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REVIEW ARTICLE

A systematic review of teachers' digital competence and its effect on students' academic self-efficacy, learning engagement and other outcomes

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ABSTRACT

This systematic review synthesizes 25 empirical studies (1/1/2015–16/6/2025) to examine the impact of teachers' digital competence on students' academic self-efficacy, learning engagement, and other related outcomes. The findings reveal that teachers' digital competence boosts academic self-efficacy by fostering confidence and self-regulation. It also enhances learning engagement across behavioral, emotional, and cognitive dimensions. These effects are supported by frameworks such as TPACK and Social Cognitive Theory. Quantitative research and questionnaires were the most commonly used methods, and technology integration environments (e.g., AR/VR, AI tools) in improving students' other related outcomes were the most frequent variable focus. However, the existing research exhibits geographical biases (with a predominance of studies from developed regions), methodological limitations (including an overreliance on cross-sectional surveys), and a focus on higher education, which leaves K-12 and vocational contexts underexplored. Key gaps include inconsistent measurement tools and insufficient examination of mediating mechanisms (e.g., the role of academic self-efficacy in the relationship between teachers' digital competence and learning engagement). This review underscores the need for longitudinal studies, standardized assessments, and more equitable research representation in economically underdeveloped regions. Practical implications highlight the importance of integrating technical and pedagogical training in teacher development programs to optimize digital learning environments.

Keywords: teachers' digital competence; academic self-efficacy; learning engagement; learning outcomes; tpack; digcomedu

1. Introduction

Digital technology has a profound impact on social development and has reshaped various fields, including education[1]. Technological products have reconstructed the social environment and changed human ways of life[2], and are expected to continue driving the digital transformation of global political, economic, cultural, social, ecological, and pedagogical systems[3]. Therefore, modern education should prioritize teaching forms and activities that incorporate information technologies, as these can personalize learning processes, enrich acquired knowledge, and enhance professional efficiency. Educational informatization involves the integration of information and communication technologies (ICT) into the

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education system, encompassing legal, socio-economic, and technological dimensions. This process aims to meet contemporary educational requirements by fostering digital literacy and innovating teaching methods[4]. In the information era, high digital competence is increasingly essential for teachers[5]. Contemporary teachers, particularly in language education, must continually reflect on and adapt to modern pedagogical approaches, since educators' professional growth contributes significantly to student performance and academic success. This emphasis is especially relevant in language teaching due to the inherently communicative and interactive nature of language acquisition, which benefits from digital tools that provide immersive, authentic, and personalized learning experiences. Furthermore, the development of teachers' digital competence enables students to access a wider range of resources, enjoy personalized learning programs, and overcome temporal and spatial constraints on learning. Teachers themselves acknowledge the crucial importance of integrating information technology into instruction[6]. Consequently, the use of digital technologies has become particularly vital in language education, making the enhancement of teachers' digital competence (TDC) a key objective across all educational levels[7].

Digital competence was first introduced by the European Union[8]. It refers to the ability to use computers to retrieve, evaluate, store, produce, present, and exchange information, as well as to communicate and collaborate via the Internet. In the educational context, Krumsvik[9] defined digital competence as a teacher's ability to use ICT with sound pedagogical-didactic understanding and awareness of its potential impact on students' learning strategies and educational development. Gudmundsdottir et al.[10] asserted that digital competence encompasses not only digital, pedagogical, and subject-specific skills but also an awareness of the need for continuous professional development through teacher education and classroom practice. In this study, based on DigCompEdu[11], teachers' digital competence (TDC) is defined as the ability to effectively and critically use digital technologies for teaching, learning, and assessment. This operational definition extends beyond technical proficiency to include professional engagement, learning design, and the facilitation of learners' digital capabilities. Although related to the Technological Pedagogical Content Knowledge (TPACK) framework[12], which emphasizes the integration of technological, pedagogical, and content knowledge and effectively outlines the knowledge domains essential for teachers, DigCompEdu offers a more pragmatic framework for implementing digital integration in educational practice. The stronger a teacher's TPACK, the higher his TDC is likely to be. While TDC is ultimately valued for its potential to enhance student academic achievement, this review argues that its influence is primarily mediated through psychological and behavioral mechanisms. The focus here is specifically on academic self-efficacy and learning engagement, as these constructs represent critical pathways through which TDC exerts its effects. A teacher's TDC serves as a key environmental factor that shapes students' learning experiences[13]. Specifically, high TDC enables teachers to design digital activities that provide mastery experiences, deliver timely feedback (verbal persuasion), and facilitate learning through modeling (vicarious experience). These experiences directly strengthen students' self-efficacy—a central personal factor in Social Cognitive Theory (SCT)—thereby promoting a more interactive, personalized, and authentic learning environment that captivates students' behavioral, cognitive, and emotional interest, ultimately enhancing their engagement.

