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Exploring In-Service and Pre-Service Teacher Digital Competence in Secondary Education: A Review

*[1]Rizka Latifah, [2]Cucuk Wawan Budiyanto, [3]Dewi Anjarsari
[1]Department of Informatics, Universitas Sragen, Indonesia
[2]Department of Informatics Education, Universitas Sebelas Maret, Indonesia
[3]Department of Elementary Teacher Education, Universitas Sragen, Indonesia

Corresponding Email: rizka.latifah62@unissra.ac.id

Abstract:

Background: Digital transformation has accelerated the integration of technology in education, positioning teacher digital competency (TDC) as a critical determinant of school readiness in the digital age.
Purpose : To bridge the gap in existing literature that frequently evaluates pre-service and in-service educators separately, this systematic literature review aims to comprehensively map TDC in secondary education by examining its core characteristics, development initiatives, and discipline-specific applications.
Method: Following PRISMA 2020 guidelines, a systematic search of the Scopus database was conducted, selecting 20 empirical papers published between 2020 and 2025 for thematic synthesis.
Result: The synthesis revealed three core insights: (1) TDC extends beyond operational IT skills to encompass pedagogical implementation, teacher willingness, and social impact; (2) competency development relies heavily on teacher training, institutional school support, and proactive university curricula; and (3) practical applications are currently concentrated in STEM courses, with growing needs in non-STEM disciplines.
Conclusion: Teacher education programs must systematically embed digital pedagogy into their curricula to align educator readiness with real-world secondary school demands. Despite methodological limitations from relying on a single database, this study provides a foundational roadmap for future mixed-methods research.

Keywords: *Digital Transformation, Secondary Education, Systematic Literature Review, Teacher Digital Competence*

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Introduction

The recent shift from conventional to online learning marks a digital transformation in education. This transformation has created a new paradigm for students, educators, and the community to adopt technology in teaching, learning, and administration (Antonopoulou et al., 2025). It has also catalyzed the integration of digital technology into the classroom and school curriculum (Karakose et al., 2021) and underscored the importance of technology in teaching and learning (Wong et al., 2025). Digital transformation in schools can also create personalized learning experiences tailored to student needs, foster interest and motivation, and develop creative thinking skills (Mohamed Hashim et al., 2022).

Digital transformation raises concerns for secondary schools. The secondary education system is crucial for students to determine their future (Yuliandari et al., 2023). Digital transformation has led students to be concerned about the accuracy of information disseminated online. The rise of hoaxes makes it difficult for them to filter information. Here, teachers play a crucial role in schools' digital transformation. This role becomes even more critical in informatics education, where teachers must not only utilize digital tools but also cultivate algorithmic thinking and digital literacy. As educators, teachers not only teach knowledge and skills, but also help students clarify information obtained online. The role of teachers is essential in determining how students respond to digital transformation (Szymkowiak et al., 2021).

In previous research, Budiyanto et al. (2024) found that to prepare for digital transformation, teachers must focus on data security, manage digital platforms, and adopt relevant learning strategies. These three things lead to teacher digital competence. Teacher Digital Competence (TDC) is more than just the ability to use digital technology in learning, but also emphasizes the concept of selecting digital resources to facilitate learning (Falloon, 2020; Pongsakdi et al., 2021).

However, not all teachers have the digital competencies to support digital transformation (Antonopoulou et al., 2025; Dolezal et al., 2025). Amhag et al. (2019) stated that teachers require extensive knowledge to develop digital learning media. Block (2018) also noted that the time required to become more familiar with digital technology is very long. A lack of digital competencies prevents teachers from teaching their subjects efficiently (García-Vandewalle García et al., 2023). As a result, digital transformation in schools will be hampered if teachers lack adequate digital competencies.

Although several literature reviews have examined TDC, most studies have focused either solely on theoretical frameworks (Basantes-Andrade et al., 2022; de los Ángeles Domínguez-González et al., 2025; Smestad et al., 2023) or on treating pre-service and in-service teachers as separate groups. Consequently, the current literature lacks a comprehensive synthesis tracing the continuity of TDC development from initial teacher training through to continuous professional development, particularly in secondary education.

