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Technology, pedagogy, and project learning for digital competence

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ABSTRACT

This study synthesizes recent evidence on how technology integration, the technological pedagogical content knowledge (TPACK) framework, and project-based learning (PBL) contribute to the development of digital competence across basic, secondary, and higher education. A systematic review was conducted following preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. Searches in Scopus, ScienceDirect, and Semantic Scholar identified 1,035 records, of which 24 studies met the inclusion criteria and were analyzed through qualitative thematic synthesis. The findings were organized into three categories: digital competence development, active methodologies and TPACK, and educational innovation through virtual tools and environments. The review shows that digital competence should be understood as a multidimensional and pedagogically mediated construct rather than a purely technical outcome. Meaningful development of digital competence was consistently associated with teacher preparation, curricular coherence, ethical guidance, and student-centered learning designs. The evidence also indicates that TPACK-informed teaching and PBL can strengthen collaboration, problem solving, critical engagement, and pedagogically meaningful uses of digital tools. However, persistent barriers remain, particularly insufficient teacher training, uneven technology integration, and weak alignment between pedagogy, content, and digital resources. Overall, integrated pedagogical approaches appear to offer a promising pathway for strengthening digital competence across educational levels.

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1. INTRODUCTION

Digital transformation has profoundly reshaped educational systems by expanding access to information, enabling collaboration, and creating new possibilities for flexible, student-centered, and technology-rich learning. In recent years, this transformation has accelerated through the growing presence of digital platforms, virtual environments, and immersive tools that are increasingly used in both school and university contexts [1]–[3]. At the same time, international policy frameworks have reinforced the need to rethink educational systems considering digital change, emphasizing inclusion, equity, and the capacity of institutions to prepare learners for participation in digitally mediated societies [4]–[6].

In this context, digital technologies are no longer viewed only as supplementary resources, but as elements that can reshape curriculum, teaching, assessment, and participation. Within this broader transformation, digital competence has become a central educational priority. However, digital competence should not be reduced to the operational use of devices or platforms.

Rather, it involves a broader set of cognitive, communicative, ethical, and participatory capacities that enable students and teachers to engage critically and responsibly with digital environments [7]–[9]. This broader understanding is also consistent with international and regional frameworks that describe digital competence as a multidimensional construct involving information management, communication, content creation, problem solving, safety, and responsible participation [10]–[12]. Recent studies in higher education have further shown that digital skills are closely linked to collaborative attitudes and participation in technology-mediated learning environments, suggesting that digital competence also has an important social and relational dimension [13].

Although the educational value of digital competence is widely recognized, important challenges remain. The literature continues to report insufficient teacher preparation, uneven access to technological resources, limited pedagogical integration, and a persistent predominance of instrumental uses of technology in schools and universities [14]–[16]. These barriers are especially relevant because they suggest that the main problem is not merely the presence or absence of digital technologies, but the lack of coherent pedagogical designs that connect technology use with curricular goals, student needs, and meaningful forms of participation.

Recent research has also shown that the development of digital competence depends strongly on teachers' professional knowledge, beliefs, and ability to align technological tools with pedagogical and disciplinary purposes [17]–[19]. In addition, teacher-related factors such as technology-related teaching skills, coping mechanisms, and professional well-being may also influence the quality and sustainability of technology integration in educational settings [20]. Within this discussion, the technological pedagogical content knowledge (TPACK) framework provides a relevant conceptual basis for understanding how teachers integrate technological, pedagogical, and content knowledge in their practice [15], [21], [22].

TPACK is especially useful because it moves beyond technocentric approaches and emphasizes that effective technology integration depends on the coherence between instructional goals, disciplinary content, teaching strategies, and the choice of digital tools. More recent applications of the model have shown value for examining teachers' practices in specific curricular areas and for identifying the conditions under which technology becomes pedagogically meaningful rather than merely available [23], [24]. In this sense, TPACK offers not only a theoretical explanation of teacher knowledge, but also a practical lens for interpreting how digital competence can be developed through intentional teaching.

At the same time, project-based learning (PBL) has been widely recognized as an active methodology that promotes inquiry, collaboration, creativity, and problem solving through authentic tasks and contextualized learning experiences [25]–[27]. In educational settings, PBL can function as the pedagogical mechanism through which digital competence is enacted in practice, while TPACK offers the framework that helps teachers justify and organize those pedagogical and technological decisions. Previous studies have shown that when PBL is combined with technology-rich teaching, students can develop not only digital skills, but also scientific literacy, engagement, and collaborative capacities in more meaningful ways [28], [29]. From this perspective, the relationship between TPACK and PBL becomes especially relevant for explaining how digital competence may be fostered through active and student-centered pedagogies.

Despite the growing body of research on digital competence, technology integration, TPACK, and active methodologies, the literature remains fragmented in at least three ways. First, many studies examine digital competence as an outcome without sufficiently explaining the pedagogical conditions that support its development. Second, other studies focus on TPACK as a teacher-knowledge framework but do not clearly show how it translates into active methodologies such as PBL. Third, research on PBL often highlights engagement, collaboration, and authentic learning, yet does not always analyze how these experiences contribute specifically to the development of digital competence through intentional technology integration [16], [28], [29].

As a result, fewer studies explicitly explain how TPACK and PBL converge as complementary pathways for strengthening digital competence across educational levels. This gap is theoretically and practically relevant. From a theoretical perspective, there is a need for a more integrated understanding of how teacher knowledge, pedagogical design, and active learning environments interact in digitally mediated education. This need is increasingly urgent because educational systems are no longer expected only to provide access to digital tools, but also to demonstrate how technological integration can support meaningful, ethical, and pedagogically coherent learning. Without a clearer explanation of how TPACK and PBL interact, digital competence may continue to be promoted as a policy goal without sufficient pedagogical grounding.

From a practical perspective, educational institutions require clearer evidence on the conditions under which technology-rich and project-based approaches move beyond instrumental use and contribute to critical, ethical, and participatory forms of digital competence [30], [31]. In addition, recent work has suggested that meaningful advances in digital competence depend less on technology use itself than on intentional design, formative assessment, sustained teacher development, and the articulation of digital competence with broader professional knowledge frameworks such as PCK and TPACK [17], [32].