According to Bandura[14], self-efficacy refers to an individual's judgment and belief in their ability to organize and execute actions required to achieve specific goals. It reflects a person's confidence and perceived competence in performing particular behaviors. Academic self-efficacy (ASE) represents an extension of self-efficacy within the educational domain. Schunk[15,16] described ASE as an individual's conviction in their capacity to organize and execute courses of action necessary to attain designated academic performance levels. Zimmerman[17] characterized ASE as the process through which students

activate and sustain cognitive, behavioral, and affective activities to achieve goals and overcome challenges. Learning engagement (LE) denotes the amount of physical and mental energy that students invest in their academic experiences[18]. Finn[19] defined engagement as students' active involvement in school and classroom activities. Fredricks et al.[20] conceptualized LE from a psychological perspective, categorizing it into behavioral, emotional, and cognitive dimensions. Hu and Hui[21] described LE as students' voluntary participation in activities designed within learning programs. Wang et al.[22] proposed that LE serves as an essential metric for evaluating online educational programs, as it correlates with both the quality of online education and student achievement.

Existing literature has extensively explored the development and assessment of TDC, often emphasizing model construction[23] and individual-level influencing factors[24]. Simultaneously, numerous studies have investigated learner-related variables—such as self-efficacy, motivation, and engagement—and their contributions to academic achievement. For example, students' ASE influences their selection of learning strategies and the amount of effort they invest in achieving goals[25]. Additionally, achieving desirable grades can foster positive emotional states among students[26]. A meta-analysis further indicates that higher ASE predicts better long-term academic performance, while academic success, in turn, strengthens ASE over time[27]. ASE also moderates the initial stage in the mediating role of perceived social support[28]. Regarding LE, research shows that it partially influences learning satisfaction and fully mediates learning perceptions[29]. Moreover, LE acts as a key mediator through which ASE indirectly predicts academic performance[30], and it partially mediates the relationship between learning motivation and learning effectiveness. However, few systematic reviews have examined how TDC directly or indirectly influences students' learning processes and outcomes—particularly self-efficacy and engagement—or clarify the pathways through which TDC affects academic performance. Therefore, this review aims to address this gap by systematically analyzing emerging evidence on the relationship between TDC and student learning, with focused attention on the mediating roles of self-efficacy and learning engagement. Accordingly, the purpose of this study is threefold: 1) to systematize the definition and composition of TDC; 2) to reveal the distribution and trends in research methodologies, measurement tools, sample characteristics, and key findings within the field; and 3) to explore the impact of TDC on students' ASE, LE, and other learning outcomes (e.g., academic achievement, motivation, and learning skills). The study proposes the following research questions:

RQ1: What is the distribution of publication year, country, education level, and sample characteristics of existing studies?

RQ2: What are the main theoretical frameworks, research design, measurement tools, and variable focus of existing studies?

RQ3: What are the effects of teachers' digital competence on students' academic self-efficacy, learning engagement, and other student-related outcomes?