To address this gap, this review maps the TDC landscape across three dimensions: core characteristics, current development initiatives, and specific instructional activities. By analyzing both pre-service and in-service domains, this study provides curriculum designers and educational stakeholders with empirical insights to better align teacher education program preparation with real-world requirements in secondary schools. Furthermore, this study contributes to informatics education by providing a clearer framework for integrating computing skills and digital pedagogy into the curriculum, ensuring that both pre-service and in-service teachers can effectively cultivate students' technological capabilities. These objectives are addressed through three research questions (RQs):

RQ 1. What are the defining characteristics of teacher digital competence according to the existing literature?

RQ 2. What initiatives and practices have been implemented to promote and develop teachers' digital competence?

RQ 3. What courses and activities focus on leveraging teachers' digital competence?

Research Method

This study adopted a Systematic Literature Review (SLR) framework following the PRISMA 2020 statement guidelines (Page et al., 2021)to ensure transparency and replicability. The thematic synthesis was conducted using an inductive thematic approach (Braun & Clarke, 2006). No review protocol was formally registered for this study, which is acknowledged as a methodological limitation.

Search Strategy and Database Justification

The literature search was executed in June 2025 utilizing the Scopus database. Sole reliance on Scopus is justified because it is high-impact, peer-reviewed international indexing, particularly in informatics and educational technology research (de los Ángeles Domínguez-González et al., 2025). This boundary ensures the exclusion of predatory literature and maintains a high baseline of methodological quality. The search string applied was: The keywords were (TITLE-ABS-KEY (“teacher digital competence”) AND TITLE-ABS-KEY (“secondary education”)).

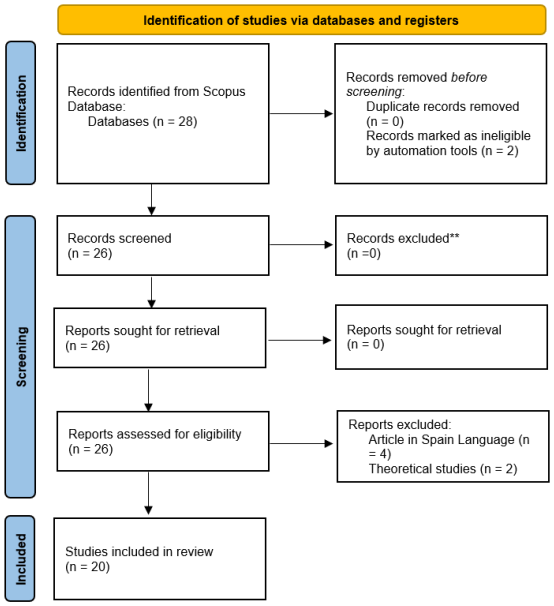

Figure 1. PRISMA Flowchart of the article selection

Inclusion and Exclusion Criteria

To be eligible for review, documents had to meet strict criteria: (1) published between 2019 and June 2025, (2) written in the English language, (3) published in peer-reviewed open-access journals, and (4) employed empirical qualitative, quantitative, or mixed-methods designs. Studies were excluded if they focused on primary or higher education, were published in non-English languages, or were non-empirical (e.g., editorial notes, pure theoretical essays, or book reviews).

Screening and Quality Appraisal

As illustrated in the PRISMA flowchart (Figure 1), the initial search retrieved 28 records. Automation tools removed 2 ineligible records, leaving 26 articles for title and abstract screening. During this screening phase, all 26 articles advanced to the full-text eligibility assessment stage. Upon full-text evaluation, 6 articles were excluded (4 were in Spanish, and 2 were purely theoretical studies). The remaining 20 reports were sought and successfully retrieved for full-text eligibility assessment. No further articles were excluded during the full-text evaluation, resulting in a final sample of 20 empirical articles. To ensure quality appraisal, each selected article was systematically evaluated using a structured framework adapted from the Mixed Methods Appraisal Tool (MMAT) (Khammatova et al., 2021) and the Joanna Briggs Institute (JBI) guidelines (Hilton, 2024). This appraisal was conducted to verify the clarity of the research objectives, the integrity of the data collection methods, and the robustness of the data analysis, as summarized in Table 1. All 20 selected empirical studies met the criteria adapted from MMAT and JBI guidelines, demonstrating clear research targets, methodological integration, and well-supported conclusions.