The novelty of this review lies in explicitly integrating digital competence, the TPACK framework, and PBL as interconnected dimensions of educational transformation, rather than examining them as separate lines of inquiry. Unlike previous studies that tend to focus on only one of these dimensions, this review offers a unified interpretation of how teacher knowledge, active pedagogy, and technology-rich learning environments converge to support digital competence across educational levels.

This review makes three main contributions. First, it offers a more integrated conceptual perspective on digital competence development by bringing together strands of literature that are often examined separately, namely technology integration, the TPACK framework, and PBL. In doing so, it clarifies how TPACK can be understood as a framework for teachers' pedagogical and technological decision-making, while PBL operates as an active pedagogical mechanism through which digital competence can be enacted in authentic learning contexts [15], [21], [28]. Second, this review identifies the main patterns, contributions, and persistent gaps in recent research, with particular attention to the conditions that strengthen or limit the pedagogical development of digital competence, such as teacher preparation, curricular alignment, and access to meaningful learning environments [16], [17], [29]. Third, the review provides an interpretive synthesis that is relevant for educational practice, as it helps explain under what conditions technology-rich and project-based approaches move beyond instrumental use and contribute to critical, ethical, and participatory forms of digital competence across educational levels [7], [9], [30].

Therefore, this study addresses that gap through a systematic review of the literature. The aim of this article is to synthesize scientific evidence on how technology integration, pedagogical approaches, and PBL contribute to the development of digital competence across basic, secondary, and higher education. More specifically, the review seeks to identify the main patterns, contributions, and gaps reported in recent studies and to clarify how TPACK and PBL can be understood as interconnected rather than isolated dimensions of digital competence development. Based on this purpose, the following research question guided the study: What patterns, contributions, and gaps emerge in the literature on technology integration, pedagogy, and PBL for the development of digital competence across educational levels?

2. METHOD

2.1. Review design

This study adopted a systematic literature review design to synthesize scientific evidence on how technology integration, pedagogical approaches, and PBL contribute to the development of digital competence across basic, secondary, and higher education. The review followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines to ensure transparency, rigor, and replicability in the processes of identification, screening, eligibility assessment, and final inclusion of studies [33], [34]. The review was structured as a qualitative thematic synthesis because the aim of the study was not to calculate effect sizes or to perform a meta-analysis, but to identify recurring patterns, major contributions, and research gaps in the literature related to digital competence, technology integration, TPACK, and PBL in educational contexts. This approach made it possible to examine how these dimensions have been addressed across different educational levels and to interpret their interrelationships from a broader analytical perspective. The methodological process included database searching, application of inclusion and exclusion criteria, record screening, full-text assessment, data extraction, quality appraisal, and thematic categorization of the selected studies. In this way, the review was designed not only to describe the available literature, but also to provide an interpretive synthesis of the main trends and limitations reported in recent research.

2.2. Data sources and search strategy

The literature search was conducted in three academic databases: Scopus, ScienceDirect, and Semantic Scholar. These sources were selected because of their broad coverage of peer-reviewed research in education, educational technology, interdisciplinary learning, and digital innovation. Their inclusion made it possible to retrieve studies addressing digital competence, technology integration, pedagogical frameworks, and active learning across different educational levels.

The search focused on studies published between 2019 and 2024 and written in English or Spanish. This time frame was established to prioritize recent evidence on the pedagogical use of digital technologies and the development of digital competence in contemporary educational settings. Only journal articles were considered during the search and filtering process. The search strategy was based on the descriptors digital competence, digital competencies, digital skills, virtual tools, digital tools, educational technology, TPACK, technological pedagogical content knowledge, project-based learning, and PBL. These terms were combined using Boolean operators such as AND and OR in order to refine the search and identify studies aligned with the objective of the review.

To improve transparency and reproducibility, the search syntax used in each database is reported:

- Scopus: (“digital competence” OR “digital competencies” OR “digital skills”) AND (“virtual tools” OR “digital tools” OR “educational technology”) AND (“TPACK” OR “technological pedagogical content knowledge”) AND (“project-based learning” OR “PBL”) AND (PUBYEAR > 2018 AND PUBYEAR < 2025) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (LANGUAGE, “English”) OR LIMIT-TO (LANGUAGE, “Spanish”))
- ScienceDirect: (“digital competence” OR “digital competencies” OR “digital skills”) AND (“virtual tools” OR “digital tools” OR “educational technology”) AND (“TPACK” OR “technological pedagogical content knowledge”) AND (“project-based learning” OR “PBL”)
- Semantic Scholar: (“digital competence” OR “digital competencies” OR “digital skills”) AND (“virtual tools” OR “digital tools” OR “educational technology”) AND (“TPACK” OR “technological pedagogical content knowledge”) AND (“project-based learning” OR “PBL”)

Additional filtering criteria were applied during the search and screening process in order to prioritize studies with direct relevance to the educational field and to exclude records that did not meet the predefined inclusion criteria.

2.3. Inclusion and exclusion criteria

The inclusion and exclusion criteria were defined to ensure the relevance, consistency, and academic quality of the studies selected for the review. Studies were included when they met all of the following conditions: i) they were peer-reviewed journal articles; ii) they were published between 2019 and 2024; iii) they were written in English or Spanish; iv) they addressed digital competence, digital tools, TPACK, PBL, or related pedagogical uses of technology; and v) they focused on educational contexts such as basic, secondary, or higher education.

Studies were excluded when they were not journal articles, were published outside the 2019–2024 period, were written in languages other than English or Spanish, did not correspond to the topic of the review, or lacked sufficient thematic relevance to the research objective. During database filtering, additional restrictions were applied to reduce unrelated records and prioritize academically relevant studies. Table 1 summarizes the inclusion and exclusion criteria applied during the screening and eligibility stages.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Publication type	Peer-reviewed academic journal articles	Publications other than journal articles
Publication period	Studies published between 2019 and 2024	Studies published outside the 2019–2024 period
Language	Articles written in English or Spanish	Articles written in languages other than English or Spanish
Thematic relevance	Studies addressing digital competence, digital tools, TPACK, PBL, or related pedagogical uses of technology in educational contexts	Studies not related to the research topic or not focused on educational contexts
Educational scope	Studies focused on basic, secondary, or higher education	Studies conducted outside the educational scope of the review
Database filtering	Studies retained after the application of database filters and screening criteria	Records excluded because of lack of relevance or mismatch with the inclusion criteria

2.4. Study selection process

The study selection process followed the PRISMA stages of identification, screening, eligibility, and inclusion [33], [34]. In the identification stage, the search across the three selected databases retrieved 1,035 records. These records were then filtered according to the predefined criteria related to publication period, language, document type, and thematic relevance.