2. Materials and methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines[31] to ensure a transparent, replicable, and rigorous process. This review aimed to synthesize existing research examining the impact of TDC on students' LE, ASE, and other educational outcomes. A comprehensive literature search was conducted on June 16, 2025, using the Scopus and Web of Science databases. The following search string was used in both databases: ("digital competence" OR "digital literacy" OR "TPACK" OR "technology integration") AND ("engagement" OR "self-efficacy" OR "learning outcomes"). The limitations were as follows: 1) time scale: 1/1/2015-16/6/2025; 2) subject

category: Scopus—social science, computer science, psychology; Web of Science—education, computer science, psychology; 3) literature type: empirical studies (quantitative, qualitative, or mixed-methods); and 4) language: English. The time scale from 1/1/2015 to 16/6/2025 was selected to capture the most recent and relevant developments in TDC. This period encompasses a crucial era in educational technology, characterized by the widespread adoption of cloud computing, mobile learning, and artificial intelligence in education. It also includes the shift to digital teaching during the COVID-19 pandemic, which rapidly accelerated research and implementation in this field. Limiting the review to this decade ensures that the included studies reflect contemporary digital tools, teaching methods, and educational environments, thereby enhancing the relevance and timeliness of our findings.

The initial search yielded 275 articles, all of which were imported into Endnote. A total of 66 duplicates were removed using the software, and the literature reached 209. In the screening and eligibility process, studies were included if they: 1) were empirical studies (quantitative, qualitative, or mixed-methods); 2) examined the relationship between TDC and at least one student-related outcome (e.g., LE, ASE, achievement); 3) involved participants at any level of elementary school, junior high school, high school, university, vocational technical high school, and higher vocational colleges; and 4) were published in peer-reviewed academic journals. Studies were excluded if they: 1) focused solely on teachers' self-perceptions or professional development without linking to student outcomes; 2) focused solely on students' learning without mention of teachers intervention or instruction behavior; 3) were review articles, opinion pieces, conference abstracts, or dissertations; 4) were not written in English; or 5) full texts were not available.

After screening the titles and abstracts, 41 studies met the requirements, and in the eligibility stage, 16 studies were not relevant or not available. Therefore, the final number of qualified studies was 25. The PRISMA flow diagram illustrating the selection process is shown in **Figure 1**.

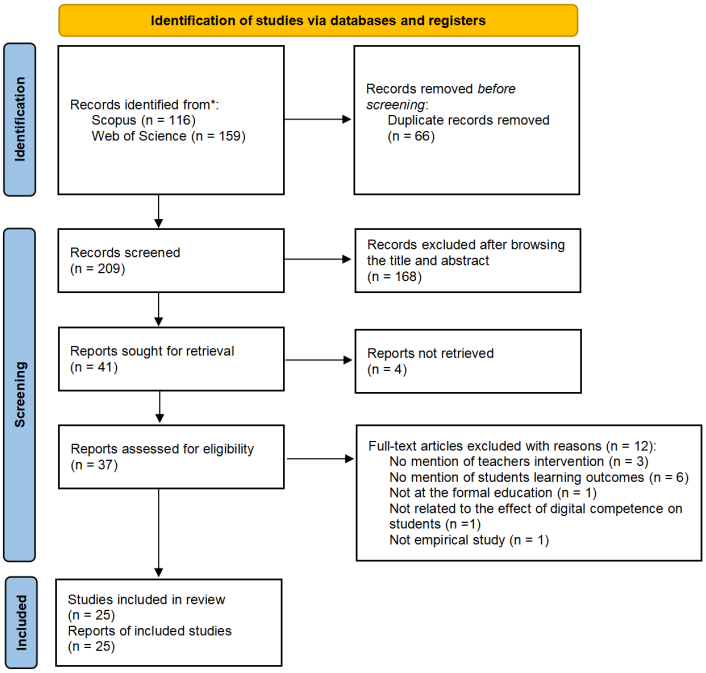

Figure 1. PRISMA flow diagram.

A standardized data extraction form (see Appendix A) was used to collect the following information from each study: 1) author(s) and year of publication; 2) country or region of the study; 3) educational level; 4) theoretical or conceptual framework; 5) research design and methodology (quantitative, qualitative,

mixed-methods); 6) instruments used to measure digital competence and student outcomes; 7) sample characteristics (size, participants); and 8) key findings regarding the impact of TDC on students. For the purpose of analyzing sample size distribution, studies were categorized into four groups based on participant number: small ($N \leqslant 50$), medium ($50 < N \leqslant 200$), large ($200 < N \leqslant 1000$), very Large ($N > 1000$). A visual analysis was conducted to summarize the characteristics of the included studies, including their publication year, country, education level, and sample features. Charts and tables were used to present the distribution of theoretical frameworks, research designs, measurement tools, and variable focus. For studies examining the impact of TDC on student outcomes—particularly LE and ASE—a thematic analysis was conducted to extract common patterns and key mechanisms of influence. Additionally, the review explored how TDC are linked to other student-related outcomes, such as learning motivation, achievement, and learner satisfaction.

