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ABC-ul digital: o analiză sistematică a practicii cadrelor didactice în reconfigurarea instruirii în învăţământul primar

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THE DIGITAL ABC: A SYSTEMATIC ANALYSIS OF TEACHER PRACTICE IN REFRAMING PRIMARY INSTRUCTION

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Abstract
The integration of technology into the educational process led to changes in educational goals by emphasizing the development of key competences necessary for integration into the labor market, including digital competence. The changes targeted both the school curriculum and the reforms needed to update it, as well as teaching practices aligned with a student-centered paradigm. This research aims to investigate, through a systematic analysis of the specialized literature, effective teaching practices for developing digital competence in primary school students, as well as the factors that influence these practices. We analyzed the following aspects: types of professional development programs for teachers which have proven effective in the long term, determinants that influence the teachers' digital competence level, the teaching practices used to develop digital competence in young students and their impact on the learning process. We also analyzed the barriers encountered in integrating technology and ensuring digital equity. The 29 included studies were selected from international databases (WoS, ProQuest, ScienceDirect), and the review process followed the PRISMA reporting guidelines. The results of the research highlighted that training programs that included applied activities, mentoring, collaborative learning, or those leading to the formation of the

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practice communities were the most effective. The level of development of teachers' digital competence is influenced by both personal characteristics and institutional factors. The development of digital competence in primary school students is a complex process that involves educational policy, teacher professional development, institutional factors, and teaching practices tailored to specific age levels.

Keywords: curriculum reforms, digital competence, digital equity, teacher professional development, teaching practices.

Rezumat

Integrarea tehnologiei în procesul educativ a condus la schimbări în ceea ce priveşte finalităţile educaţionale, prin accentuarea formării competenţelor-cheie necesare pentru integrarea pe piaţa muncii, inclusiv competenţa digitală. Schimbările au vizat atât curriculumul şcolar şi reformele necesare actualizării acestuia, cât şi practicile didactice adaptate unei paradigme centrate pe elev. Prezenta cercetare îşi propune să investigheze, printr-o analiză sistematică a literaturii de specialitate, care sunt practicile didactice eficiente pentru formarea competenţei digitale a elevilor din ciclul primar, dar şi factorii care le influenţează. Au fost analizate următoarele aspecte: tipurile de programe de dezvoltare profesională destinate cadrelor didactice care s-au dovedit eficiente pe termen lung, factorii care influenţează nivelul competenţei digitale a profesorilor, practicile didactice utilizate pentru formarea competenţei digitale la şcolarii mici şi impactul acestora asupra procesului de învăţare, dar şi barierele întâmpinate în integrarea tehnologiei şi asigurarea echităţii digitale. Cele 29 de studii incluse au fost selectate din baze de date internaţionale (WoS, ProQuest, ScienceDirect), iar procesul de revizuire s-a realizat folosind metoda de raportare PRISMA. Rezultatele obţinute în urma cercetării au evidenţiat faptul că programele de formare care au inclus activităţi aplicative, mentorat, bazate pe învăţare colaborativă sau care au condus la formarea unor comunităţi de practică s-au dovedit cele mai eficiente. Nivelul de dezvoltare a competenţei digitale a profesorilor este influenţat atât de caracteristici personale, cât şi de factori instituţionali. Formarea competenţei digitale a elevilor din ciclul primar este un proces complex, care implică atât elemente de politică educaţională, pregătire profesională a cadrelor didactice, cât şi factori instituţionali ori practici didactice adaptate specificului nivelului de vârstă.

Cuvinte-cheie*: competenţe digitale, echitate digitală, formare profesională continuă, practici didactice, reforme curriculare.*

1. Introduction

The development of society, in its current form, was made possible by the widespread use of the latest technological systems across multiple fields, which have facilitated considerable progress in a relatively short time. The introduction of technology into educational systems was a natural step, given the need to prepare students, the future full-fledged citizens, able to be active and integrated members of society (European Commission, 2019). These changes have led to a rethinking of the purposes of the school curriculum and teaching practices, aligning them with current realities and the necessary preparation for entering the labor market, while also developing skills in digital technology use (Vidal-Esteve & Martín-Gómez, 2023).

Despite all the benefits that digital technology brings to daily activities, its integration into the educational process is not at the expected level. In some developed countries, where school digital equipment is at a high level, technology is not integrated into teaching practice as anticipated (Lomos et al., 2023) due to low levels of digital competence among teachers or to curricular integration that is not adapted to the context.

Teachers are, for the most part, digital immigrants (Prensky, 2001). The teacher's digital competence refers to "general digital competences for life and work and educator-specific digital competences to be able to effectively use digital technologies for teaching" (Redecker, 2017, p. 15). Some of them had a positive attitude toward technology in general and an easy embrace of new things due to their awareness of their usefulness (Fütterer et al., 2023; Sáez-López et al., 2024), while others showed a certain reluctance.

The integration of Information and Communication Technology (ICT) content into the school curriculum has led to the emergence of new teaching methods and strategies, which have been subscribed to the field of digital pedagogy (Cucoş, 2023; Friend et al., 2015; Istrate, 2022). Considering that it is a recently conceptualized area that is encountered in teaching practice at all levels of education, the need has arisen for teachers to familiarize themselves with the new concepts through continuous professional development courses and mutual support within practice communities (Pongsakdi et al., 2021; Väätäjä, 2023).

One of the biggest challenges is integrating technology at the primary school level to develop digital skills in young school-age students. In Romania, the students' digital competence is defined as "the assembly of key competencies which aim to prepare graduates for facing current challenges in both personal, and professional plan" (p. 1) and covers six areas: digital literacy, digital communication and collaboration, creating digital content, cyber security, and responsible use of technology (Ministerul Educaţiei, 2024). Although there are numerous types of digital educational resources (DER) adapted to the age level (Van Allen & Katz, 2019), the specific nature of cognitive development in primary school children requires additional attention in designing activities, selecting relevant resources, and using them creatively and effectively. It is not enough to form an algorithmic mental pattern (Chen et al., 2017); it is necessary to stimulate students' curiosity and creativity through engaging learning experiences (Sherwood et al., 2024).

Considering all these aspects, which need to be taken into account when implementing curricular changes, this systematic literature review aimed, as main objectives, to identify the teaching practices through which the digital competence of primary school students is formed, as well as the factors that facilitate or hinder the integration of digital technology in primary education.

1.1. Teaching practices for developing digital competence

The development of digital competence in schools, starting from the primary cycle, involves, in addition to legislative and curricular changes, modifications to teaching practices to integrate activities aimed at developing it (Arruda & Kerres, 2024).

Taking into account its definition (as stated in the DigComp reference frameworks – transposed in Romania through DigCompRo and detailed for students through Order no. 6466/30.08.2024), we can observe that digital competence represents more than just the simple operation of technological tools. This includes the knowledge, skills, and attitudes necessary to use digital technologies confidently, critically, creatively, and ethically, to solve problems and create digital content (Ferrari et al., 2012). This is included in the National Curriculum for primary school students and in the graduate

training profile for primary school students, and states that they should be able to "utilize digital devices and applications for learning purposes, with support from adults", and "develop simple digital content in the context of learning activities". This should be done "respecting basic safety rules in the use of devices, applications, digital content and the internet" (Institutul de Ştiinţe ale Educaţiei, 2015, p. 4). Bănuţ and Albulescu (2024) counted the number of examples for learning activities in the Romanian current primary school curriculum, which would help children develop their digital competences. They found that the references regarding learning activities that use technology are scarce (28 in number, less than 2% of the suggested activities for each learning year).

All these references and current teaching practices are insufficient for achieving this competence, as it is described in the graduate training profile. Moreover, the only study regarding the Romanian students' digital competence (Iancu & Iliescu, 2023) revealed a minimum functional level for this school level.

The development of primary students' digital competence is directly linked to the teacher's ability to implement student-centered digital pedagogy. The emphasis should not only be on integrating digital tools available for this level of education into the educational process, which can be easily accessed by most teachers, but also on how these tools are used to develop students' digital competence.

There are several theoretical models that have proven efficient in integrating technology into the educational process. One of these is Technological Pedagogical Content Knowledge (TPACK), developed by Mishra and Koehler (2006), that provides a coherent framework for technology integration. TPACK results from the intersection of three main domains: Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK). Implementing this model requires having a solid understanding of the subject, good knowledge of the way students learn, selecting appropriate teaching strategies and digital tools that facilitate a more engaging learning experience. Bratland et al. (2023) emphasize that, although teachers declare an openness to using technology in the educational process, its integration is only done

sequentially, as support within lessons conducted using traditional methods. Moreover, in most situations, student involvement consists only of completing routine tasks focused solely on familiarization with digital technology, rather than on digital literacy, digital citizenship, internet safety, or problem-solving. However, research shows that teaching practice changes in contexts with methodological, technical, and institutional support.