In the screening stage, titles and abstracts were reviewed to verify their alignment with the purpose of the study. This process was conducted jointly by the two authors, who collaboratively examined the retrieved records and discussed their relevance in relation to the objective of the review. In the eligibility stage, full texts were examined to confirm their consistency with the inclusion criteria and their contribution to the research question. The full-text assessment was also carried out jointly by the two authors until consensus was reached regarding inclusion or exclusion. After this process, 24 studies were retained as the final units of analysis. Of these, 14 were retrieved from Scopus, 2 from ScienceDirect, and 8 from Semantic Scholar. These studies constituted the analytical corpus of the review and are summarized in the PRISMA flow diagram presented in Figure 1.

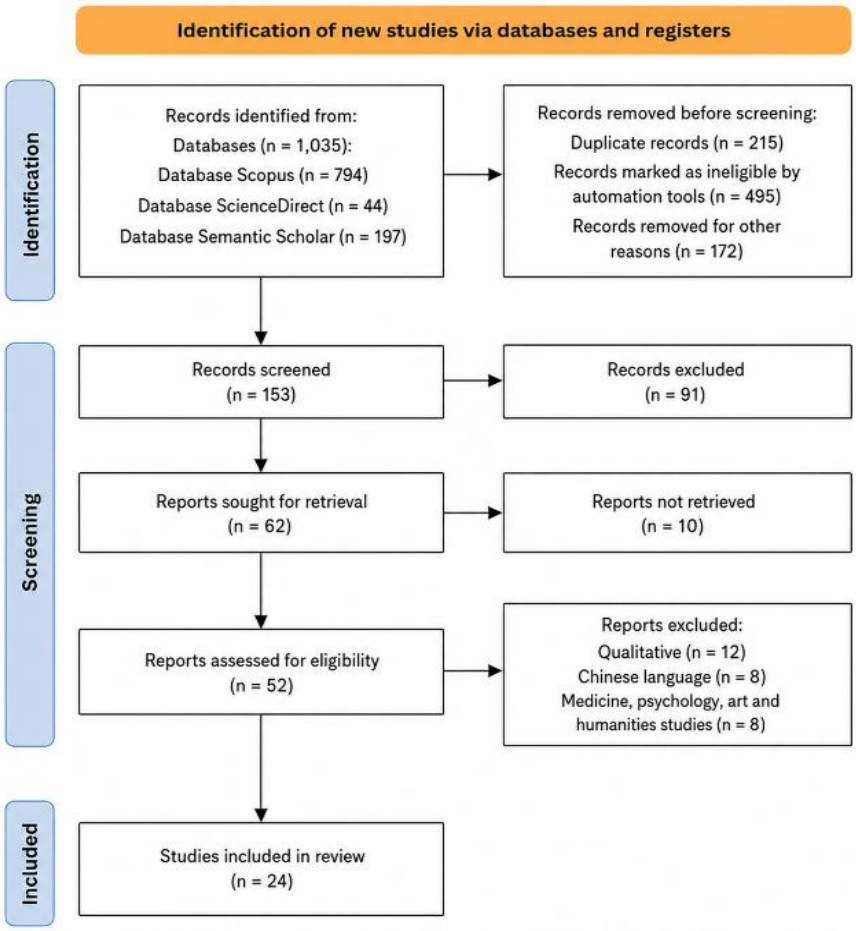


Figure 1. PRISMA flow diagram of the study selection process

2.5. Data extraction and coding

After the final selection of studies, a structured data extraction and coding process was conducted to ensure systematic comparison among the included articles. First, the titles and abstracts of the retained records were revisited to verify their consistency with the inclusion criteria and the objective of the review. Second, a full-text analysis was carried out in order to construct a data extraction matrix that enabled the organization and comparison of the selected studies.

The data extraction matrix included the following variables: author(s), year of publication, country or educational context, educational level, research design, theoretical or conceptual framework, type of technology or pedagogical approach addressed, main findings, reported limitations, and contribution to the relationship among digital competence, TPACK, and PBL. This procedure allowed the evidence to be organized systematically and supported consistency throughout the review process. After data extraction, the selected studies were coded and compared in order to identify recurring themes and conceptual relationships. The coding process focused on the way each study addressed digital competence, technology integration, TPACK, active methodologies, and digital or virtual tools. This analytical procedure provided the basis for the subsequent thematic synthesis and discussion of findings.

2.6. Data synthesis

The final stage of the review consisted of a qualitative thematic synthesis. After data extraction and comparison of the selected studies, recurring patterns, convergences, and conceptual relationships were identified across the evidence. These patterns were grouped into three analytical categories: i) development of digital competence; ii) active methodologies and TPACK; and iii) educational innovation with virtual tools and environments, as shown in Figure 2.

These categories emerged from the repeated reading of the included studies and from the comparative analysis of their main contributions within the data extraction matrix. More specifically, the synthesis examined how each study addressed the relationship among digital competence, technology

integration, pedagogical approaches, and PBL, as well as the contexts, limitations, and educational implications reported in the literature. This thematic organization made it possible to structure the findings coherently and to interpret how the literature addresses the relationship between technology, pedagogy, and digital competence across educational settings. Rather than presenting isolated summaries of individual studies, the synthesis emphasized common trends, convergences, differences, and gaps in the reviewed literature, thereby supporting a more interpretive discussion of the evidence.