3. Results

3.1. Publication trends and study characteristics

3.1.1. Temporal trends

The text continues here. A total of 25 empirical studies published between 1/1/2015 and 16/6/2025 were included in this review. These studies varied in publication year, country, education level, and sample characteristics. Regarding temporal distribution, a lack of relevant research on this topic was observed in 2015 and 2016. Beginning in 2017, the number of studies gradually increased, though overall output remained relatively low, averaging 1–2 articles per year, indicating a late start in this field of research. After 2022, accelerated by the global pandemic, investigations into the impact of TDC on students' learning outcomes grew significantly, reaching a peak in 2023 with eight studies included. For example, Hazzam and Wilkins[32] noted that many universities suspended face-to-face classes and transitioned to online instruction to mitigate the negative effects of COVID-19 on education. This trend suggests that, alongside continuous advancements in educational technology, the proliferation of online teaching, and the demand for digital solutions in exceptional circumstances, research on the relationship between TDC and students' learning behaviors has gained increasing attention (as shown in **Figure 2**).

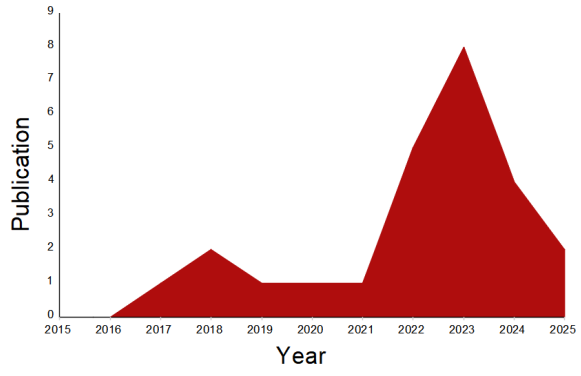

Figure 2. Number of studies from 2015-2025.

3.1.2. Countries distribution

This systematic review included studies conducted in at least 18 countries and regions across Asia, Europe, North America, and the Middle East. The United States (3 studies), China (2), Indonesia (2), Taiwan (China) (2), and South Korea (2) were the most frequently represented. Other countries, such as Germany,

Australia, Iran, Norway, the Czech Republic, Ukraine, Finland, Saudi Arabia, and Canada, have also contributed to the literature. Overall, a significant proportion of the studies were conducted in American and Asian countries, reflecting growing academic interest in TDC and its effects on students within these regions. Additionally, several studies focused on broader geographical areas, such as "six Arab countries" and the "Asia-Pacific region," underscoring the global relevance of this topic. However, research from low-income and underdeveloped regions remained scarce, resulting in a notable gap in the current literature (**Figure 3**).

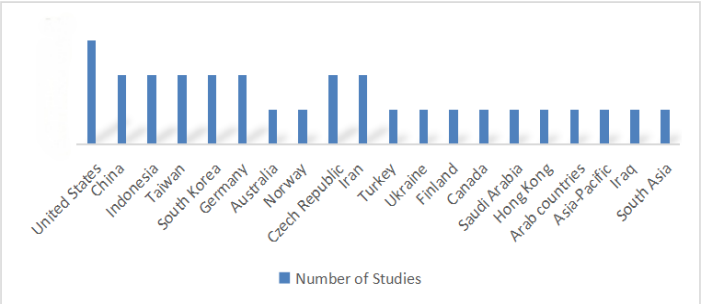

Figure 3. Countries and regions distribution of studies.

Note: *As some studies covered multiple countries, the total number of countries exceeded 25.*

3.1.3. Education levels

Although a growing number of studies have explored the impact of TDC on students' learning outcomes, most existing research has predominantly concentrated on the university and college levels. As shown in **Figure 4**, 14 studies were conducted in higher education settings, while far fewer focused on secondary and elementary education. Notably, there was a clear lack of research targeting K-12 teachers and vocational technical high schools. This uneven distribution suggests that the effects of TDC on students at younger ages and in non-university contexts remain unexplored. Consequently, more empirical investigations are needed across different educational levels to provide a more comprehensive and balanced understanding of how digital competence influences students' LE and ASE.