Even when teachers benefit from support in terms of equipment and access to technology, inadequate or insufficiently practical continuous professional training can be one of the factors hindering the integration of technology into practice (Lomos et al., 2023). The most effective courses are those in which theoretical training is followed by practical application, with teachers implementing what they have learned in the classroom (Loureiro et al., 2024). A natural next step is mentoring, in which the trainer or fellow trainees provide support to improve or diversify teaching practices. Furthermore, communities of practice represent a way to ensure the continuity of new approaches (Väätäjä, 2023). Pflaumer et al. (2021) observed that teachers who participated in interactive workshops and practiced using digital educational games integrated the concepts more easily into their daily activities. The integration of new concepts is influenced by the following aspects: the relevance and the applicability of the training content; peer support and a collaborative culture; the time allocated for testing and reflection; the existence of professional practice communities (El-Hamamsy et al., 2024; Jaipal-Jamani et al., 2015; Väätäjä, 2023).

In addition to changing the way continuous professional development for teachers is conducted, one of the most discussed and analyzed changes involves the introduction of ICT elements and concepts of algorithmic thinking as essential parts of the education of children and students, starting from the preschool level, given the alignment with the recommendations of the European Commission. In many countries, programming and computer science elements have been introduced into the curriculum, with these subjects offered as separate subjects or integrated into existing subjects (van der Vlies, 2020). Thus, changes have emerged not only in the reformulation of the taught content but also in the reconfiguration of educational objectives and methodologies.

Also, there has been an increased interest in collaborative, problem-solving, interdisciplinary projects and real-world task-based learning approaches (Hsu et al., 2019; Searle et al., 2023). In this way, technology is used to develop skills applicable in the real world, not just for identifying and accumulating new knowledge. Studies conducted in Germany and Norway (Pflaumer et al., 2021; Yang, 2022) highlight curricular changes aimed at supporting digital literacy, developing algorithmic thinking, and implementing work tools adapted to the primary cycle.

For the sustainability of changes at the educational system level, in curricular and methodological plans, it is necessary for technology to be integrated into regular teaching practice, not just treated as a one-off innovation. In many situations, teachers are forced to integrate technology into the educational process without having adequate methodological or technical support (Raihan et al., 2025).

In the Romanian context, where there is a desire to accelerate digitalization across all levels, including the educational field, from the primary cycle onward, it is necessary to investigate how this can be achieved in an efficient, equitable, and sustainable manner.

Before implementing legislative and curricular changes in teaching practice, it is recommended to first analyze the conditions under which they can be applied and their determinants.

In this regard, the present research aims to explore the conditions necessary to move beyond the stage of using technology as support and transform it into an integrated and sustainable component of the instructional-educational process, addressing the following questions:
R.Q.1. What are the factors that influence the digital competence level of primary school teachers?
R.Q.2. What types of training and professional development programs for teachers have proved effective in the long term for integrating digital technology into primary-level teaching practice?
R.Q.3. What types of barriers do teachers encounter in integrating technology into primary teaching practices, and what are their reasons?

R.Q.4. What models of technology integration are effective for developing the digital competence of primary school students?
R.Q.5. How does the integration of technology influence the learning process, algorithmic thinking, or creativity of young school-age students?

The results of this research can be useful to decision-makers in countries undergoing digitalization, such as Romania, to implement efficient, coherent, and viable changes.

2. Research methodology

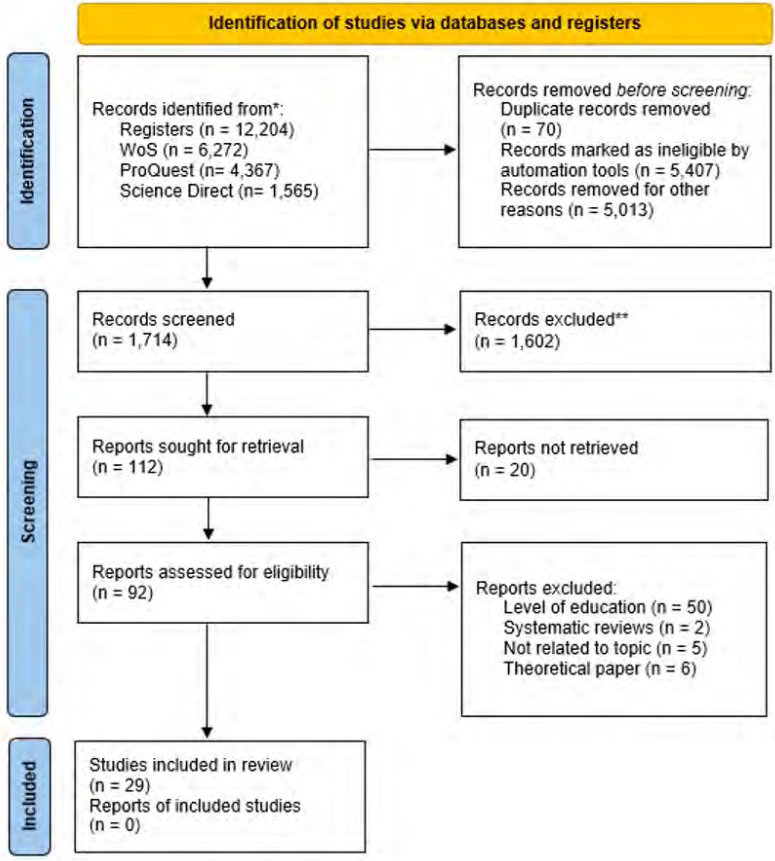
For this research, the focus was on classroom pedagogical practices for developing digital competence in primary school students and the factors that influence them. The study was conducted using the systematic literature review method (Higgins et al., 2024; Randles & Finnegan, 2023), while the reporting of the selection of studies included in the analysis was done using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Haddaway et al., 2022).

2.1. Eligibility criteria for studies

The search and selection of studies were conducted in May 2025, using the following databases: Web of Science (WoS), ProQuest, and ScienceDirect. To ensure the credibility of the analysis, from all the studies conducted on this topic, only articles published in the last 10 years (2016–2025), in English, that have undergone the peer-review process, with free access for viewing, and that have addressed the subjects were selected: educational research, scientific research, teaching methods, teaching, educational technologies, and key competencies. For each of the three mentioned databases, the following combination of keywords was used: (“digital teaching practices” OR “digital instructional practices” OR “digital pedagogical practices”) AND “digital pedagogy” AND (“primary school curriculum” OR “elementary curriculum” OR “elementary education”) AND “development of digital competencies” AND “curriculum integration”. The table below lists the inclusion and exclusion criteria for the search.

***Table no. 1**. Selection criteria for the included articles*

Inclusion criteria	Exclusion criteria
Published between 2016–2025	Published before 2016
Published in English language	Published in other languages
Subjects: Educational research, Scientific research, Teaching, Teaching methods, Educational technologies, Key competences	Other subjects
Free access	Payment for the article
Peer-reviewed	Not peer-reviewed



Source: https://estech.shinyapps.io/prisma_flowdiagram/

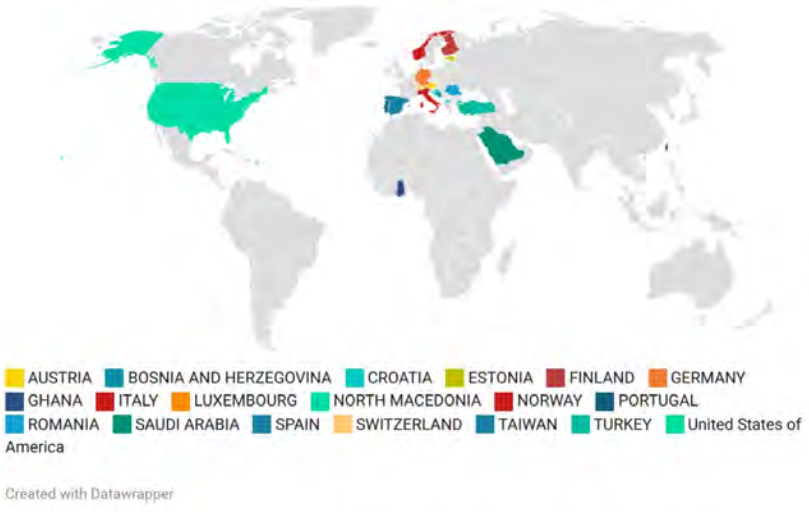
***Figure no. 1**. Reporting selected studies using the PRISMA flowchart (Haddaway et al., 2022)*

The initial search of the databases using the keywords revealed a total of 12,204 articles (WoS = 6272, ProQuest = 4367, ScienceDirect = 1565). The application of inclusion criteria in the automated research selection reduced the number of articles to 10,490. Of the remaining, 70 were eliminated as duplicates of other articles.