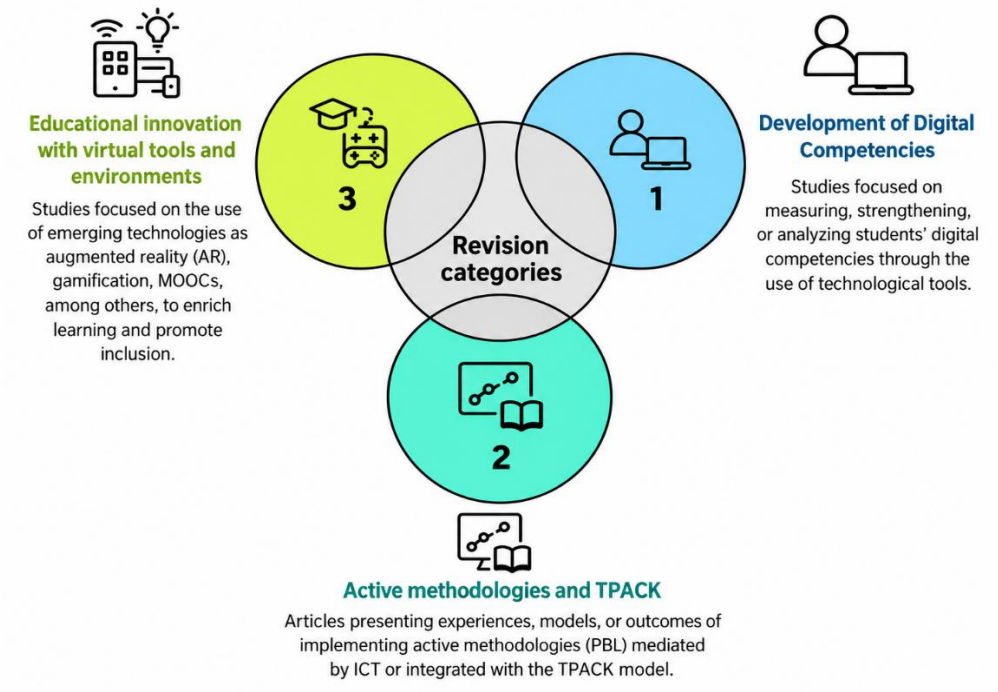


Figure 2. Thematic categories derived from the review

2.7. Quality appraisal of included studies

To strengthen the methodological rigor of the review, a quality appraisal procedure was conducted for the included studies. Given the methodological heterogeneity of the corpus, the mixed methods appraisal tool (MMAT) was applied to the empirical studies included in the review, while conceptual papers, theoretical articles, development papers without clear empirical validation, and systematic reviews were assessed through narrative methodological appraisal rather than direct MMAT scoring. The empirical studies were classified according to their predominant methodological design (qualitative, quantitative descriptive, non-randomized quantitative, or mixed methods), and their appraisal considered the coherence between the research questions and the design, the adequacy of sampling and data collection procedures, the clarity of the analysis, the validity or reliability of the instruments when reported, and the alignment between results and conclusions. This appraisal was not used as an exclusion criterion; instead, it was incorporated to support a more cautious interpretation of the evidence and to identify the relative methodological strength of the included studies.

Overall, the empirical corpus showed predominantly moderate to high methodological quality, especially in studies using validated instruments, pretest-posttest designs, structured questionnaires, or clearly described qualitative procedures. By contrast, several development-oriented or exploratory studies provided useful pedagogical insights but reported limited information about sampling, validation, or analytic rigor. Table 2 summarizes the methodological appraisal of all 24 studies included in the review. MMAT was applied only to empirical studies. Conceptual papers, theoretical contributions, and systematic reviews were not directly scored with MMAT and were therefore considered through narrative methodological appraisal.

As shown in Table 2, the empirical studies included in the review were predominantly of moderate to high methodological quality. Stronger studies tended to report validated instruments, clearer analytic procedures, and better alignment between objectives, design, and conclusions. By contrast, conceptual and review-based articles were retained for their theoretical contribution and were appraised narratively rather than scored with MMAT.

Table 2. Methodological quality appraisal of included studies using MMAT

Study	Design	MMAT criteria met	Methodological appraisal	Brief note
[35]	Mixed-methods developmental study	3/5	Moderate	Uses surveys, interviews, observations, t-tests, Pearson correlations, and factor analysis, but the sample reporting and design description remain limited for a stronger appraisal.
[36]	Systematic review	N/A	Narrative appraisal only	Secondary review study with database screening and article selection; not a primary empirical study suitable for direct MMAT scoring.
[8]	Mixed descriptive-exploratory study	4/5	High	Uses questionnaire and interview, expert validation, reliability checks, and descriptive/inferential analysis; the procedure is clearly reported.
[14]	Descriptive qualitative study	3/5	Moderate	Reports a qualitative descriptive design with survey, documentary analysis, and expert judgment, but methodological detail remains relatively brief.
[37]	Conceptual/editorial synthesis article	N/A	Narrative appraisal only	The article synthesizes lines of analysis on digital competence, TPACK, and teacher education, but it is not a primary empirical study.
[38]	Qualitative study	4/5	High	Clearly reports aims, participants, two online focus groups, ethical procedures, and thematic analysis using Atlas.ti.
[39]	Qualitative meta-synthesis	N/A	Narrative appraisal only	Review-type meta-synthesis based on prior literature; not directly scorable with MMAT as a primary empirical study.
[40]	Theoretical framework paper	N/A	Narrative appraisal only	Foundational conceptual article explaining TPACK; included for theoretical grounding rather than empirical evidence.
[41]	Developmental model study with expert validation	3/5	Moderate	The study synthesizes a conceptual framework, develops a model, and evaluates it through seven purposively selected experts; however, evidence regarding learner outcomes remains limited.
[28]	Quasi-experimental quantitative study	4/5	High	Uses a pretest-posttest three-treatment design, validated instruments, and analysis of covariance (ANCOVA); method and analysis are clearly aligned.
[15]	Quantitative correlational study	4/5	High	Uses an online questionnaire with 212 in-service teachers and structural equation modeling; instrument development and validity procedures are reported.
[42]	Review article	N/A	Narrative appraisal only	Critical review and theoretical discussion of TPACK structure and dynamics; not a primary empirical study.
[43]	Mixed-methods study	4/5	High	Combines questionnaire-based assessment of TPACK-related attitudes with semi-structured interviews; qualitative saturation and analytic procedures are explicitly described.
[44]	Systematic review	N/A	Narrative appraisal only	Systematic review of 75 TPACK studies using database screening and PRISMA flow; not directly scorable as a primary empirical study.
[9]	Conceptual model paper	N/A	Narrative appraisal only	Proposes the digitality-related pedagogical and content knowledge (DPACK) model as an extension of TPACK; theoretical contribution rather than empirical study.
[29]	Quantitative descriptive study	4/5	High	Administers a questionnaire to 245 science and mathematics teachers and analyzes TPACK-related competence and self-efficacy with contextual factors.
[25]	Quasi-experimental study	4/5	High	Uses control and experimental groups, pretest-posttest design, validated digital competence instrument, and independent t-tests with assumption checks.
[45]	Development/innovation paper	N/A	Narrative appraisal only	Describes the SCRUM-based development of a virtual world as a pedagogical resource, but the available methodological reporting does not support direct MMAT scoring.
[46]	Systematic review	N/A	Narrative appraisal only	Large-scale systematic review using PRISMA and MMAT across 112 studies; included here as a secondary review source.
[47]	Multi-stage survey-based educational study	3/5	Moderate	Reports five surveys across different stages of implementation and motivation analysis, but sample sizes are small and the design is largely evaluative/self-report based.
[48]	Developmental study with student evaluation	3/5	Moderate	Develops a Metaverse learning experience platform (MLXP) platform, validates the process with experts, and evaluates 36 students using rubric-based outcomes; useful but not strongly controlled.
[49]	Mixed-methods study	4/5	High	Combines interviews, focus groups, pre-post surveys, classroom observations, artifacts, and backend learning analytics in a clearly articulated mixed-methods design.
[50]	Quantitative descriptive study	3/5	Moderate	Uses a web-based questionnaire with 300 lecturers and descriptive statistical analysis; relevant and sizeable, though analytically limited compared with stronger designs.

