would open up new lines of research and strengthen knowledge about the conditions necessary to achieve an equitable and effective integration of technologies in education.

Finally, it is proposed that longitudinal or long-term studies be conducted to observe how digital competence evolves over the course of teachers' careers

Author contributions: **María de los Ángeles Domínguez-González:** methodology, formal analysis, funding acquisition, software, writing - original draft; writing - review & editing; **Antonio Luque de la Rosa:** conceptualization, investigation, visualization; **Carlos Hervás-Gómez:** supervision, validation, writing - review & editing; **Pedro Román-Graván:** data curation, project administration, resources. All authors approved the final version of the article.

Funding: This article was funded by the VI Research and Transfer Plan of the University of Seville (VI PPIT-US).

Ethics declaration: The authors declared that the studies involving human participants were reviewed and approved by University of Seville. The participants provided their written informed consent to participate in this study.

Declaration of interest: The authors declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

REFERENCES

- Area, M., & Adell, J. (2021). Tecnologías digitales y cambio educativo. Una aproximación crítica [Digital technologies and educational change. A critical approach]. *Revista Iberoamericana Sobre Calidad, Eficacia y Cambio en Educación*, 19(4), 83–96. <https://doi.org/10.15366/reice2021.19.4.005>
- Barkatsas, T., & McLaughlin, P. (Eds.). (2021). *Authentic assessment and evaluation approaches and practices in a digital era: A kaleidoscope of perspectives*. Brill. <https://doi.org/10.1163/9789004501577>
- Baytar, E. M., Elyacoubi, H., Saqri, N., & Ouchaouka, L. (2023). Teachers' sense of competence in terms of ICT use: The case of secondary school teachers. *Research in Learning Technology*, 31. <https://doi.org/10.25304/rlt.v31.2874>
- Biggs, E. E. (2023). Strengthening professional networks to serve students with autism who have communication needs. *Intervention in School and Clinic*, 58(3), 173–182. <https://doi.org/10.1177/10534512221081250>
- Caneva, C., Monnier, E., Pulfrey, C., El-Hamamsy, L., Avry, S., & Delher Zufferey, J. (2023). Technology integration needs empowered instructional coaches: Accompanying in-service teachers in school digitalization. *International Journal of Mentoring and Coaching in Education*, 12(2), 194–215. <https://doi.org/10.1108/IJMCE-04-2022-0029>
- Cattaneo, A. A. P., Antonietti, C., & Rauseo, M. (2022). How digitalised are vocational teachers? Assessing digital competence in vocational education and looking at its underlying factors. *Computers and Education*, 176. <https://doi.org/10.1016/j.compedu.2021.104358>
- Chiu, T. K. F., Falloon, G., Song, Y., Wong, V. W. L., Zhao, L., & Ismailov, M. (2024). A self-determination theory approach to teacher digital competence development. *Computers and Education*, 214. <https://doi.org/10.1016/j.compedu.2024.105017>
- Dias-Trindade, S., & Moreira, J. A. (2020). Assessment of high school teachers on their digital competences. *Magis*, 13. <https://doi.org/10.11144/javeriana.m13.ahst>
- Diz-Otero, M., Portela-Pino, I., Domínguez-Lloria, S., & Pino-Juste, M. (2023). Digital competence in secondary education teachers during the COVID-19-derived pandemic: Comparative analysis. *Education and Training*, 65(2), 181–192. <https://doi.org/10.1108/ET-01-2022-0001>
- ElSayary, A. (2023). The impact of a professional upskilling training programme on developing teachers' digital competence. *Journal of Computer Assisted Learning*, 39(4), 1154–1166. <https://doi.org/10.1111/jcal.12788>
- Ertmer, P. A. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development*, 47(4), 47–61. <https://doi.org/10.1007/BF02299597>
- Esteve, F., Castañeda, L., & Adell, J. (2018). Un modelo holístico de competencia docente para el mundo digital [A holistic model of teaching competence for the digital world]. *Revista Interuniversitaria de Formación del Profesorado*, 91(32), 105–116.
- Fernández-Batanero, J. M., Román-Graván, P., Montenegro-Rueda, M., López-Meneses, E., & Fernández-Cerero, J. (2021a). Digital teaching competence in higher education: A systematic review. *Education Sciences*, 11(11), Article 689. <https://doi.org/10.3390/educsci11110689>
- Fernández-Batanero, J.-M., Román-Graván, P., Reyes-Rebollo, M.-M., & Montenegro-Rueda, M. (2021b). Impact of educational technology on teacher stress and anxiety: A literature review. *International Journal of Environmental Research and Public Health*, 18(2), Article 548. <https://doi.org/10.3390/ijerph18020548>
- Gallardo Montes, C. P., Rodríguez Fuentes, A., & Caurcel Cara, M. J. (2023). ICT training for educators of Granada for working with people with autism. *Heliyon*, 9. <https://doi.org/10.1016/j.heliyon.2023.e13924>
- Gallego Joya, L., Merchán Merchán, M. A., & López Barrera, E. A. (2025). Development and strengthening of teachers' digital competence: Systematic review. *Contemporary Educational Technology*, 17(1), Article ep555. <https://doi.org/10.30935/cedtech/15744>
- Gómez-Trigueros, I. M. (2025). Self-perception of teachers in training on the ethics of digital teaching skills: A look from the TPACK framework. *European Journal of Educational Research*, 14(1), 121–133. <https://doi.org/10.12973/eu-jer.14.1.119>