After each refinement of the search, 1714 articles remained. After reviewing the title and/or abstract of the studies, 112 articles were selected for in-depth analysis. Of those, 20 were eliminated because they could not be accessed. The remaining 92 articles were carefully analyzed, and it was found that 50 of them represented research conducted on students under the age of 6 or over the age of 11 (ages considered for kindergarten children or middle school students in Romania), two studies represented systematic literature reviews, 5 of them did not refer to the proposed topic for this analysis, but to other research topics, and 6 of them were articles presenting exclusively theoretical aspects of the targeted theme, rather than articles resulting from applied research. Thus, 29 articles were selected for the present analysis.

2.2. Data extraction and content analysis

From each selected study, the following information was extracted: research method, number of subjects, the country where the research was conducted, the theoretical framework followed, the purpose and the research questions. In the end, a brief description of the results obtained was provided (Appendix). The selected research studies were conducted worldwide to obtain a global perspective on teaching practices. Most of the research was conducted in the United States of America (six studies), followed by Spain (four studies) and Norway (two studies). From the other countries, only one study was selected.



Source: https://app.datawrapper.de/

***Figure no. 2**. The geographical distribution of research*

The analysis of the content and subjects of the selected studies led to their grouping into several main themes, presented in Table no. 2.

***Table no. 2**. Main themes of the selected articles*

Main theme	Authors
Teacher's digital competence	Akayoğlu et al. (2020); Bešić et al. (2025); El-Hamamsy et al. (2024); Lomos et al. (2023); Loureiro et al. (2024); Siddiq & Scherer (2016); Teidla-Kunitsõn et al. (2023); Vidal-Esteve & Martín-Gómez (2023); Xie et al. (2023)
Training and professional development of teaching staff	Callaghan et al. (2018); Čepić & Pejic Papak (2021); El-Hamamsy et al. (2021a); Killen et al. (2023); Sherwood et al. (2024); Väätäjä (2023)
Didactic innovations and the integration of digital technology (including emerging technologies) in pedagogical practices	Abedi (2024); Alenezi & Alfaleh (2024); Area-Moreira et al. (2016); Arruda & Kerres (2024); Bănuț & Albulescu (2024); Bratland et al. (2022); Hsu et al. (2019); Novak et al. (2024); Ramírez et al. (2023); Rogne et al. (2024); Searle et al. (2023)
STEM education and the development of algorithmic thinking	Bănuț & Albulescu (2024); El-Hamamsy et al. (2021a); Novak et al. (2024); Pflaumer et al. (2021); Vandenberg et al. (2020)
Inclusive education and digital equity	Bešić et al. (2025); Alcalá del Olmo-Fernández et al. (2024); Xie et al. (2023)

Most of the research has been based on the theoretical foundation of practices for integrating technology into teaching (10 studies – Abedi, 2024; Akayoğlu et al., 2020; Area-Moreira et al., 2016; Bešić et al., 2025; Lomos et al., 2023; Loureiro et al., 2024; Pflaumer et al., 2021a; Rogne et al., 2024a; Sherwood et al., 2024; Xie et al., 2023), constructivist learning theories – Piaget's cognitive constructivism, Vygotsky's social constructivism; socio-cultural constructivism (seven studies – Bănuț & Albulescu, 2024; Čepić & Pejic Papak, 2021; Hsu et al., 2019a; Matos et al., 2019; Novak et al., 2024; Vandenberg et al., 2020; Vidal-Esteve & Martín-Gómez, 2023); Technology Acceptance Model (TAM) theory (four studies – El-Hamamsy et al., 2021b; El-Hamamsy et al., 2023; Pflaumer et al., 2021; Siddiq & Scherer, 2016); The Technological Pedagogical Content Knowledge (TPACK) framework (three studies – Alenezi & Alfaleh, 2024; El-Hamamsy et al., 2023; Pflaumer et al., 2021); the community of practice theory (three studies – Killen et al., 2023; Reis-Andersson, 2024; Väätäjä, 2023), DigCompEdu and DigComp 2.2. (three studies – Arruda & Kerres, 2024; Lomos et al., 2023; Loureiro et al., 2024) and the UNESCO-ISTE reference framework (one study – Teidla-Kunitsőn et al., 2023). Some of the articles were based on multiple theoretical paradigms, which is why they appear in multiple classifications.

3. Results

The 29 selected articles of quantitative, qualitative, or mixed research focus on the research questions and provide examples of effective teacher practices for developing the digital competencies of primary school students. They also highlight the factors that influence the integration of technology in the educational process.

The analysis of the articles on long-term, effective training and professional development programs revealed seven studies that investigated continuous professional training and development for in-service teachers or future teachers (students at the time of the study) to integrate technology into the teaching practice. The purpose of the research and the results of implementing teacher training programs were extracted.

Regarding the types of training and professional development programs for in-service teachers, *collaborative professional learning and practice*

communities were some of the most long-term effective programs for teachers willing to integrate digital technology in their teaching practice or to improve their pedagogical strategies. This finding is supported by El Hamamsy et al. (2021a), who analyzed the sustainability of the curricular reform in digital education two years after the completion of the professional development programs for teachers. The results indicated that it depends on the perceived usefulness of teaching new content, the ease of implementation, and the availability of sufficient technical support in schools. However, barriers such as lack of time, effort, and clear evidence of student learning remain significant challenges in digital education. Similar results were reported by Čepić & Pejic Papak (2021), who analyzed teachers' experiences in grades I, V, and VII following the implementation of a curriculum reform program in Croatia, which emphasized competency-oriented learning. Despite the challenges posed by curricular planning and administrative requirements, teachers appreciate the autonomy to choose teaching methods and materials, as well as the emphasis on interdisciplinary connections. Although a positive attitude toward technology was observed, there is also a need for additional training and issues related to the digital infrastructure in schools.

Building on the need to develop algorithmic thinking [AT] for students' digital competence, Killen et al. (2023) analyzed the impact of a GA training program for both students and active teachers. The results highlighted the effectiveness of collaborative professional learning and communities of practice on the classroom implementation of new pedagogical models. The study by Sherwood et al. (2024) also focused on professional development centered on lesson planning to foster students' AT within the existing curriculum. Although they did not significantly change their assessment practices, teachers were supported in gradually adapting their practices and placing students as active thinkers, capable of using algorithmic thinking in various real-world contexts.

Professional training and development are a constant in the activity of teaching staff, considering the increasingly frequent curricular innovations. Each curricular reform requires informing teachers about the new methods and teaching strategies they can implement in the classroom. However, simple theoretical training without support and assistance in the practical domain is not sustainable in the long term (El-Hamamsy et al., 2021b). Although new

concepts may seem attractive and easy to integrate into educational activities (such as robotics and computational/algorithmic thinking training), both future teachers and experienced educators appreciate follow-up sessions and the value of practice communities. In these meetings, they can clarify unclear concepts, receive answers on the effectiveness of certain teaching practices, observe examples of good practice to use as models in their future activities, or find solutions to the cultural adaptation of practices observed in other contexts. Initial training programs (specific courses for digital initiation, courses for developing existing skills), completing modules within university programs, represent the basic condition for using technological devices for both personal and professional purposes (El-Hamamsy et al., 2024). Following the completion of these training programs, some teachers continue to improve through independent study (Loureiro et al., 2024), while others need support to integrate technology into their teaching activities. Those who can assist them may be more experienced colleagues or teachers with more advanced knowledge, as well as members of communities of practice (Väätäjä, 2023). The inclusion of technology in all stages of the educational process, as well as in administrative activities, has generated the need for *teachers to develop both general digital competencies and competencies specific to the educational environment* (OECD, 2023). The development of teachers' digital competence is conditioned by both internal influences (the perceived level of technology utility, attitude toward it, beliefs about personal abilities, perceived ease of using technology, age, professional experience) (Fütterer et al., 2023) and external factors (access to technology and the internet, support received during training programs, the existence of communities of practice) (El-Hamamsy et al., 2023; Väätäjä, 2023). Each of these factors influences both the level of digital competence of teachers and the way in which teachers subsequently integrate technology into their teaching activities as a supportive tool in instruction, as well as for the purpose of developing students' digital competencies (Vidal-Esteve & Martín-Gómez, 2023). The perception of technology's usefulness and the perceived ease of use are other determinants that influence the use of technology and its integration into the teaching process. Integral variables of the Technology Acceptance Model (Davis et al., 1989), the two influence the attitude toward technology use, and perceived usefulness determines the manifestation of behavioural intention to use, which leads to the actual use of technology. When teachers have a positive perception of technology and consider it easy to use, they

will adopt a positive attitude and find ways to use and integrate it into their teaching activities. Pflaumer et al. (2021) conducted a classification of teachers based on their level of digital competence and the degree of recognition of the benefits of integrating technology into teaching activities, resulting in four categories: 1) the expert (who has a high level of digital competence and is aware of the benefits of technology); 2) the skeptic (who has a high level of digital competence but does not recognize the benefits); 3) the willing one (who has a low level of digital competence but recognizes the benefits of technology) and 4) the negative one (who has a low level of digital competence and is not aware of the usefulness of technology).