2.8. Ethical considerations

This study analyzed secondary data from previously published research and therefore did not require formal ethical approval or informed consent from human participants. Nevertheless, the review was conducted in accordance with principles of academic transparency, rigorous source selection, and accurate reporting of the evidence.

3. RESULTS AND DISCUSSION

The findings of this systematic review are organized into three thematic categories derived from the analysis of the 24 selected studies: i) digital competence development; ii) active methodologies and TPACK; and iii) educational innovation through virtual tools and environments. These categories, as presented in Figure 2, reflect the main patterns identified in the literature regarding the relationship between technology integration, pedagogy, and digital competence across educational levels. Rather than presenting isolated summaries of individual studies, this section discusses the main contributions, convergences, and limitations emerging from the reviewed evidence.

3.1. Digital competence development

The first category highlights digital competence as a central educational priority in contemporary teaching and learning processes. The reviewed studies describe digital competence as a multidimensional construct that extends beyond the technical use of devices and platforms, since it also includes information management, communication, content creation, safety, problem solving, and critical participation in digital environments [8], [9], [15], [25]. In this sense, the literature suggests that digital competence should not be reduced to operational skills, but rather understood as a pedagogical, ethical, and reflective dimension of educational practice [37], [38]. This broader view is also consistent with recent evidence showing that digital skills are linked not only to individual performance, but also to collaborative attitudes and participation in technology-mediated learning environments [13].

A recurrent pattern in this category concerns limitations in teacher preparation. Several studies indicate that weak technological and pedagogical training restricts teachers' ability to design meaningful learning experiences supported by digital tools and, consequently, constrain the development of students' digital competence [8], [14], [50]. This finding is particularly relevant because it shows that the problem is not simply one of technology access, but of pedagogical readiness and curricular articulation. As shown in Table 3, the studies included in this category consistently associate digital competence development with structured training processes, ethical guidance, and pedagogically meaningful uses of technology rather than with mere access to digital devices or platforms.

The studies synthesized in Table 3 also reveal that digital competence is addressed across different educational contexts, including graduate education, higher education, teacher education, and continuing professional development. In these settings, the main findings converge on three major issues: insufficient teacher preparation, the need for flexible and sustained training opportunities, and the importance of broadening digital competence toward critical and responsible participation. For instance, Dangprasert [35] emphasizes the need for structured training in technological use and digital content creation, whereas Loyola and Esparza [36] identify massive open online courses (MOOCs) and nano open online courses (NOOCs) as valuable environments for virtual training and continuous competence development. Similarly, previous researches [8], [37] underline that digital competence cannot be separated from ethical knowledge and responsible information and communication technology (ICT) use, while Aramburuzabala *et al.* [38] extend the discussion toward digital empowerment, participation, and critical citizenship.

At the same time, the reviewed studies show that digital competence can be strengthened when educational institutions provide structured opportunities for professional development and pedagogically guided practice. In particular, open and flexible learning environments such as MOOCs and NOOCs have been identified as valuable spaces for virtual training, autonomous learning, and the continuous expansion of digital skills beyond conventional classroom settings [36]. Likewise, empirical evidence reports improvements in students' digital literacy and digital competence when technology is integrated through active learning, project-based work, and TPACK-oriented instructional designs [25], [28]. These findings suggest that digital competence develops more consistently when it is embedded in purposeful instructional design rather than treated as an isolated technical skill.

Another important convergence concerns the ethical and critical dimension of digital competence. The reviewed evidence indicates that educational quality in digitally mediated contexts increasingly depends on teachers' ability to guide students not only in the use of digital resources, but also in issues of responsibility, safety, participation, and critical engagement [8], [37]. In higher education settings, this perspective has also been linked to broader notions of digital empowerment, inclusion, and socially meaningful participation, especially when digital practices are connected to collaborative and service-

oriented learning experiences [25]. This broader view expands digital competence beyond performance and technical efficiency, positioning it instead as part of responsible and critical participation in digital society.

Overall, the studies in this category suggest that digital competence should be understood as a multidimensional and pedagogically mediated construct. Across educational levels, the literature points to a shift from instrumental views of technology toward more integrative approaches in which digital tools are linked to curriculum, pedagogy, ethics, and professional development [15], [25], [29]. Therefore, digital competence should not be treated as an isolated outcome of technology access, but as part of a broader educational transformation that depends on teacher preparation, curricular coherence, and meaningful learning design.