- Guillén-Gámez, F. D., Linde-Valenzuela, T., Ramos, M., & Mayorga-Fernandez, M. J. (2022). Identifying predictors of digital competence of educators and their impact on online guidance. *Research and Practice in Technology Enhanced Learning*, 17(1). <https://doi.org/10.1186/s41039-022-00197-9>
- Guillén-Gámez, F. D., Mayorga-Fernández, M. J., & Contreras-Rosado, J. A. (2021). Validity and reliability of an instrument to evaluate the digital competence of teachers in relation to online tutorials in the stages of early childhood education and primary education. *Revista de Educación a Distancia*, 21(67). <https://doi.org/10.6018/RED.474981>
- Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and open synthesis. *Campbell Systematic Reviews*, 18. <https://doi.org/10.1002/cl2.1230>
- Hathaway, D. M., Gudmundsdottir, G. B., & Korona, M. (2024). Teachers' online preparedness in times of crises: Trends from Norway and US. *Education and Information Technologies*, 29(2), 1489–1517. <https://doi.org/10.1007/s10639-023-11733-5>
- Hurtado-Mazeyra, A., Núñez-Pacheco, R., Barreda-Parra, A., Guillén-Chávez, E. P., & Turpo-Gebera, O. (2022). Digital competencies of Peruvian teachers in basic education. *Frontiers in Education*, 7. <https://doi.org/10.3389/educ.2022.1058653>
- Jiang, L., & Yu, N. (2023). Developing and validating a teachers' digital competence model and self-assessment instrument for secondary school teachers in China. *Education and Information Technologies*, 29, 8817–8842. <https://doi.org/10.1007/s10639-023-12182-w>
- Kirinić, V., Čerepinko, D., & Rosanda Žigo, I. (2023). Factor analysis of Croatian secondary school teachers' readiness for digital transformation. *Social Sciences*, 12(12). <https://doi.org/10.3390/socsci12120650>
- Larrañaga, N., Jiménez, E., & Garmendia, M. (2023). Oportunidades y necesidades percibidas entre los docentes de educación primaria para el uso educativo de las TIC [Opportunities and perceived needs among primary school teachers for the educational use of ICT]. *Educación*, 59(2), 301–314. <https://doi.org/10.5565/rev/educar.1618>
- Lorenzo Martín, E., Reinoso Tapia, R., Usategui Martín, R., & Delgado-Iglesias, J. (2022). Spanish secondary school teachers' digital competence in COVID-19 time. *Investigaciones em Ensino de Ciências*, 27(3), 59–77. <https://doi.org/10.22600/1518-8795.ienci2022v27n3p59>
- Maksimović, J., & Dimić, N. (2016). Digital technology and teachers' competence for its application in the classroom. *Research in Pedagogy*, 6(2), 59–71. <https://doi.org/10.17810/2015.35>
- Mas García, V., Gabarda Méndez, V., Peirats Chacón, J., & Llin Más, J. A. R. (2024). The impact of initial and in-service training on secondary school teachers' digital competence. *Revista Fuentes*, 26(1), 72–84. <https://doi.org/10.12795/revistafuentes.2024.23817>
- Mazzotti, V. L., Shogren, K. A., Stewart-Ginsburg, J. H., Kwiatek, S. M., Hagiwara, M., Wysenski, D. C., & Chapman, R. A. (2024). The goal setting challenge app: Promoting self-determination through technology. *Remedial and Special Education*, 45(1), 3–17. <https://doi.org/10.1177/07419325221147698>
- Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054. <https://doi.org/10.1111/j.1467-9620.2006.00684.x>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J., Akl, E., Brennan, S., Chou, R., Glanville, J., Grimshaw, J., Hróbjartsson, A., Lalu, M., Li, T., Loder, E., Mayo-Wilson, E., McDonald, S., ..., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, Article n71. <https://doi.org/10.1136/bmj.n71>
- Palacios-Rodríguez, A., Llorente-Cejudo, C., Lucas, M., & Bem-Haja, P. (2025). Macroevaluación de la competencia digital docente. Estudio DigCompEdu en España y Portugal [Macroassessment of teachers' digital competence. DigCompEdu study in Spain and Portugal]. *RIED-Revista Iberoamericana de Educación a Distancia*, 28(1), 177–196. <https://doi.org/10.5944/ried.28.1.41379>
- Pongsakdi, N., Kortelainen, A., & Veermans, M. (2021). The impact of digital pedagogy training on in-service teachers' attitudes towards digital technologies. *Education and Information Technologies*, 26(5), 5041–5054. <https://doi.org/10.1007/s10639-021-10439-w>
- Pozo, J. I., Cabellos, B., & del Puy Pérez Echeverría, M. (2024). Has the educational use of digital technologies changed after the pandemic? A longitudinal study. *PLoS ONE*, 19(12), Article e0311695. <https://doi.org/10.1371/journal.pone.0311695>