Age, teaching experience, professional profile, and gender of teachers also play a role in the development of teachers' digital competence and the integration of technology into teaching activities. Area-Moreira et al. (2016) observed that younger teachers, who have fewer years of professional experience but have received training for the development of digital competence, integrate technology less into their teaching activities, unlike those aged between 45 and 55, who have more extensive professional experience, come from the ranks of digital immigrants, and did not receive digital training during their university studies. Moreover, the more frequently teachers use technology in their daily lives, the more they develop their level of competence and can quickly transfer knowledge to any field.

Numerous recent studies confirm that technology, when used intelligently and is pedagogically integrated, not only facilitates learning but also transforms it into an innovative experience. Regarding the *effective technology integration models in developing the digital competence of primary school students*, the analyzed articles highlight several pedagogical models and strategies that have proven effective and can be grouped as follows:

1) those that involve students in the active creation of digital content (PBL, AR);
2) those that use technology as a scaffold tool;
3) those that integrate digital skills into the disciplinary curriculum;
4) those that encourage personalized learning.

Hsu et al. (2019) illustrate the effectiveness of Project-Based Learning method combined with situated learning, observing and analyzing the creation

of augmented reality (AR) artifacts by primary school students. They observed significant increases in key areas of digital competence.

Another effective model is technology-enhanced scaffolding, in which students are provided with digital support to help them get across learning difficulties and set them to success in achieving progress. The concept of "scaffolding" refers to the temporary and adaptable support provided to students to aid them achieve learning objectives that they could not accomplish independently (Wood et al., 1976, as cited in Bănuț & Albulescu, 2024). Usually, this support comes from the teacher or peers. In the digital age, it has been observed that technologies could also be used for this purpose. Bănuț and Albulescu (2024) applied this model of music learning through programming (using Sonic Pi), showing that technology can support cognitive processes such as memorization and understanding. Musical programming activities have contributed to the development of skills in memorizing and understanding musical notation, as well as stimulating algorithmic thinking through the process of logically and sequentially structuring sounds. Additionally, AT is naturally trained through activities that involve visual or creative programming. Killen et al. (2023) emphasize that AT is increasingly integrated into the disciplinary curriculum, including in Science, at the primary level, and its integration into interdisciplinary contexts, such as STEM, requires prior teacher training.

Creativity can also be stimulated through technology in primary education. Students can use digital applications or interactive platforms to create new content, thus expressing their own ideas or points of view. Under teachers' supervision and guidance, they become content creators, not just content "consumers", developing their digital competence across all areas.

Pflaumer et al. (2021) discuss adaptive literacy games as tools for personalizing learning, which can contribute to the development of digital competence. However, their success relies on teachers' understanding of the pedagogical benefits of technology adaptability. Bratland et al. (2022) complete this picture by explaining that the integration of technology revolves around a specific content of each subject and the teaching practices of the teachers, suggesting that a generic approach to integration might be less effective.

Hsu et al. (2019) investigated the development of digital literacy (DL) skills of 32 primary school students through the creation of augmented reality (AR) artifacts. The students created multimodal, contextual, and interactive AR artifacts, which led to an increase in creative skills. The game design process (similar to creating AR artifacts) increases "opportunities for students to improve their technological fluency and build knowledge" (Kafai, 2006, as cited in Hsu et al., 2019). This "learner-as-creator" approach develops higher-order thinking skills, creativity, and critical analysis (Bower et al., 2014, as cited in Hsu et al., 2019).

Instructional design combined situated and spiral learning showed significant increases in five areas of students' digital competence: information management, collaboration, communication and sharing, creation, and evaluation/ problem-solving. These results highlight that technology enables students to "effectively and creatively apply existing ICT in our technology-based society" (Ferrari et al., 2012; Ng, 2012, as cited in Hsu et al., 2019). On the other hand, the study conducted by Ramírez et al. (2023) highlights a clear difference between educational fields regarding the use of technology. Thus, for subjects like Natural Sciences or Social Sciences, digital resources (interactive maps, explanatory videos) are more frequently adopted, unlike the mother tongue or Mathematics, where traditional resources continue to dominate.

Regarding the *barriers encountered by teachers in using technology in teaching activities*, these can be of an external nature, such as lack of resources (equipment, internet, digital educational resources, instructional software), lack of support (lack of technical support, professional development opportunities), or lack of institutional strategies (Xie et al., 2023). Among the internal barriers are the digital skills of teachers, the importance given to the relevance of digital resources in supporting student learning, and the time spent using digital resources. Except the lack of technological infrastructure in schools, insufficient professional training is considered another significant barrier to integrating technology into teaching practices (Čepić & Pejic Papak, 2021). Sometimes, the technology itself can be a barrier when teachers do not know how to use it and, consequently, cannot integrate it into their teaching (Pflaumer et al., 2021).

Bešić et al. (2025) observed that sustained efforts are being made to ensure

digital equity in schools and teaching practices and different curricular reforms to support the integration of technology into school programs are experimented. But change often comes from schools as a result of collaboration between school leaders and teachers to identify specific needs, improve digital infrastructure, and provide support. Additionally, continuous evaluation of teaching and organizational practices is necessary to ensure equitable and accessible digital education for all students.

4. Discussion and conclusions

The present systematic literature review aimed to identify and analyze effective teaching practices in developing digital competence among primary school students, as well as the factors that support or hinder this process. The results of the analysis of the 29 articles presenting national or international studies, published between 2016 and 2025, revealed aspects which facilitate to create a general picture of the challenges of integrating technology at the primary school level, in order to implement coherent and effective changes.

A synthesis of the reviewed studies demonstrates a clear consensus on the necessity of practice-oriented professional development and highlights the mediating influence of teacher attitudes in technology integration. Across various national contexts, findings indicate that isolated technical training is inadequate; instead, sustained and collaborative models, such as communities of practice and ongoing mentoring, are considered essential for developing long-term competence (Čepić & Pejic Papak, 2021). However, the literature diverges regarding technology implementation: some studies present technology as a direct scaffolding tool for specific subjects (Bănuț & Albulescu, 2024), while others advocate for systemic, project-based, or transversal approaches, such as STEAM (Chappell & Hetherington, 2024). Additionally, significant uncertainty remains concerning the causal impact of specific barriers. Although infrastructure and access are frequently identified as foundational, it is unclear whether increased equipment availability alone can address pedagogical resistance without substantial changes in organizational culture (Raihan et al., 2025). These gaps indicate that future research should progress beyond documenting successful interventions and focus on analyzing the scalability and long-term sustainability of digital integration models.

Regarding the first research question, the analysis of the selected studies highlighted the central role of training and professional development programs based on practical experiences. By completing them at the initial training stage (as students, future teachers), or as continuous professional development (for active teachers), contexts are created for training and developing teachers' digital competencies. However, these prove their effectiveness only if they include practical activities, not just theoretical elements. They should also be followed by post-course sessions and mentoring. The most effective training includes the formation of communities of practice, which encourage collaboration among colleagues (Väätäjä, 2023), mentoring sessions during and after the training programs (Callaghan et al., 2018), and the development of digital self-efficacy (El-Hamamsy et al., 2021b). It would also be advisable to have more professional development courses.

Among the personal characteristics that influence the level of digital competence of teachers are the attitude toward technology, determined by perceived usefulness and perceived ease of use (Pflaumer et al., 2021), age and teaching experience (Area-Moreira et al., 2016; Siddiq & Scherer, 2016), as well as the pre-existing level of digital literacy and the frequency of daily technology use. The attitude toward technology is a determining factor in its use. The greater the openness to the advantages of using it, the more frequently it is used (Area-Moreira et al., 2016). Regarding external factors, the degree of access to technology is the primary one that influences the level of competence. This is followed by participation in initial and continuous training, organizational support, and collaboration among teachers to overcome technical barriers (Loureiro et al., 2024; Xie et al., 2023). Support from school leaders, an organizational culture based on collaboration among teachers, and the sharing of valuable digital educational resources can encourage teachers to develop digital competencies and surmount barriers to integrating technology into teaching practice.