Table 1. Summary Quality Appraisal

Appraisal Criteria	Number of Studied Meeting Criteria	Percentage
Q1: Clearly defined or explicitly stated research objectives/aims	20	100%
Q2: Appropriate research design and methodology	20	100%
Q3: Transparent sampling strategy and participant selection	20	100%
Q4: Robust data collection tools and data analysis procedures	20	100%
Q5: Justified conclusions aligned with presented findings	20	100%

Overall Quality Grade: High Quality
(Score 5 / 5)

Data Extraction and Synthesis

The 20 included articles underwent a six-phase inductive thematic analysis (Braun & Clarke, 2006). First, the authors familiarized themselves with the datasets by reading the abstracts and full texts. Second, initial codes were generated for statements relating to teacher characteristics, digital initiatives, and classroom activities. Third, these codes were clustered into potential broader themes. Fourth, the themes were reviewed against the entire dataset to ensure consistency. Fifth, the final themes were defined and named (resulting in the thematic structures presented in Tables 2, 3, 4, and 5). Sixth, the final narrative synthesis linked the themes back to the overarching research questions.

State of the Art in the Last Five Years

Chronologically, the publication trend within the selected dataset spans from 2020 to 2025, with a notable peak in 2023 (n=8). The preceding years, 2020, 2021, and 2022, contributed 2 articles each, followed by a resurgence in 2024 (n=5) and a single contribution in 2025 (n=1). The publication-year graph is shown in Figure 2. Methodologically, the literature relies heavily on quantitative approaches (n=15), followed by mixed-methods (n =3) and qualitative designs (n=2). In terms of sample demographics, the reviewed studies predominantly examine practicing in-service teachers rather than pre-service educators, resulting in a 3:1 ratio favoring in-service secondary school settings. This demographic and methodological distribution indicates that, while the global literature is highly robust in quantitatively measuring existing teacher capabilities, there remains an urgent need for more qualitative and mixed-methods explorations that capture the nuanced, longitudinal development of pre-service teachers' digital readiness.

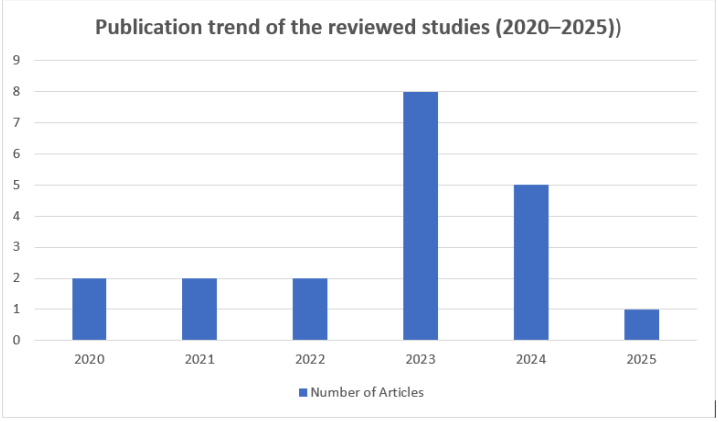

Figure 2. Publication trend of the reviewed studies (2020–2025)

Beyond methodological trends, this review maps the structural frameworks used throughout the literature to conceptualize teachers' digital competence. The frameworks deployed are considerably varied, including Digital Competence for Educators (DigCompEdu), TPACK, INTEF, the Chinese theoretical framework, SAMR, COMDID-A, and other TDC-specific scales and models. Among these, the DigCompEdu framework (Redecker, 2017) emerges as the most widely adopted paradigm, serving as the foundational baseline in more than half of the reviewed datasets (n=8). This widespread reliance on DigCompEdu highlights a standardized, European-led consensus in current research for evaluating multi-dimensional digital competencies in secondary education.