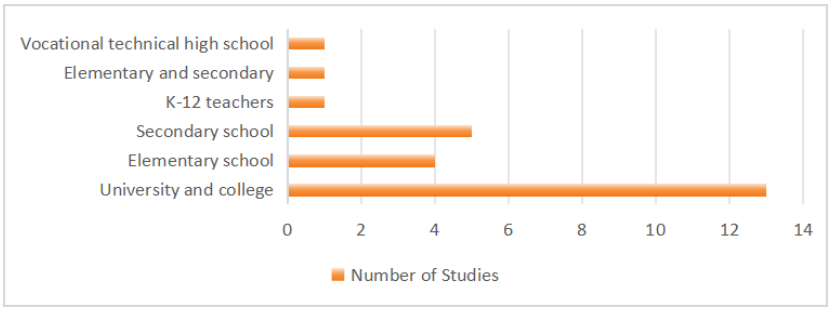

Figure 4. Education level distribution of studies.

3.1.4. Sample characteristics

A total of 25 studies were included in this review, encompassing a combined sample size of 30,111 participants. The characteristics of the study samples were summarized in **Table 1**.

Table 1. Distribution of participants and sample sizes.

Participant Category	Number of Studies	Total Sample Size	Sample Size Category (n, %)
University Students	11	2,454	Small: 4 (36.4%) Medium: 5 (45.5%)

Participant Category	Number of Studies	Total Sample Size	Sample Size Category (n, %)
			Large: 2 (18.2%)
Secondary School Students	3	9,964	Medium: 1 (33.3%) Very Large: 2 (66.7%)
Elementary School Students	3	156	Small: 2 (66.7%) Medium: 1 (33.3%)
K-12 Teachers	2	225	Medium: 2 (100%)
Secondary School Teachers	1	15,015	Very Large: 1 (100%)
Pre-service Teachers	1	230	Large: 1 (100%)
University Teachers	1	17	Small: 1 (100%)
Vocational HS Teachers	1	775	Large: 1 (100%)
Mixed Participants	2	1,275	Large: 2 (100%)
Total / Overall	25	30,111	Small: 7 (28.0%) Medium: 9 (36.0%) Large: 5 (20.0%)

Table 1. (*Continued*)

Note: *Sample Size Category was defined as follows: Small (N ≤ 50), Medium (50 < N ≤ 200), Large (200 < N ≤ 1000), Very Large (N > 1000). Mixed Participants include one study with Elementary students/teachers (n=829) and one with Secondary students/teachers (n=446).*

For the participant distribution, university students were the most frequently studied group, featured in 11 studies (44% of the total). Secondary school students and elementary school students were the focus of three studies each. Educators were also well-represented, with studies involving K-12 teachers, secondary school teachers, pre-service teachers, university teachers, and vocational high school teachers. Regarding sample size distribution, the sample sizes across the studies varied considerably. Based on our pre-defined categories (Small: N ⩽ 50; Medium: 50 < N ⩽ 200; Large: 200 < N ⩽ 1000; Very Large: N > 1000), the distribution was as follows: 7 studies (28.0%) had a small sample size, 9 studies (36.0%) had a medium sample size, 5 studies (20.0%) had a large sample size, and 4 studies (16.0%) had a very large sample size. The median sample size was 119. The distribution was highly skewed, driven by a few large-scale studies. For instance, one study on secondary school teachers (N=15,015) alone accounted for nearly half of the total combined sample size.

From the above analysis, it is clear that research on the relationship between TDC and student learning has been increasing annually, reaching a peak in 2023. Second, research in this field has mainly concentrated in the United States and Asia, with a focus on developed regions, lacking research on economically underdeveloped regions. Third, most of this research has been conducted at the higher education level, indicating that future research should focus more on primary and secondary education. Finally, the diverse participants and sample sizes provide a broad perspective for the research field. The prevalence of small and medium-sized studies indicates a focus on exploration in the field, while the inclusion of large-scale surveys points to another research approach.