The methods of integrating technology into teaching activities are varied. Some are student-centered and support them in creating digital content (Bănuţ & Albulescu, 2024; Hsu et al., 2019), while others are used to provide students with opportunities to personalize their learning through the use of digital platforms and games (Pflaumer et al., 2021). The most complex methods

aim at the transversal integration of technology into the curriculum, through the implementation of projects targeting STEM or STEAM fields. In these situations, the teacher acts as a facilitator of learning, designing learning activities that focus on developing students' competencies. The learning process is supported through activities in which technology is used as a "scaffolding" tool, providing real-time feedback and allowing collaboration between students (Alenezi & Alfaleh, 2024; Bănuţ & Albulescu, 2024). The use of interactive applications and digital tools supports the creative process of students, placing them in a position to create and present their own digital materials (El-Hamamsy et al., 2021a; Hsu et al., 2019; Istenic Starčič et al., 2016).

External barriers (lack of technical equipment, qualitative and suitable digital educational resources, etc.), or internal barriers (Xie et al., 2023), can be overcome through the concerted efforts of institutional factors, sustainable continuous training programs, realistic curricular reforms, and culturally adapted teaching practice models (Cheng & Wang, 2023; Čepić & Pejic Papak, 2021; El-Hamamsy et al., 2024).

In conclusion, this review presents a structured scheme for teachers, redirecting focus from technological infrastructure to the nuanced pedagogical strategies within the classroom. By synthesizing the main practices that define digital teaching in early education, this study offers a starting point for educators and trainers. The principal contribution lies in identifying teacher agency and instructional design, rather than digital tools alone, as the primary drivers of digital literacy. These findings can guide the development of professional training programs, ensuring that future primary education is informed by pedagogically robust, teacher-led digital innovation.

5. Limitations

The limitations of the present study are related to temporal, linguistic, thematic, contextual, and methodological aspects. The selection of studies published in the last 10 years was made to have an updated perspective on the analyzed issue. However, earlier research that contributed to the foundation of pedagogical theories guiding the integration of technology into teaching

practice was excluded. Future research could include a longitudinal analysis of the evolution of teaching practices for developing students' digital competence across different periods (e.g., pre- and post-COVID-19).

The exclusion of research published in other languages and the selection of articles published only in English represent another limitation of the study. This approach was taken to facilitate the coherence of the analysis of the articles' contents, as well as because the majority of articles focused on this topic were published in English. To avoid such a limitation in the future, it would be useful to integrate studies published in other internationally circulated languages, and academic translations will be used for content interpretation.

Another limitation concerns filtering studies based on the criteria of *open access* and *peer-reviewed* studies. The publication of studies reviewed by specialists in the field provides credibility and scientific validity; however, this has led to the exclusion of studies that are in the process of being published and which can offer valuable insights into the researched issue. Additionally, studies found in databases with limited or restricted access were omitted, from which relevant research results could have been selected.

The various research methodologies (qualitative, quantitative, mixed) limit the generalization of the obtained results and make it difficult to conduct a meta-analysis to measure the effectiveness of teaching practices on the development of digital competence. Subsequent research could include only quantitative studies, which could be used to conduct meta-analyses focused on the effects of training and professional development programs or the efficiency of pedagogical practices.

This analysis is focused mainly on the teachers' perspectives. A better understanding of effective practices would be obtained from measuring students' outcomes from these practices. Including more long-term studies could show the sustainability of students' digital competence to secondary school.

The development of digital competence in young school-age students is a comprehensive process. By cultivating these skills through a creative, ethical, and responsible manner, young students will grow to become active, engaged citizens in a society that is constantly transforming.

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Appendix

Author/ Year of publication	Original title of the article	Type of research/ Method/ Number of subjects/ Country	Theoretical framework	Aim of the research	Results
Main focus: Teacher's digital competence					
1.Louriero et al. (2024)	Digital Competence for Pedagogical Integration: A Study with Elementary School Teachers in the Azores	Quantitative research Online questionnaire 207 responding teachers Portugal	DigCompEdu Self-perceived digital competence of teachers	Verification, analysis, and categorization of the digital competencies of primary school teachers to assess the level of influence of digital competence on innovative learning practices	This research assessed the degree of digital competence possessed by primary educators in the Azores, aligned with the framework of the European DigCompEdu, while also drawing attention to the correlation between professional development for teachers and innovative educational practices. Despite acknowledgment of advancements since previous research, nearly 50% of teachers indicated that they had not received specific training focusing on how to use digital educational technologies (for example computers, tablets, mobile phones). Based on these findings, the authors stress the need for such training to be designed around the genuine needs of teachers; in order to rectify the competence gap that exists between teachers and their pupils, as well as develop coherent educational policies regarding how best to integrate technology into the educational process.
2. El-Hamamsy et al. (2024)	Modelling the sustainability of a primary school digital education curricular reform and professional development program	Quantitative Two questionnaires (one applied at the end of professional training, one applied nearly two years after the completion of professional training) 287 primary school teachers Switzerland	Sustainable Adoption of Digital Education (SADE), Technology Acceptance Model (TAM)	Analysis of the sustainability of the curricular reform regarding digital education and the factors influencing the continuity in the implementation of reforms, two years after the completion of teacher professional development programs	Through structural equation modeling, the study identifies critical sustainability factors. The validated Sustainable Adoption of Digital Education (SADE) model confirms that sustainability depends on the perceived usefulness of teaching the new content, the ease of implementation, and access to sufficient support in schools. The conclusions show that the reform model contributes to a positive self-efficacy of teachers and increased adoption over time. However, barriers such as lack of time, the required effort, and the absence of clear evidence regarding student learning remain significant challenges.
3. Siddiq & Scherer (2016)	The relation between teachers' emphasis on the development of students' digital information and communication skills and computer self-efficacy: the moderating roles of age and gender	Quantitative research Questionnaire with two scales: TEDDICS and CSE 1071 teachers Norway	Perceived computer self-efficacy (CSE)	Identifying the existing relationship between perceived computer self-efficacy (CSE) and the development of students' digital competencies (TEDDICS), using multidimensional measurements for both constructs	The study analyzed the relationship between teachers' self-efficacy regarding digital competences and their emphasis on developing students' digital skills. The results indicated a significant positive correlation between teachers' self-efficacy and the emphasis on digital competences in the classroom. Regarding the influence of gender, subsequent statistics do not indicate significant differences between female and male teachers. However, age acts as a moderator on the positive relationship between self-efficacy and the emphasis on developing students' digital skills, with more experienced teachers being more likely to emphasize digital competences in the classroom than younger ones, especially when they feel more competent. Therefore, the confidence of teachers in their own digital capabilities is a prerequisite for integrating technology into the instructional-educational process, and in teacher training, the emphasis must be on developing pedagogical technological skills.

Author/ Year of publication	Original title of the article	Type of research/ Method/ Number of subjects/ Country	Theoretical framework	Aim of the research	Results
Main focus: Teacher's digital competence					
4. Vidal-Esteve & Martín-Gómez (2023)	Digitalization of Classrooms: A Comparative Study on Teachers' Perceptions about the Use of Digital Teaching Materials in Early Childhood and Primary Education	Qualitative, comparative study Focus group interviews 24 teachers, 10 primary school teachers (digital school - 2016-2019) and 14 educators (digital kindergarten, 2019-2022) Canary Islands and Valencia, Spain	Digital pedagogy, use of digital teaching resources - Digital educational resources	Analyzing the teachers' perspective on the integration of digital teaching materials (DTM) Exploring the manners that DTM are used in the educational context of the Canary Islands and the Valencian Community	The discussions show that, in spite of the flexibility and motivation that digital educational resources (DER) might offer, preschool teachers emphasize the need for complementing the learning experiences with manipulable and experiential resources. They have concerns about excessive use of technology at home. Primary school teachers consider DTM important for student's learning, but emphasize the importance of effective pedagogical use of RED and traditional materials. The conclusions of the study indicate that teachers need to ensure a balance between digital and traditional resources, adapting the use for each educational stage and teaching objective.
5. Bešić et al. (2025)	Digital technology use in inclusive schools in four European countries: Within- and between-school differences	Quantitative SELFIE Questionnaire 656 participants, 68 directors and 588 teachers from 4 countries: Austria, Bosnia and Herzegovina, Italy, and North Macedonia	DigCompOrg	Exploring the digital capacity of inclusive schools in four European countries and identifying potential areas for improvement	The research highlights that digital technologies offer significant opportunities for inclusive education, facilitating personalized learning and accessibility for students with disabilities. Discussions, however, reveal major challenges: the lack of accessible digital resources, insufficient digital skills among students and teachers, and the absence of technology integration strategies. Many teachers were not prepared for inclusive teaching using digital technology. The conclusions indicate that school leaders and local communities need to collaborate with teachers in identifying students' specific needs, improve digital infrastructure and provide technical support for both teachers and students. Moreover, the teaching and organizational practices must also be adapted, in order to ensure equitable digital education for all students.
6. Teidla-Kunitsõn et al. (2023)	A Bridge or a Wall: Teachers Mediating ICT in the Classroom	Qualitative Semi-structured interview 8 teachers Estonia	Attitude toward the integration of technology in teaching	Examining how teachers' attitudes toward the integration of ICT in the classroom are put into practice through their regular use of ICT in daily teaching Analyzing how teachers perceive their own role in preparing young people for adult life in the digital age	Although the general attitude of Estonian teachers toward the use of ICT is positive, in practice students have a more passive role. Few teachers actively encourage students to involve in content creation or help them develop digital skills. These differences between attitudes and practices, can be explained by the expectations of the society and the fact that the students main use of ICT is at home, for homework, not in class. Addressing the digital divide, the study shows that few students are prepared to use ICT effectively in their daily lives. Even if there are some methodological limitations, that might make difficult the generalization of some practices, the study offers several teacher practices that can be applied in different educational systems.