Result and Discussion

This section presents the empirical findings from the systematic review, structured to address the research questions. The presentation begins with a descriptive profile of the 20 selected studies, as detailed in Table 2, followed by a thematic synthesis of the literature.

Overview of Included Studies

This section presents a systematic overview of the mapping of 20 empirical studies selected for the final synthesis. To provide a detailed description of these studies, a comprehensive data extraction matrix outlining the specific context, methodology, targeted teacher groups, and structural framework of each selected paper is presented in Table 2.

Table 2. Overview of Included Studies

Authors	Country	Teacher Group	Sample	Method	Framework	Subject Area
(Dias-Trindade et al., 2021)	Portugal	In-Service	434	Quantitative	self-assessment scale of teachers' digital competences prepared by the EU Science Hub	Social and Human Sciences; Expressions; Languages; Mathematics and Experimental Sciences
(Galindo-Domínguez et al., 2024)	Spain	In-Service	445	Quantitative	The Scale to Measure Teachers' Digital Competence	Natural Sciences, Biology, Physics, Chemistry; Social Sciences, Geography, History; Mathematics; Languages; Technology; Physical Education; Visual and Audiovisual Arts Education; Religion and Ethical Values.
(Moreno et al., 2020)	Spain	In-Service	50	Quantitative	INTEF Common Framework for the Teachers' Digital Competence	Mathematics
(Berková et al., 2024)	Czech Republic	In-Service	147	Quantitative	DigCompEdu	Economic
(Dolezal et al., 2025)	Central-Europe	Pre-Service	322	Mix Method	DigCompEdu	STEM
(Ortega-Sánchez et al., 2020)	Spain and France	Pre-Service	428	Quantitative	INTEF and DigComEdu	not specifically described
(Gómez-Trigueros et al., 2021)	Spain	Pre-Service	428	Quantitative	Other TDC-Specific Scales and Models	not specifically described
(Yang et al., 2022)	China	Pre-Service and In-Service	498	Quantitative	Chinese theoretical framework "Information Technology Application Ability Standards for Primary and Secondary School Teachers	not specifically described
(Mosquera-Gende, 2024)	Spain	Pre-Service	78	Mix Method	Other TDC-Specific Scales and Models	English Languages
(Madsen et al., 2023)	Norway, Slovenia, Portugal, Poland, Turkey, Ukraine, England and Jordan	Pre-Service	772	Quantitative	Teachers' professional digital competence framework	not specifically described
(Seabra et al., 2023)	Portugal	In-Service	329	Mix Method	DigCompEdu	not specifically described

Table 2. Overview of Included Studies

Authors	Country	Teacher Group	Sample	Method	Framework	Subject Area
(Verdú-Pina et al., 2023)	Italia	In-Service	166	Quantitative	DigCompEdu	not specifically described
(Palacios-Rodríguez et al., 2023)	Spain	In-Service	78,966	Quantitative	DigCompEdu	not specifically described
(González-Pérez & Marrero, 2023)	Spain	In-Service	31	Quantitative	Other TDC-Specific Scales and Models	STEM
(Gilje, 2024)	Sweden	In-Service	54	Qualitative	TPACK and SAMR	STEM
(Tzafilkou et al., 2023)	Greece	In-Service	845	Quantitative	Other TDC-Specific Scales and Models	STEM
(Dias-Trindade & Moreira, 2023)	Spain	In-Service	500	Qualitative	Other TDC-Specific Scales and Models	STEM
(Verdú-Pina et al., 2024)	Spain	In-Service	256	Quantitative	COMDID-A	not specifically described
(García-Delgado et al., 2023)	Spain	In-Service	150	Quantitative	DigComEdu	not specifically described
(Rahimi & Tafazoli, 2022)	Iran	Pre-Service and In-Service	350	Quantitative	DigComEdu	English Languages

RQ1. What are the defining characteristics of teacher digital competence according to the existing literature?