3.2. Theoretical and methodological characteristics

3.2.1. Theoretical framework

The analysis of the included studies reveals a rich and diverse theoretical landscape, which can be systematically organized into three main categories based on their primary focus and application: 1) theories

concerning teacher knowledge and competence; 2) theories centered on student motivation and behavior; and 3) integrated and multi-theoretical approaches that bridge both perspectives.

Teacher-focused theoretical frameworks

The most frequently adopted theory in this domain was the Technological Pedagogical Content Knowledge (TPACK) framework, which appeared in five studies. TPACK served as the primary lens for understanding teachers' knowledge structures and competencies required for effective technology integration. Additionally, several studies utilized technology adoption models, such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), to examine teachers' behavioral intentions and actual use of digital tools. Further complementing these approaches, Digital Competence Frameworks (e.g., DigCompEdu, DiKoLAN) provided structured models for assessing and developing teachers' digital proficiencies.

Student-focused theoretical frameworks

Studies investigating student outcomes predominantly employed psychological and motivational theories. Social Cognitive Theory (SCT) and Self-Efficacy Theory were widely referenced, particularly in studies examining how students' beliefs about their capabilities influenced their learning processes and outcomes. Simultaneously, Self-Determination Theory (SDT) and Engagement Theory were commonly applied to understand students' intrinsic motivation, need satisfaction, and behavioral persistence in digital learning environments. Additional frameworks such as Constructivism and Self-Regulated Learning (SRL) provided further insights into how students actively construct knowledge and manage their learning processes.

Integrated and multi-theoretical approaches

A significant finding was the emergence of integrated theoretical approaches that combine multiple frameworks to better capture the complexity of digital teaching and learning processes. For instance, Al-khresheh and Alkursheh [33] applied both TPACK and SCT to obtain a deeper analysis of both teacher-level and student-level variables, creating a more comprehensive understanding of how teacher competencies influence student outcomes. Similarly, Czok et al. [34] integrated TPACK and DiKoLAN to explore digital competence in specific pedagogical contexts, demonstrating how complementary frameworks can provide richer insights than single-theory approaches.

3.2.2. Research designs

In terms of research design of the 25 studies, 11 studies (44%) employed quantitative designs, 11 studies (44%) used mixed methods, and three studies (12%) used qualitative approaches, as shown in **Figure 5**.

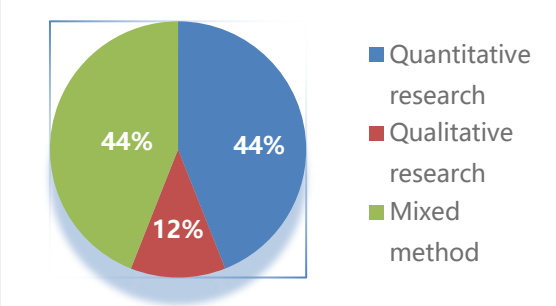

Figure 5. Distribution of research design.

Questionnaires were the dominant data collection tool, particularly in quantitative and mixed studies, and were often used to evaluate students' ASE and LE. Several studies have employed quasi-experimental designs to examine the effects of digital competence-related interventions. Qualitative components, such as interviews and focus group discussions, enriched the findings by capturing learners' perspectives, while case studies provided contextual insights into TDC across educational settings. From the data above, it can be seen that while the current research provides valuable insights, the lack of rigorous experimental methods limited qualitative depth, and single cross-sectional surveys suggest important directions for future studies.

3.2.3. Measurement instruments

Measurement tools used in the included studies showed considerable diversity. For TDC, most studies used self-developed or adapted questionnaires, with several employing frameworks such as the DigCompEdu and TPACK. For example, Habibi et al.[35] used the Behavioral Beliefs Scale as an evaluation tool. The overall average reliability of the survey was 0.87, and the validity of the instruments was examined through content validity and face validity. Students' ASE was primarily measured using established tools such as Lent et al.'s Self-Efficacy Scale[36], with Cronbach's alpha coefficient was 0.897, the AM questionnaire was 0.718, and the AP questionnaire was 0.765. All of them were greater than 0.70. These values indicated that the questionnaires had sufficient reliability. And Chemistry Motivation Questionnaire was a modified form of the Self-Reported Science Motivation Questionnaire developed by Glynn[37]. The Cronbach's alpha coefficient was 0.685, and the composite reliability was 0.792, which confirmed the reliability and convergent validity of the instrument. LE was assessed using self-report questionnaires, such as Sun and Rueda's five-item scale[38]. The Cronbach's alpha coefficient exceeded 0.7 and AVE was more than 0.5, suggesting the reliability and validity of this scale. Except for quantitative instruments, qualitative instruments, such as focus groups or interviews[39] were applied. As for other learning outcomes, the scales contained various aspects such as learning satisfaction, learning confidence, learning strategies, and academic achievements.