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Main focus: Teacher's digital competence					
7. Xie et al. (2021)	Examining changes in teachers' perceptions of external and internal barriers in their integration of educational digital resources in K-12 classrooms	Quantitative research Questionnaire administered twice, at an interval of approximately 1 year Application 1 - 639 subjects; Application 2 -301 subjects; Common subjects: 301 USA	Ertmer's theory (1999) on barriers to technology integration	Examining teachers' perceptions regarding external and internal barriers to technology integration has changed over the years Analyzing how changes in external barriers are related to changes in internal barriers and technology integration behaviors in practice (of open educational resources)	This study examines how teacher perceptions regarding challenges in using digital educational resources (DER) change throughout a school year. Teacher perceptions of external barriers (technology itself, time and technical support) and internal barriers (digital skills and attitudes toward technology) were evaluated. At the beginning of the school year, among the main external limitations were considered insufficient time, technological resources, effective technical assistance or inability to access appropriate DER. During the school year, the external barriers have lessened in the overall perceived importance, while the internal barriers (like personal digital competence and their pedagogical beliefs regarding the integration of technology in teaching practices) increased. The authors conclude that professional development programs should be adaptable over time, and should focus on improving teachers' digital skills and views regarding effective use of technology in the educational process.
8. Lomos et al. (2023)	Implementing ICT in classroom practice: what else matters besides the ICT infrastructure?	Quantitative research ICILS 2018 questionnaire 420 teachers Luxembourg	Four in Balance educational model (Kennisnet, 2011, Koster et al., 2009, Law et al., 2008)	Identification of important factors explaining the variation in ICT implementation in a context of high availability of digital resources	Even if there is a solid digital setup in Luxembourg, the use of technology in teaching is still quite limited. Discussions show that, beside a good ICT infrastructure, successful integration depends on factors like teachers' ICT skills, the school curriculum, technological educational resources and the school's vision. When teachers lack digital skills, and the curriculum does not incorporate technology efficiently, the technology alone is not enough. Continuous professional teacher training is essential, aiming to improve both digital skills and teaching methods to integrate ICT.
9. Akayoğlu et al. (2020)	Digital literacy practices of Turkish pre-service EFL teachers	Qualitative Questionnaire with 4 open-ended questions sent via email and semi-structured interviews with students 113 students from 3 universities Turkey	Conceptualization of digital literacy	Exploring how students who aspire to become teachers understand the concept of "digital literacy" and what it entails Investigating the digital literacy practices of future English teachers, focusing on the skills they can incorporate into their future teaching experiences	The understanding of digital literacy of trainee teachers in Turkey varies from the simple usage of digital tools to critical, creative and collaborative use. Their perceived level of digital competence depends on their level of exposure and training, many of them considering themselves as digitally competent. The purposes for which they use technology vary from social media platforms (which is the most common), to educational purposes (more limited). Student-teachers use technology especially for learning management tools, quizzes or presentations and less for professional development. The conclusions stress that training university professors should become models for digital practice and should familiarize their students with online communities and critical thinking into teacher training.

Author/ Year of publication	Original title of the article	Type of research/ Method/ Number of subjects/ Country	Theoretical framework	Aim of the research	Results
Main focus: Teacher training and professional development programs					
1. Väätäjä (2023)	A community of practice approach to the co-development of digital pedagogy: a case study of primary school teacher education practicum	Qualitative Case study 2 educators, 5 trainee teachers (students), 6 mentor teachers; Finland	Digital Pedagogy Communities of Practice TPACK	Identifying the specific characteristics of a community of practice that can be recognized within the pedagogical practice of students Analyzing the perception of the involved actors on digital pedagogy as a co-development practice	The study shows that the pedagogical practice included key elements of a community of practice: establishing common goals, intentional and regular interactions, leveraging individual expertise, and collaboration in the co-development of digital pedagogy. Although the official practice documents do not clearly encourage collaboration, the interviews indicate a genuine involvement of the actors in the co-development process. Students were the main initiators of the change, proposing technological solutions, while mentors and trainers had more passive roles. Co-development primarily took place at the level of direct interaction in individual lessons, without broadly influencing curricular planning or school organization. The study emphasizes that there is a real need for digital platforms for continuous collaboration and the model can be replicated in different educational contexts.
2. El Hamamsy et al. (2021a)	The symbiotic relationship between educational robotics and computer science in formal education	Quantitative Questionnaire administered twice, at 1-year intervals 350 primary school teachers Switzerland	Continuous professional development, curricular reform through the introduction of robotics courses in the computer science curriculum	Evaluation of the impact of introducing educational robotics classes following the implementation of the curricular reform, from the practitioners' perspective Covering gaps in the study of continuous professional development programs by evaluating the adoption of robotics activities proposed by teachers and correlating it with their perception of the same activities, from the researchers' perspective	The analysis focused on two main questions: (1) How much can the integration of educational robotics (ER) help teach computer science in primary schools? and (2) What factors affect teachers' views and use of ER? The results show a significant increase in the time spent on ER activities, especially unplugged ones (RU). This happened even though there were more unplugged computer activities (CSU) in the program. Teachers found RU to be more accessible and adjustable, despite their technical complexity. Adoption was not related to age, gender, or previous experience, which suggests that ER can be integrated fairly. The positive views on ER have grown even among teachers with no prior experience. Preferences did not show a lack of seriousness. The variety of activities (RU and CSU) seems crucial for the ongoing integration, and support in the curriculum along with continuous training are key factors for the successful adoption of ER.

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Main focus: Teacher training and professional development programs					
3. Killen et al. (2023)	Teacher Education to Integrate Computational Thinking into Elementary Science: A Design-Based Research Study	Qualitative 3 training/professional development sessions over a period of 3 years, followed by field observations regarding the implementation of curricular changes Iteration 1 - 52 students, 38 teachers and students; Iteration 2 - 63 students, 47 teachers and students; Iteration 3 - 22 students USA	Cognitive-Affective Model of Conceptual Change (CAMCC); Theory of Communities of Practice	Analyzing how a professional training program in the field of algorithmic thinking education, consisting of classroom instruction for trainee teachers (students) and collaborative professional learning over several months for active teachers, can support teachers in successfully integrating algorithmic thinking into the teaching of basic science concepts	Analyzing how a professional training program in the field of algorithmic thinking education, consisting of classroom instruction for trainee teachers (students) and collaborative professional learning over several months for active teachers, can support teachers in successfully integrating algorithmic thinking into the teaching of basic science concepts.
4. Sherwood et al. (2024)	Teacher Practices for Formatively Assessing Computational Thinking with Early Elementary Learners	Mixed research: interviews and questionnaire 22 teachers USA	Cognitive constructivism - development of computational/algorithmic thinking; Teaching strategies; Teacher Training and Professional Development	Analyzing how different types of professional development resources could be best used to support preschool and primary school teachers (up to second grade) in learning about computational thinking, integrating it into their regular curricular content, and assessing their students' ability to use computational thinking skills to support their problem-solving efforts	Taking into account the increased interest in developing algorithmic thinking in primary school students, the authors analyzed the effects of applying teaching strategies for developing algorithmic thinking on students' problem-solving skills. Teachers received continuous professional training to apply specific strategies for developing students' algorithmic thinking in their teaching practice. The analysis of the results revealed that, although there were no significant changes in teaching activities, teachers showed curiosity about the new practices applied and confidence in their students' abilities. Although there were no significant changes in assessment practices, teachers adapted existing approaches to recognize new problem-solving strategies.