Based on a systematic analysis of the selected literature, three primary themes emerged as defining characteristics of teacher digital competence (TDC), summarized in Table 3. These themes include teachers' willingness to use digital technology, educational activities conducted through digital media, and the promotion of societal transformation. Among these, the integration of educational activities through digital media represents the most frequently discussed characteristic in current research

In the digital era, digital competence is a fundamental skill for all teachers. Teachers are willing to use digital technology. This characteristic highlights a teacher's response to technology. Dias-Trindade et al. (2021) state that teacher digital competence reflects teachers' feelings when implementing digital technology in learning. Teachers respond positively to digital technology because it can increase student motivation and develop students' ability to adapt to social life (Madsen et al., 2023).

Table 3. Characteristics of Teacher Digital Competence

Themes	Number of Articles
Willingness to use digital technology	2
Educational activities through digital media	14
Promote the transformation of society	4

Educational activities through digital media require digital teacher competencies that connect technology with pedagogy (Galindo-Domínguez et al., 2024). This aspect focuses on the practical application of digital competencies, specifically how teachers design, implement, and facilitate learning experiences using various platforms, tools, and digital content. The literature highlights that teacher digital competence (TDC) manifests across multiple operational layers. At an individual level, higher competence directly increases teachers' awareness and personal utilization of ICT tools (Dolezal et al., 2025; Seabra et al., 2023). Beyond personal use, these capabilities are structurally required to successfully integrate pedagogical technology into the school curriculum (Berková et al., 2024; Rahimi & Tafazoli, 2022; Trindade & Moreira, 2023; Verdú-Pina et al., 2024).Ultimately, this competence extends into

practical problem-solving, entailing the capacity to strategically use digital technology to address various pedagogical problems in the classroom (García-Delgado et al., 2023; Ortega-Sánchez et al., 2020; Palacios-Rodríguez et al., 2023; Pérez & Galván, 2023; Yang et al., 2022).

Promoting the transformation of society emphasizes the teacher's role in using technology for instruction and fostering digital citizenship, critical thinking, and innovation among students (Moreno et al., 2020; Pérez & Galván, 2023). The more competent a teacher is, the more skilled they are at imparting knowledge to students. A high level of digital competence can help teachers guide their students in developing their digital skills (Verdú-Pina et al., 2023) and promote societal transformation (Gómez-Trigueros et al., 2021). Teachers' digital competence is a powerful tool for future educators to foster engagement and active learning within their university programs (Mosquera Gende, 2024). Ultimately, understanding these three core characteristics provides a foundational framework for evaluating how pre-service preparation and in-service professional training in secondary education can be systematically structured.

A critical interpretation of this literature review reveals that the focus of teacher digital competence is on educational activities through digital media, as well as knowledge of *digital pedagogy*. The large number of articles on the implementation of *digital pedagogy* (n=14) compared with those on *teacher willingness* (n=2) indicates that the literature prioritizes operational implementation over educators' psychological readiness. This finding implies that while frameworks focus heavily on how teachers use tools in the classroom, they often overlook the underlying motivations and technological pressures educators face. Digital pedagogy cannot be treated solely as a set of technical tasks; it must encompass a balanced approach that cultivates teachers' psychological willingness and pedagogical capabilities to deliver technology-enhanced learning.

RQ 2. What initiatives and practices have been implemented to promote and develop teacher digital competence?

As presented in Table 4, the systematic review identified five core initiatives and practices implemented to promote and develop teacher digital competence (TDC). These include *training teachers*, *developing educational resources*, *providing school support*, *raising teacher awareness*, and *offering university courses*. Among these practices, *professional training for teachers* emerged as the most widely implemented initiative in the literature

Developing TDC extends beyond basic technology usage to encompass curriculum integration, a process effectively facilitated through structured teacher training (Dias-Trindade et al., 2021; Madsen et al., 2023). This training serves a critical role in narrowing the digital divide between educators and students (Moreno et al., 2020) by covering practical tools such as software, learning applications, presentation tools, and online platforms. To ensure maximal efficacy, the literature underscores that such professional development must prioritize pedagogical application, focusing on competencies directly linked to educational practices rather than isolated, general technical skills (Seabra et al., 2023).