Table 3. Key studies related to digital competence development

Study	Educational context	Main finding	Relevance to digital competence
[35]	Graduate education	Identified insufficient skills in the use of digital technologies and the creation of high-quality digital content; proposed a learning activity model to strengthen these skills.	Shows that digital competence requires structured training in technological use and digital content creation.
[36]	Higher and continuing education	Identified MOOCs and NOOCs as effective environments for online training and the development of digital competences.	Supports the role of open and flexible learning environments in sustained digital competence development.
[8]	Higher education/teacher education	Reported gaps in teachers' digital and ethical preparation, limiting effective technology integration in teaching.	Emphasizes that digital competence includes ethical knowledge in addition to technical ability.
[14]	Initial teacher education	Found limited ICT training in teacher preparation, which restricts the pedagogical use of digital tools.	Reinforces teacher education as a core condition for digital competence development.
[37]	Pre-service teacher education	Argued for the integration of digital skills and ethical foundations in teacher education.	Highlights the responsible and critical use of ICT as a key dimension of digital competence.
[38]	Higher education	Proposed digital empowerment as a necessary educational aim for active participation in digital society.	Broadens the discussion from digital competence toward empowerment, participation, and critical citizenship.

3.2. Active methodologies and TPACK

The second category focuses on the relationship between active methodologies and the TPACK framework. The reviewed studies suggest that TPACK remains a relevant conceptual model for understanding how teachers integrate technological, pedagogical, and disciplinary knowledge in practice [15], [39], [40]. However, the evidence also indicates that the educational value of TPACK becomes more visible when it is implemented through active methodologies that place students in collaborative, problem-solving, and inquiry-based situations rather than in transmissive instructional models.

In this regard, PBL emerges as one of the most consistent approaches for operationalizing TPACK in educational practice. The literature shows that when PBL is combined with technology-rich teaching, it can strengthen digital competence, scientific literacy, collaboration, and student engagement [25], [28], [29]. Other active methodologies identified in the reviewed studies include science, technology, engineering, arts, and mathematics (STEAM) education, gamification, and makerspace-based learning, all of which emphasize creativity, participation, and the situated use of digital tools [41], [43]. As shown in Table 4, the studies in this category converge in presenting TPACK not only as a theoretical model of teacher knowledge, but also as a practical framework that becomes more meaningful when linked to active and student-centered pedagogies.

The reviewed evidence also shows that active methodologies help move technology integration beyond instrumental use. In several studies, TPACK-oriented teaching is associated with environments in which students are expected to inquire, create, collaborate, and solve authentic problems, rather than simply consume digital content. This is particularly visible in the cases of TPACK-based active learning in science education, project-based models in vocational teacher education, and makerspace experiences in prospective teacher preparation [25], [28], [43]. In addition, recent analyses of teachers' use of ICT in curricular practice reinforce the idea that TPACK becomes educationally relevant when technological resources are intentionally aligned with teaching decisions and learning goals [23]. From this perspective, TPACK gains practical relevance when it is connected to pedagogical designs that require meaningful participation and contextualized use of technology.

Despite these contributions, literature also identifies important limitations. Some studies point out that teachers often struggle to apply TPACK in real educational settings because technological integration is not always accompanied by sufficient pedagogical reflection [39], [42]. Other studies note that innovation-

oriented environments such as makerspaces, science, technology, engineering, and mathematics-PBL (STEM-PBL) contexts, or interdisciplinary digital ecosystems demand competencies that are not always developed in initial or in-service teacher education [29], [43]. In addition, critical perspectives suggest that TPACK may be insufficient on its own to explain the complexity of digitality in contemporary education, especially in interdisciplinary and socioculturally mediated contexts [9].

Overall, the studies in this category suggest that TPACK should not be treated as a purely theoretical construct, but as a pedagogically situated framework whose value depends on how it is enacted in practice. The reviewed evidence support the argument that digital competence develops more meaningfully when technology integration is combined with active methodologies, curricular relevance, and pedagogical intentionality. In this sense, the relationship between TPACK and active methodologies appears to be one of the strongest pathways identified in the literature for moving from technology use toward meaningful educational transformation.

Table 4. Key studies related to active methodologies and TPACK

Study	Approach or focus	Educational context	Main finding	Relevance to TPACK and digital competence
[39]	TPACK-based teacher education/meta-synthesis	Teacher education	Proposed a broader and more holistic understanding of TPACK and argued that teacher preparation should move beyond fragmented views of technology, pedagogy, and content.	Shows that TPACK can guide teacher development, but its implementation depends on coherent and sustained training.
[40]	Foundational TPACK perspective	General educational practice	Defined TPACK as the intersection of technological, pedagogical, and content knowledge required for effective technology integration.	Provides the conceptual basis for linking teacher knowledge, pedagogy, and technology integration.
[28]	TPACK-based active learning	Science/genetics education	Found that active learning models grounded in TPACK improved students' digital and scientific literacy.	Demonstrates that TPACK supports digital competence when connected to active and inquiry-based learning.
[41]	STEAM and gamification	Vocational education	Proposed a digital learning ecosystem combining STEAM education and gamification to foster creativity, teamwork, and innovation.	Shows how interdisciplinary and active methodologies can strengthen technology-rich learning environments related to TPACK.
[15]	Technology integration and professional development	In-service teacher education	Highlighted the need to integrate technology both as a teaching medium and as content of instruction, supported by teacher knowledge and attitudes.	Reinforces TPACK as a practical framework for meaningful technology integration in teacher development.
[42]	Critical perspective on TPACK	Teacher education	Argued that technology integration should not be reduced to technical incorporation and questioned whether TPACK is always implemented with sufficient pedagogical reflection.	Warns that TPACK without critical reflection may lead to instrumental uses of technology.
[43]	Makerspaces and collaborative project work	Prospective teacher education	Reported that makerspace-based learning promoted TPACK growth, but also exposed challenges related to teamwork, task complexity, and ICT-rich project environments.	Suggests that TPACK application requires additional competencies for innovation-oriented and collaborative settings.
[44]	TPACK and self-efficacy/systematic review	Teacher professional development	Found that professional development interventions strengthen teachers' TPACK self-efficacy and support technology integration in practice.	Positions teacher confidence and professional development as central to digital competence integration.
[9]	DPACK/critical extension of TPACK	STEM education	Argued that TPACK does not fully capture the sociocultural complexity of digitality and proposed extending it toward DPACK.	Provides a critical lens on the limits of TPACK in contemporary digital education.
[29]	TPACK with PBL and STEM	Science and mathematics teaching	Examined teachers' competencies and self-efficacy in TPACK for PBL and STEM and highlighted the role of training and contextual factors.	Supports the link between TPACK, active methodologies, and teacher digital competence.
[25]	PBL integrated with TPACK	Pre-service vocational teacher education	Reported significant improvement in digital competence through a PBL model combined with TPACK.	Offers one of the clearest examples of convergence between TPACK, PBL, and digital competence development.