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Main focus: Teacher training and professional development programs					
5. Čepić & Pejic Papak (2021)	Challenges of Curriculum Planning and Achieving Learning Outcomes: A Case Study of Croatian Elementary School Teachers' Experiences	Qualitative Case study 23 teachers Croatia	Constructivism	Analysis of the experiences of first, fifth, and seventh-grade teachers in competency-oriented learning in a primary school included in the implementation of the experimental curriculum reform program in Croatia.	The discussions highlight the challenges of curriculum planning, including the effort required for the new annual programs and the extensive administrative requirements. However, teachers appreciate the increased autonomy in choosing teaching methods and materials, as well as the emphasis on interdisciplinary correlations. Regarding the application of methods, teachers widely use collaborative activities, discovery learning, problem-solving, and digital tools such as PowerPoint presentations and online platforms. A positive attitude toward technology is observed, but there is also a need for additional training and issues related to digital infrastructure (e.g., poor internet connection). Regarding the achievement of learning outcomes, most teachers have managed to meet them, but some face difficulties due to the emotional immaturity of first-grade students, the incorrect assessment of the time needed, and the large number of students with diverse abilities in the class.
6. Callaghan et al. (2018)	How teachers integrate a math computer game: Professional development use, teaching practices, and student achievement	12 teachers interviewed, 863 teachers responding to the questionnaire 10,715 students USA	Professional development of teaching staff, the effectiveness of pedagogical practices in supporting student learning	Analysis of how primary school teachers use professional development resources and the characteristics of computer games to assist in the integration of games, and identify how self-reported teaching practices are associated with students' math achievement scores.	This study shows the importance of ongoing communication between trainers and teachers after completing continuous professional development modules. Even though teachers attended a series of modules and learned new methods, they need support and specific examples for integrating new teaching methods into their current practice, along with feedback on their performance. Reviewing course videos or recording game objectives to match lessons led to important improvements in students' outcomes. The efficiency in the implementation of these new practices is influenced by organizational culture or teacher collaboration. The conclusions stress the importance of continuous professional training focused on teachers' actual needs, communication between the trainer and the teachers after the completing of a course and combining technical skills with teaching development.
Main focus: Didactic innovations and the integration of digital technology (including emerging technologies) into pedagogical practices					
1. Bănuț & Albulescu (2024)	Technology-Enhanced Thinking Scaffolding in Musical Education	Quantitative 24 weekly musical programming activities using the Sonic Pi program 87 subjects, 11 years old, Romania	Using technology as a support in learning - Scaffolding	Analyzing how the introduction of digital technology through programming activities using the Sonic Pi program supports the cognitive process in delivering music education for fourth-grade students in mainstream education in Romania	The authors analyze the effects of using the Sonic Pi application in the process of learning music theory for fourth-grade students. The integration of music and programming has led to substantial acquisitions of musical knowledge. The post-test results indicate a significant improvement in students' ability to understand and memorize musical notes compared to the pre-test. The conclusion of the study emphasizes that digital technologies, used as "scaffolding" support, can stimulate both basic cognitive processes (memorization, understanding) and creativity, becoming an effective tool in music education in modern days.

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Main focus: Didactic innovations and the integration of digital technology (including emerging technologies) into pedagogical practices					
2. Rogne et al. (2024)	Effects of digitalisation on learning to write – A naturalistic experiment	Experimental Experiment on multimodal writing ability (dictation and transcription) using paper/pencil and digital devices/keyboard 557 first-grade students, 6 years old Norway	Cognitive model of writing as a process (interactions between motor and cognitive components)	Investigating the development of writing skills for first grade students under the influence of technology, integrated in different degrees Analyzing the handwriting legibility, spelling and narrative text composition quality on paper and digital writing in dictation and transcription	The results indicate that students who wrote more on digital devices had poorer legibility in handwriting, but produced longer texts with more correctly written words on digital devices. There were no observed difference in performance between the groups in dictation. The study confirms that performance in a specific writing experience improves performance in that mode. The conclusion is that both handwriting and digital writing offer distinct benefits and each method must be used in a balanced way, according to the purpose of the activity and students' needs.
3. Hsu et al. (2019)	Developing Elementary Students' Digital Literacy Through Augmented Reality Creation: Insights From a Longitudinal Analysis of Questionnaires, Interviews, and Projects	Mixed method Case study - Instructional program, preceded and followed by student questionnaires, teacher interviews, classroom observations, and evaluation of student activities (RA artifacts) 32 students, aged 11 (N = 24) and 12 (N = 8), Taiwan	Constructivism, spiral curriculum, experiential learning	Investigating how primary school students develop their digital literacy skills through a pedagogical approach that combines experiential learning and spiral curriculum, by creating artifacts in augmented reality	The discussion and conclusions of the research highlight the effectiveness of a pedagogical approach that combines situated and spiral learning to develop digital literacy (DL) among primary school students through the creation of augmented reality (AR) artifacts. Students recorded significant improvements in five areas of DL: information management, collaboration, communication and sharing, creation, evaluation, and problem-solving. The only area without significant progress was ethics and responsibility, due to limited practice opportunities. The study recommends integrating emerging technologies into educational projects and personalizing instruction based on students' initial levels, while also suggesting the need to explore additional tools and practices to develop digital responsibility.

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Main focus: Didactic innorations and the integration of digital technology (including emerging technologies) into pedagogical practices					
4. Searle et al. (2023)	Affordances and limitations of teachers instructional styles when teaching computer science and computational thinking	Qualitative Classroom observations, filming instructional sequences, transcribing and analyzing teacher discourse 4 teachers USA	5E instructional model: engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2009)	Investigating differences in instructional approaches to teaching algorithmic thinking/computer science and the type of discourse accompanying these instructional approaches	Using observations in primary education classrooms, the authors identified three main instructional approaches: direct instruction, discovery learning, and modeling/scaffolding. The first approach, direct instruction, is effective for teaching content, but can reduce algorithmic thinking to a series of steps and can limit students' involvement in resolving problems or expressing their creativity. The second approach, discovery learning, offers students more freedom and stimulates creativity, but is more time consuming and without a solid conceptual foundation, can lead to slow progress. The third one, modeling/scaffolding, has proven most effective, combining demonstration with individualized support in learning. The results indicate that teachers' professional development programs should focus more on preparing them for integrating algorithmic thinking in their teaching practices.
5. Bratland et al. (2022)	Technology and knowledge. In what way are knowledge and teachers' knowledge practices in subject areas crucial for the integration of technology in education?	Quantitative Questionnaire on the use of technology in teaching core subjects 152 mathematics and Norwegian language teachers; Norway	Social and realist framework (Maton & Moore, 2010) and Karl Maton's Legitimation Code Theory [LCT] (Maton, 2014, 2016)	Investigating the influence of different forms of existing knowledge in the subjects and practices of teachers on the degree of technology integration in schools	The study reveals that Norwegian teachers integrate technology different, depending on the subject they teach. Language teachers use it more frequently than mathematics teachers. This difference is explained by the significant aspects that are emphasized depending on discipline. In the exact sciences, the emphasis is on specialized knowledge, while in the Mother Tongue, the student's qualities and relevant experiences are highlighted. The conclusions indicate that the success of integrating technology in education depends on the specific forms of knowledge of the disciplines and the teaching practices of teachers.
6. Area-Moreira et al. (2016)	Models of educational integration of ICTs in the classroom	Quantitative Questionnaire 3164 subjects Spain	Digital skills, Technology Acceptance Model, TPACK, educational technologies	Identification of educational patterns or trends in the use of ICT, correlating with the frequency and type of educational assignment in which they are involved Identifying a possible relationship between the teaching models used in ICT education and the teachers personal and professional profile	The discussions show two different models of ICT integration: one in which teachers with high digital competence and a significant professional experience demonstrate an effective integration of ICT in teaching practices, and one in which the teachers have lower digital competences or perceive themselves less digital competence, thus showing a "weak integration teaching model". The results suggest that the effective integration of ICTs does not depend only on the availability of resources, but also on the digital competence of the teachers and their confidence in using technology for pedagogical purposes.