Table 4. Initiatives and practices have been implemented to promote and develop teacher digital competence

Themes	Number of Articles
Training Teacher	17
Educational Resource	5
School Support	6
Teacher Awareness	6
University Courses	6

To maximize effectiveness, the growth of TDC is heavily reliant on the availability of adequate educational resources, which enable teachers to refine their use of instructional technology. For instance, these resources enable the integration of advanced tools, such as Artificial Intelligence, for tasks such as text generation, digital image creation, and automated assignment feedback (Galindo-Domínguez et al., 2024). Furthermore, advanced digital competence empowers educators to become active creators of diverse digital content rather than passive consumers (Gilje, 2024; Moreno et al., 2020), with literature indicating a direct positive correlation between a teacher's competence level and the quality of the content they produce (García-Delgado et al., 2023).

At the institutional level, schools serve as vital role in fostering teachers' digital competence. This institutional support manifests structurally through the establishment of administrative regulations and encourages technology

integration in classrooms (Dias-Trindade et al., 2021). Beyond regulatory frameworks, schools actively manage instructional processes, allocate financial resources, and cultivate a supportive digital ecosystem for both educators and learners (Berková et al., 2024), while simultaneously hosting targeted training initiatives to continuously upgrade teacher skills (Ortega-Sánchez et al., 2020).

Cultivating teacher awareness regarding the significance of digital literacy is important. Educators with high digital awareness demonstrate greater ease in adopting and using technology (Galindo-Domínguez et al., 2024; Seabra et al., 2023), particularly when navigating complex dimensions such as information ethics and data security (Yang et al., 2022). Ultimately, this heightened internal awareness translates into practical classroom benefits, significantly aiding teachers in effectively managing and orchestrating ICT-enhanced learning environments (Rahimi & Tafazoli, 2022).

Finally, higher education institutions bear the foundational responsibility of preparing future educators by embedding dedicated digital competency courses into their curricula (Madsen et al., 2023; Mosquera Gende, 2024; Pérez & Galván, 2023). These specialized modules are designed to bridge technical skills with fundamental educational theories (Dolezal et al., 2025; Tzafilkou et al., 2023). This alignment meets a critical demand among pre-service teachers, who prefer receiving career-ready digital preparation within their formal university programs rather than seeking external training later (Ortega-Sánchez et al., 2020), thereby ensuring a robust digital baseline prior to entering the professional workforce. In synthesis, these five initiatives cleanly map out the TDC development pipeline. While *university courses* explicitly build the digital foundation for pre-service teachers, initiatives such as *training teachers* and *school support* ensure the continuous professional growth of in-service teachers in secondary education.

These findings offer profound implications for the structural design of teacher education. The fact that *teacher training* for in-service educators is studied almost three times as often as *university courses* for pre-service teachers (17:6) suggests that university teacher education programs may not adequately equip pre-service secondary school teachers with advanced digital competencies, thereby shifting the burden of digital transformation onto professional development workshops later in their careers. To redress this imbalance, the teacher education framework must shift toward one in which advanced informatics skills, digital citizenship, and data security are deeply embedded in undergraduate curricula rather than treated as remedial training after graduation.

RQ 3. What courses and activities focus on using teachers' digital competence?

Analysis of the selected literature indicates that the deployment of teacher digital competence (TDC) is heavily prominent within STEM fields (Science, Technology, Engineering, and Mathematics). As synthesized in Table 2, digital learning media is an essential instructional tool for teaching STEM in face-to-face environments and e-learning platforms (Moreno et al., 2020). STEM educators frequently exhibit more positive attitudes toward digital adoption than non-STEM teachers (Galindo-Domínguez et al., 2024). Nevertheless, the literature emphasizes that TDC is increasingly vital in non-STEM domains within secondary education, such as languages, social sciences, arts, and literature. This cross-disciplinary distribution underscores that digital pedagogy is no longer confined to technical specializations but has become a baseline requirement for all instructional subject areas.