3.3. Educational innovation with virtual tools and environments

The third category groups studies that examine educational innovation through virtual tools and digital environments. The reviewed evidence shows that virtual platforms, gamified environments, virtual worlds, immersive learning systems, and metaverse-based experiences can create more interactive, flexible, and motivating educational settings across different levels and contexts [45], [46], [48]. In these studies, innovation is not presented as the simple adoption of technological resources, but as the redesign of teaching and learning experiences in ways that promote participation, collaboration, and more dynamic engagement with knowledge.

A second recurring pattern concerns the pedagogical affordances of these environments. The literature suggests that virtual tools can support not only content delivery, but also experimentation, collaboration, practical skill development, and situated problem solving. This is especially visible in studies on metaverse environments, virtual worlds, and game-based learning experiences, where students are given opportunities to interact with content, peers, and tasks in more immersive and participatory ways [45], [47], [48]. As shown in Table 5, the studies in this category converge in presenting virtual environments as mediating spaces that can enhance motivation, creativity, and interaction when they are embedded in explicit pedagogical designs. Recent comparative evidence also supports this perspective by showing that virtual reality can function as a meaningful educational tool for both students and teachers when its use is linked to clearly defined instructional purposes [3].

Table 5. Studies related to educational innovation with virtual tools and environments

Study	Type of tool or environment	Educational context	Main contribution	Reported limitations or implications
[46]	Virtual reality and gamification	General education	Showed that virtual reality and gamification can enrich teaching and learning by increasing interactivity, engagement, personalization, and hands-on experiences across educational levels.	Highlighted the need for more objective measures of impact beyond self-reported perceptions and experiences.
[45]	Virtual world integrated with hybrid and mobile learning	Higher education	Showed that virtual worlds can support more flexible, participatory, and student-centered learning by combining immersive interaction with mobile and online access.	Suggests that innovation requires pedagogical redesign and prior user training, not only the adoption of emerging technologies.
[48]	MLXP/immersive design thinking environment	Higher education	Reported positive results in digital intelligence quotient, collaboration, creativity, and virtual game developer skills through an immersive metaverse-based learning platform.	Suggests that immersive environments can strengthen collaboration and creative problem solving when supported by structured design processes.
[47]	Holistic online learning environment/game-based learning	Higher education	Found that digital design learning can be enriched through game-based and simulation-supported environments that improve attention, relevance, confidence, and satisfaction.	Results rely strongly on subjective measures and are limited by students' prior experiences and motivation.
[50]	Technological tools for foreign language teaching	Higher education/language education	Emphasized that technological advancement can support language teaching when tools are aligned with pedagogical goals and lecturer knowledge.	Highlights that innovation depends on pedagogical coherence and teacher preparedness, not only on access to digital tools.
[49]	Cyber Sleuth Science Lab/blended virtual learning environment	STEM and youth education	Created an inclusive and motivating environment that promoted collaboration, problem solving, and engagement through digital forensic science scenarios.	Suggests that virtual environments are more effective when combined with inquiry-based design, real-world problems, and inclusive instructional strategies.

The reviewed studies also indicate that these innovations may contribute to different dimensions of student learning. In higher education, immersive and virtual environments are associated with flexibility, self-paced access, collaboration, and the development of digital and creative skills [45], [48]. In school settings, mixed gamification and virtual tools have been linked to gains in cognitive processes related to mathematics and science, although not all domains respond in the same way. Likewise, broader review evidence shows that virtual reality and gamification can improve engagement, participation, and learning experiences across multiple educational contexts, especially when they are designed around clear

pedagogical goals rather than novelty alone [46]. These findings reinforce the view that virtual tools can enrich learning, but their educational value depends on instructional coherence and contextual relevance.

At the same time, literature also identifies important limitations. Some studies rely predominantly on self-reported perceptions of motivation, usefulness, or satisfaction, which makes it difficult to assess the full educational impact of these environments through objective indicators alone [46], [47]. Other studies emphasize that contextual factors such as prior digital experience, curriculum design, and the conditions under which the technology is implemented may significantly influence outcomes [50]. In this sense, innovation with virtual tools should not be understood as inherently transformative, since its effects are mediated by pedagogical alignment, institutional conditions, and the quality of the educational design.

Overall, the studies in this category suggest that educational innovation through virtual tools and environments becomes meaningful only when these resources are connected to explicit learning purposes and to teaching decisions that respond to students' needs. Virtual tools and immersive environments should therefore be regarded as mediating resources rather than ending in themselves. Their contribution to digital competence depends on how they are integrated into broader educational approaches oriented toward meaningful learning, participation, creativity, and critical engagement.

3.4. Cross-cutting discussion

Across the three categories, the reviewed literature reveals a consistent shift from instrumental views of technology toward more pedagogically grounded and context-sensitive approaches. In the first category, digital competence is presented as a multidimensional construct that depends on teacher preparation, ethical guidance, and curricular integration [8], [15], [37]. In the second category, TPACK appears as a relevant framework for understanding how technological, pedagogical, and disciplinary knowledge can be articulated in practice, especially when linked to active methodologies such as PBL, STEAM, and makerspace-based learning [25], [28], [43].