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Main focus: Didactic innovations and the integration of digital technology (including emerging technologies) into pedagogical practices					
7. Arruda & Kerres (2024)	Education Practices Mediated by Digital Technologies: Mobilization and Teachers' Strategies in Primary and Secondary Schools in Germany	Mixed research: document analysis and questionnaire 166 respondents Germany	DigComp 2.2.; digital competencies; culturally adapted teaching practices	Understanding teachers' motivation for integrating digital technologies into daily teaching practice	The study highlights an increase in German teachers' awareness of the importance of digital technologies in education and alignment with public policies such as the "DigitalPakt Schule". Although the potential of technology in education is well understood and teachers are using teaching practices that involve them, there are still particular challenges regarding their effective integration due to gaps in continuous professional development and in school infrastructure. It also underlines the need that digital education must address all aspects of technology use (ethical, social, and cultural), not just the technical ones. The conclusions stress the need for real collaboration between teachers, policy makers, and the academic community, with a particular focus on teachers continuous professional development, to support inclusive and equitable digital education.
8. Alenezi & Alfaleh (2024)	Enhancing digital citizenship education in Saudi Arabian elementary schools: designing effective activities for curriculum integration	Mixed-method research: questionnaire and semi-structured interview 398 questionnaire respondents, 15 teachers interviewed Saudi Arabia	Reference frameworks: TPACK, UNESCO ISTE Digital Citizenship	Identifying the interaction between teachers' knowledge domains and the practical challenges they face, which could ultimately contribute to the development of effective strategies for improving the integration of digital citizenship education into the curriculum, through the comparative analysis of the variables offered by the two reference frameworks	This study focuses on how DCE is currently delivered in the primary school system in Saudi Arabia, identifying strengths and areas for improvement. There is considerable emphasis on the development of learners' digital emotional intelligence, demonstrating both the appropriate level of pedagogical knowledge and content knowledge needed to be implemented within this area. The main gaps of the research refers to student's "digital participation and action", along with "digital footprint and identity". In addition, schools with limited access to digital platforms face infrastructural barriers to embracing digital participation and identity, while those that utilize a more cautious approach to online participation experience a cultural barrier. The study also produced significant interaction effects among several demographic factors–age, gender, and years of experience–for teachers on select elements of DCE indicating that younger or certain-schooled teachers may have better success in incorporating these elements into their curriculum. The findings of this study highlight the importance of individualized teacher training focusing on both technology, teaching methods, and subject knowledge related to the gaps that have been identified through this research. In addition, when developing DCE strategies, it is important to find a balance between developing students' global digital competencies and respecting individual cultural norms.
9. Novak et al. (2024)	Efects of a Creativity-Enhan cement Intervention on Preservice Elementary Teachers' Creativity in Computing Education	Experimental design, with pre-test and post-test 76 teachers in training (students) USA	Curricular design in teachers beliefs regarding creativity	Examining the effects of an intervention for improving the creativity of future teachers (personal, procedural, regarding the product, Rhodes, 1961)	This research investigated the impact of a creativity development intervention in the computer science education of future teachers, relating to three dimensions of creativity: personal, process and product. Following the intervention, the Scratch+Creativity group recorded significant increases in personal and process creativity, especially in terms of "creative agency", confirming the effectiveness of creativity-focused training. The study highlights the importance of explicit training in creativity and design thinking in teacher training. Interventions of this type can increase the effectiveness of teaching computer science in primary education, reducing the reluctance and low self-efficacy of novice teachers towards the use of technology.

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Main focus: Didactic innovations and the integration of digital technology (including emerging technologies) into pedagogical practices					
10. Abedi (2024)	Tensions between technology integration practices of teachers and ICT in education policy expectations: implications for change in teacher knowledge, beliefs and teaching practices	Quantitative research Semi-structured interviews 20 teachers Ghana	Constructivism	Investigating pedagogical practices regarding technology integration in primary schools in Ghana Examining the role of technology in teachers' instructional practices and evaluating how ICT aligns with educational policies and the school curriculum	The research shows that teachers mainly use technology for lesson preparation and direct instruction, viewing it as a productivity tool for traditional, teacher-centered tasks. This approach goes against the goals of Ghana's ICT policies and curriculum, which promote constructivist methods and student-centered learning. The findings reveal a big gap between the goals of ICT policies and the actual practices of teachers in the classroom. Thus, changing teachers' knowledge, beliefs, and teaching methods is essential to close this gap and turn ICT policy plans into real educational practices.
11. Ramírez et al. (2023)	Powerful knowledge, transposition/transformation and ICT: an empirical study across school subjects in primary education	Mixed research: Case study and statistical analysis of variables 10 primary education teachers Spain	Curriculum development, teaching practices	Exploring activity models used for teaching various subjects in the primary education curriculum in Spain Identifying links between activity models and the incorporation of ICT and RED in the classroom, in real contexts	Answering the question regarding resource usage, the study shows that the choice between digital and analog resources varies depending on the nature of the subjects and the type of teaching activity. The question about the influence of content highlights that descriptive subjects (science) use ICT more frequently, while instrumental subjects (mathematics, language) resort to traditional resources. Regarding teaching activities, ICT is primarily integrated into the explanation and completion of tasks, but less so in evaluation. The results suggest the need for critical reflection on the reasons and impact of these pedagogical choices, depending on the specific nature of the disciplines.

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Main focus: STEM Education and Algorithmic thinking					
1. Vandenberg et al. (2020)	Elementary Students' Understanding of CS Terms	3 Qualitative Studies Interviews using the STEM attitudes questionnaire, with slight modifications to the original questionnaire questions Study 1 - 33 students, 9-11 years old; Study 2 - 31 students, ages 9-11; Study 3 - 32 students, 9-11 years old USA	Cognitive development stages according to Piaget; students' perceptions and attitudes toward technology and computer science.	Evaluation and understanding of primary school students' perceptions, knowledge, and attitudes toward basic terms and concepts in CS and computing Adapting and validating assessment tools to measure the students level of understanding and perception regarding CS topics Identifying their difficulties and misconceptions in order to base effective educational interventions in the field	In the first study, researchers observed difficulties in the clear interpretation of questions by students, highlighting the need to reformulate items to increase the validity of interpretations. In the second study, the authors analyzed how students understand and respond to questions related to CS terms, encountering difficulties in explaining concepts such as programming and debugging. The conclusion showed that the language must be adapted to the students age, so there will be less cases of misunderstanding of the terms. Also, this adaptation, according to their cognitive level development, would result in an open attitude and more interest toward CS.
2. Novak et al. (2024). Effects of a Creativity-Enhancement Intervention on Preservice Elementary Teachers' Creativity in Computing Education					
3. Bănuț & Albulescu (2024). Technology-Enhanced Thinking Scaffolding in Musical Education					
4. Pflaumer et al. (2021)	Appropriation of adaptive literacy games into the German elementary school classroom	Qualitative Semi-formal interviews 21 teachers Germany	TPACK	Exploring how teachers adopt the iRead learning technology in their teaching in German primary schools to effectively support the acquisition of new knowledge	The study, based on interviewing 21 teachers from 9 schools, identified several common obstacles in integrating technology in the educational process: the technology itself, teachers' digital literacy, and the understanding of the pedagogical use of adaptive learning games. Discussions revealed four types of teachers, "personas", based on their digital competence and their views on the benefits of technology for the students: expert and sceptic, both with high digital competence, and willing and denier, both digitally not competent. Depending on their characteristics, teachers that are experts or willing are more open to integrate the game Navigo in their lessons to support students reading acquisitions, while the sceptic or the denier were less enthusiastic or open to integrating technology. The conclusions emphasize the need for technological support in schools and teacher training that includes digital skills and openness to independent learning pathways for students.

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Main focus: STEM Education and Algorithmic thinking					
5. El Hamamsy et al. (2021a). The symbiotic relationship between educational robotics and computer science in formal education					
Main focus: Digital equity and inclusive education					
1. Alcalá del Olmo-Fernández et al. (2024)	Pedagogical strategies with ICT in vulnerable educational contexts: Impact on the pandemic and future projections	Qualitative Structured interview 8 people, school counselors (3), institution directors (5) Spain	Digital education, digital equity, inclusive pedagogy	Exploring the ITC-mediated teaching practices in educational centers from Malaga (Spain) during the COVID-19 pandemic	Because of numerous difficulties that both teachers and students faced (lack of digital equipment, insufficient training of teaching staff, and challenges in involving families), many students developed "curricular gaps". In the post-confinement period, teachers used different methods (Flipped classroom, PBL) and adapted curriculum to support students in filling those gaps. As a result, teachers created and used more OER as part of the lesson planning. The conclusion indicates that one of the most important focus for the future is continuous teaching training in digital competencies. Other factors, like parental involvement and the proper equipping of centers for inclusive and equitable education, must be taken into consideration.
2. Bešić et al. (2025). Digital technology use in inclusive schools in four European countries: Within- and between-school differences					
3. Xie et al. (2023). Examining changes in teachers' perceptions of external and internal barriers in their integration of educational digital resources in K-12 classrooms					