- Pranckutė, R. (2021). Web of Science (WoS) and Scopus: The titans of bibliographic information in today's academic world. *Publications*, 9(1), Article 12. <https://doi.org/10.3390/publications9010012>
- Rahmawati, S., Abdullah, A. G., Widiaty, I., & Islami, A. R. (2022). The distributions of vocational high school teachers' advanced digital competence (ADC). *Journal of Technical Education and Training*, 14(2), 190–201. <https://doi.org/10.30880/jtet.2022.14.02.017>
- Redecker, C. (2017). *European framework for the digital competence of educators: DigCompEdu*. Publications Office of the European Union. <https://doi.org/10.2760/159770>
- Rodríguez Muñoz, F. J., & Ruiz-Domínguez, M. (2021). La competencia digital del profesorado de literatura en educación secundaria en España [The digital competence of literature teachers in secondary education in Spain]. *Texto Livre*, 14(3). <https://doi.org/10.35699/1983-3652.2021.31351>
- Røkenes, F. M., Grütters, R., Skaalvik, C., Lie, T. G., Østerlie, O., Järnerot, A., Humphrey, K., Gjøvik, Ø., & Letnes, M. A. (2022). Teacher educators' professional digital competence in primary and lower secondary school teacher education. *Nordic Journal of Digital Literacy*, 17(1), 46–60. <https://doi.org/10.18261/njdl.17.1.4>
- Sánchez-Rivas, E., Ruiz-Roso Vázquez, C., & Ruiz-Palmero, J. (2024). Teacher digital competence analysis in block programming applied to educational robotics. *Sustainability*, 16, Article 275. <https://doi.org/10.3390/su16010275>
- Starks, A. C., & Reich, S. M. (2023). "What about special ed?": Barriers and enablers for teaching with technology in special education. *Computers and Education*, 193. <https://doi.org/10.1016/j.compedu.2022.104665>
- Syahid, A. A., Herry Hernawan, A., & Dewi, L. (2023). SMART for the improvement of primary school teachers' digital competence in the 21st century: An action research study. *International Journal of Learning, Teaching and Educational Research*, 22(3), 448–469. <https://doi.org/10.26803/ijlter.22.3.27>
- Trujillo Torres, J. M., Gómez García, G., Navas-Parejo, M. R., & Soler Costa, R. (2020). The development of information literacy in early childhood education teachers. A study from the perspective of the education center's character. *Journal of Technology and Science Education*, 10(1), 47–59. <https://doi.org/10.3926/jotse.728>
- Tzafilkou, K., Perifanou, M., & Economides, A. A. (2023). Assessing teachers' digital competence in primary and secondary education: Applying a new instrument to integrate pedagogical and professional elements for digital education. *Education and Information Technologies*, 28(12), 16017–16040. <https://doi.org/10.1007/s10639-023-11848-9>
- Valério Neto, L., Fontoura Junior, P. H., Bordini, R. A., Otsuka, J. L., & Beder, D. M. (2019). Details on the design and evaluation process of an educational game considering issues for visually impaired people inclusion. *Educational Technology & Society*, 22(3), 4–18.
- Yasar-Akyar, O., Rosa-Feliz, C., Sunday-Oyelere, S., Muñoz, D., & Demirhan, G. (2022). Desarrollo profesional de maestros de educación especial a través de la narración digital [Special education teacher's professional development through digital storytelling]. *Comunicar*, 71, 93–104. <https://doi.org/10.3916/C71-2022-07>