Notably, the inconsistency in measurement tools across the reviewed studies poses a significant challenge to the establishment of a uniform standard and, crucially, impedes the direct comparability of research findings. This lack of standardization manifests in several ways: First, studies used everything from self-developed questionnaires to adapted versions of established scales, covering different sub-dimensions and item wording. The reliability and validity of these instruments are often not rigorously established or reported, making it difficult to assess the accuracy of the measurements. Moreover, the heterogeneity of this methodology makes meta-analysis work more complex and makes it challenging to determine the relationships and characteristics between variables. Although this diversity reflects the evolving nature of the field, it highlights the urgent need to develop and widely adopt validated universal tools to advance the field in a more systematic and coherent manner.

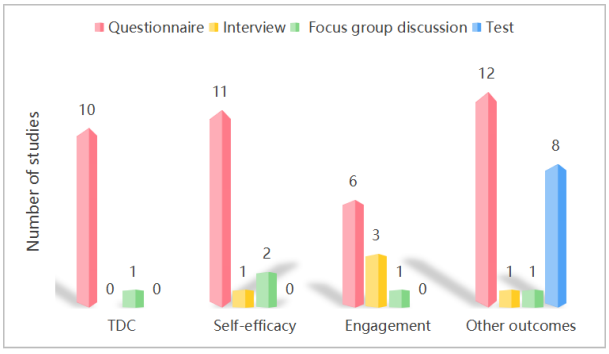

Figure 6. Distribution of measurement tools.

Figure 6 illustrates the distribution of the main measurement tools used to assess the four research variables: TDC, ASE, LE, and other outcomes. Questionnaires were the most frequently used data collection method. Specifically, TDC was assessed in 10 studies using questionnaires. Only one study employed interviews, and none used focus group discussions. For ASE, 11 studies used a questionnaire. In addition, two studies incorporated interviews, while one study used focus group discussions. Regarding LE, six studies relied on questionnaires, three used interviews, and one used focus group discussions. Compared to other variables, LE was assessed using qualitative methods to capture the real reaction of participants. For other outcome variables (e.g., performance, motivation, satisfaction), 12 studies used questionnaires, and only one study each used interviews or focus group discussions. Moreover, the test tool only appeared in this category because the standard tests were more reasonable for evaluating students' academic achievement. It is worth noting that a few other measurement tools appeared in the studies reviewed. However, their use was too infrequent to allow meaningful categorization or comparison. Therefore, they are not included in this discussion.

3.2.4. Variable focus

The UpSet plot (**Figure 7**) visualizes the intersection of the four main variables. It provides not only the overall frequency of each variable (Set Size on the left), but also the specific combinations of variables that co-occurred in the research (Intersection Size on the top). Concerning the variable focus of the 25 studies, other outcomes appeared most frequently (n = 17), indicating a broad interest in additional constructs such as academic achievement, behavioral intention, satisfaction, and motivation. This provides a more comprehensive understanding of the learning outcomes in technology-integrated environments. ASE was included in 14 studies, reflecting its prominent role in education research. This aligns with the social cognitive theory, which considers ASE a key predictor of motivation and learning behavior. LE, closely related to ASE, was examined in 11 studies, highlighting the current interest in how digital tools and environments affect students' behavioral, emotional, and cognitive involvement. In contrast, TDC was measured in only 10 studies, despite being the main focus of this review. This relatively low frequency suggests that TDC is sometimes treated as a contextual background rather than a directly measured variable. This also reflects the ongoing need for reliable and valid tools to assess TDC.