In the third category, virtual tools and immersive environments are associated with innovation only when they are embedded in explicit pedagogical designs rather than used as isolated digital resources [45], [46], [48]. Taken together, these findings suggest that the educational value of technology does not lie in the tool itself, but in the pedagogical logic that organizes its use. A second recurring pattern concerns the central role of teachers. Although the reviewed studies focus on different educational levels and contexts, they consistently show that meaningful technology integration depends on teachers' capacity to connect digital resources with instructional purposes, student needs, and curriculum goals [15], [29], [39]. This explains why several studies identify insufficient teacher preparation as one of the main barriers to digital competence development and pedagogically meaningful innovation [14], [42], [50].

In this sense, literature does not support a deterministic view in which technology automatically improves education. Rather, it indicates that educational transformation depends on teacher education, professional development, and the creation of conditions that allow teachers to adopt critical, reflective, and purposeful uses of digital technologies. Recent work also suggests that variables such as technology-related teaching skills, coping mechanisms, and teacher well-being may shape the sustainability of digital innovation processes, especially in online and hybrid contexts [20].

Another cross-cutting finding is that active and participatory learning environments appear to be one of the most effective pathways for connecting technology integration with competence development. According to the reviewed studies, PBL, gamification, service-learning, immersive collaboration, and inquiry-oriented activities are repeatedly associated with stronger engagement, richer participation, and more meaningful use of digital tools [38], [47], [49]. These approaches seem to support not only digital performance, but also broader outcomes such as collaboration, critical thinking, problem solving, and socially meaningful participation. This is particularly important because it suggests that digital competence is more likely to develop in educational environments where students use technology to create, solve, interact, and reflect, rather than simply to consume information. Recent evidence on collaborative digital learning in higher education further supports this view by showing that digital skills are closely linked to participation and collaborative attitudes in technology-mediated environments [13].

The review also reveals several limitations in the current body of literature. First, some studies rely strongly on self-reported perceptions of competence, motivation, or usefulness, which may overestimate the effects of technological innovation if not complemented by more objective indicators of learning or performance [46], [47]. Second, the corpus remains methodologically heterogeneous, combining empirical studies with conceptual and review-based contributions, which enriches interpretation but also limits direct comparability across findings [9], [44]. Third, although the literature increasingly recognizes the ethical and sociocultural dimensions of digital education, these aspects are not always operationalized with the same clarity as technological and pedagogical variables [8], [9]. These limitations indicate the need for future research that includes more robust empirical designs, clearer measures of digital competence outcomes, and deeper attention to the social and ethical implications of technology integration.

An additional point emerging from the quality appraisal is that the evidence base is not methodologically uniform. While several empirical studies showed high methodological quality, particularly those using validated instruments, structured designs, or clearly reported analytic procedures, other contributions were more exploratory or relied heavily on self-reported data. This suggests that the conclusions of the review should be interpreted with greater confidence in areas supported by stronger empirical evidence, while findings derived from more descriptive or development-oriented studies should be understood with greater caution.

Overall, the evidence reviewed supports the argument that digital competence development, active methodologies, and virtual innovation should not be treated as separate lines of inquiry. Instead, they should be understood as interconnected dimensions of a broader educational transformation in which technology becomes meaningful only when it is integrated with pedagogy, curriculum, ethics, and participation. From this perspective, the convergence between digital competence, TPACK, and active learning represents one of the most promising pathways for strengthening educational practice across different levels and contexts.

3.5. Limitations of the review

This review has some limitations that should be acknowledged. First, the search was restricted to three databases and to publications in English and Spanish, which may have excluded relevant studies indexed elsewhere or published in other languages. Second, the review focused on journal articles published between 2019 and 2024, so earlier foundational studies and other types of academic outputs were not systematically included. Third, the methodological heterogeneity of the selected studies limited direct comparability across findings, particularly when empirical, conceptual, and review-based contributions were interpreted together. Finally, although quality appraisal was used to strengthen interpretation, not all included studies provided the same level of methodological detail, which may affect the consistency of evidence across categories.

4. CONCLUSION

This systematic review examined how technology integration, the TPACK framework, and PBL contribute to the development of digital competence across basic, secondary, and higher education. The evidence reviewed shows that digital competence should not be understood as a merely technical outcome, but as a pedagogically mediated construct that involves communication, problem solving, collaboration, critical thinking, and ethical participation in digitally mediated environments. Across the selected studies, its development was consistently associated with teacher preparation, curricular coherence, and the quality of pedagogical integration rather than with access to technology alone.

A central finding of this review is that the relationship between digital competence, TPACK, and PBL is stronger when these dimensions are approached as interconnected rather than isolated. In particular, the literature suggests that TPACK provides a useful framework for guiding teachers' technological and pedagogical decision-making, while project-based and other active methodologies create the conditions under which digital competence can be enacted through authentic, collaborative, and student-centered learning experiences. In this sense, the educational value of digital tools depends less on the resources themselves than on the pedagogical designs that organize their use.

The review also identified persistent barriers that continue to limit meaningful progress in this field. These include insufficient teacher training, uneven integration of digital tools into curriculum and instruction, and a frequent mismatch between educational goals, disciplinary content, and technology use. In addition, the literature remains methodologically and conceptually fragmented, since many studies examine digital competence, TPACK, active methodologies, or virtual innovation separately rather than analyzing how they converge within the same educational design. One of the main contributions of this review, therefore, is to bring these strands of literature into dialogue and to provide a more integrated interpretation of the conditions that support digital competence development.

Finally, this review has implications for both research and practice. For educational practice, it suggests that digital competence is more likely to be strengthened when institutions invest in sustained teacher development, active methodologies, and coherent curricular integration of technology. For research, it highlights the need for more robust empirical studies that examine how integrated pedagogical models operate across educational levels and how digital competence is assessed beyond self-reported perceptions. Future studies should also pay greater attention to the ethical and sociocultural dimensions of digital education, since these remain less consistently developed than technological and pedagogical variables. Overall, the findings support the view that meaningful educational transformation requires not only digital tools, but also pedagogical intentionality, critical reflection, and sustained institutional support.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
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O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
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CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

Not applicable because this study is a systematic review based on previously published studies and did not involve direct participation of human subjects.

DATA AVAILABILITY

The data supporting the findings of this study are available within the article. This study is based on the analysis of previously published literature.

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