In terms of specific classroom activities, educators primarily use digital competence to navigate virtual learning environments, integrate technology into instructional strategies, and cultivate students' digital literacy. These activities are systematically mapped by their primary pedagogical focus in Table 5.

Table 5. Classroom activities using teachers' digital competence

Classroom Activities	Number of Articles
Integrate technology into instructional strategies	8
Navigating virtual learning environments	7
Cultivate students' digital literacy	5

Within virtual learning environments, teachers deploy Learning Management Systems (LMS)—such as Google Classroom, Edmodo, or Moodle—to manage classrooms, distribute materials, and streamline assessments (Palacios-Rodríguez et al., 2023; Pérez & Galván, 2023). Beyond administrative utility, the primary objective of TDC is the purposeful integration of technology into active teaching methodologies (Gilje, 2024). This integration serves a higher educational purpose: enabling teachers to facilitate and develop students' own digital competencies (Verdú-Pina et al., 2024; Verdú-Pina et al., 2023). Ultimately, a teacher's proficiency in digital pedagogy directly correlates with their capacity to effectively transfer modern informatics skills to secondary students.

Ultimately, the distribution of courses and activities in RQ3 yields direct implications for real-world secondary education practices. While the high concentration of digital competencies in STEM courses is expected, the emerging need for TDC in non-STEM fields (such as languages and social sciences) demonstrates that digital literacy is no longer a specialized technical skill, but a universal pedagogical requirement. In secondary school practice, this means that school administrators and policymakers must dismantle the misconception that informatics education is solely the responsibility of IT teachers. Creating sustainable digital learning environments requires cross-disciplinary integration, with non-STEM teachers also supported by specialized infrastructure and digital platforms to facilitate active learning and mitigate students' exposure to online misinformation.

Conclusion

This systematic literature review successfully maps the continuum of Teacher Digital Competence (TDC) by addressing three critical dimensions: its defining characteristics, current development initiatives, and specific instructional activities within secondary education. The synthesis provides clear answers to the stated research questions. First, TDC extends beyond mere technical proficiency; its core characteristics contain pedagogical application in digital media, teacher willingness, and a broader role in driving students to promote digital transformation. Second, developing these competencies requires a balance of initiatives, in which university courses lay the digital foundation for pre-service teachers, while teacher training and institutional school support sustain the growth of in-service educators. Finally, the instructional activities of TDC have been proven to be cross-disciplinary; while heavily embedded in STEM courses, digital competence has become an absolute necessity for non-STEM educators to implement effective learning strategies, manage digital platforms, and cultivate secondary students' digital literacy.

This study makes distinct contributions to the landscape of informatics education by providing stakeholders, curriculum designers, and school administrators with a unified blueprint for aligning university teacher preparation with real-world school requirements. The implications for practice demand that digital literacy no longer be treated as an isolated or optional skill. Universities must structurally embed digital pedagogy and information ethics directly into core teacher education programs. Concurrently, secondary school leaders must dismantle the misconception that digital transformation is solely the responsibility of IT teachers, ensuring that cross-disciplinary infrastructure and financial support are provided to establish a sustainable digital learning ecosystem.

Despite its insights, this systematic review possesses certain limitations that warrant consideration. By strictly confining the search strategy to a single database (Scopus) to maintain a high-quality baseline, relevant empirical datasets archived in other indexes (such as Web of Science, Springer, or ScienceDirect) may have been omitted. Furthermore, the inclusion of English-only and open-access literature means that valuable local-context insights published in non-English formats were not captured. Future research should address these boundaries by integrating multi-database searches and broadening the inclusion criteria to capture localized teacher training models. Additionally, given the heavy reliance on quantitative methods in the current literature, future studies should employ longitudinal mixed-methods designs to capture educators' readiness and evolving competencies over time.

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