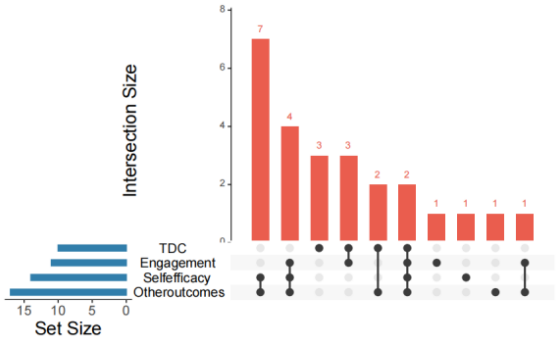

Figure 7. Distribution and intersection of variables.

The most frequent combination—ASE and other outcomes—was investigated in seven studies, indicating a strong interest in examining the comprehensive impact of ASE on student-related outcomes. The next most common combinations were LE + ASE+other outcomes (four studies) and TDC + LE and TDC only (three studies each). These combinations highlight the importance of ASE in this research field, which is theoretically grounded in Social Cognitive Theory, where ASE functions as a mediating or explanatory variable for both LE and performance. Fewer studies focused solely on a single variable or investigated

minimal combinations, indicating that most empirical research in this domain tends to adopt a multivariable approach, possibly to better capture the complexity of technology integration in educational settings. However, as the core of this review, the combination of TDC +ASE+LE+other outcomes was not frequent, being presented in 2 studies, which demonstrates that the current research lacks a deep exploration of how TDC simultaneously affects both ASE and LE in one study. Future research should measure TDC as an independent variable, especially in relation to student-level outcomes.

From the above discussion, it can be seen that theoretical frameworks reveal a consensus regarding the need to consider both TDC and student learning processes when examining technology integration in educational contexts. The multi-theoretical approaches highlight to create more comprehensive models that can account for the complex interactions between teaching practices and learning outcomes in digital environments. Besides, quantitative and mixed-method research were the most commonly used research methods in this field, with questionnaires being the most frequently used measurement tool. Finally, the relationship between ASE and other outcomes was the most frequently studied topic in this field, but there was limited research on the impact of TDC on student learning. Therefore, future research should employ more diverse theoretical frameworks, utilize more standardized and consistent questionnaires to enhance comparability, and use more qualitative tools to gain deeper insights. Additionally, under the information-based teaching, the relationship between TDC and ASE and LE needs further exploration.

3.3. Effects of teachers' digital competence

3.3.1. Students' academic self-efficacy

Several studies have reported a positive association between TDC and students' ASE with a single research method. For example, Gunawan and Shieh[40] indicated that Technology + Multiple Intelligences (MI) instructional design is effective in increasing students' ASE. Sukma and Pum[39] considered that AR/VR simulations, AI tools, and other technology integration enhance students' ASE. In some cases, mixed research methods were employed in various studies. The combination of quantitative research (questionnaire survey) and qualitative research (interviews, group discussions, journals) provided a general description as well as a deep interpretation of how TDC in a digital environment enhances students' ASE. The two methods complement each other and present a more comprehensive result[41,42]. In addition, quasi-experiments were applied frequently. For instance, the use of a variety of technology instruments in experimental groups to enhance the teaching process generates a significantly positive effect on students' ASE[34,36,37,43]. Moreover, Hu and Li[44] conducted a 19-week Intervention Design and Implementation (IDI) and confirmed the positive role of the digital drawing tool in significantly improving students' ASE. Kurt[45] compared the pre-test and post-test scores and found that technology-mediated tasks increase students' ASE. At last, Ostrovska et al[46]. proved that teachers with higher digital competence significantly enhance academic students' efficacy.

However, there was a study that conflicts with other research results. Beirnes[47] asserted that the virtual format can limit the use of some instructional strategies, and also limit the ability for students to receive help. It suggests that the integration of digital technology should be student-centered to have a positive effect on students' ASE. These studies showed that when teachers effectively combine digital tools with pedagogy, students tend to perceive themselves as having greater control over their learning, greater confidence in completing tasks, and greater motivation to achieve academic goals. Several quasi-experimental and mixed-methods studies further confirmed that students who receive digital instruction have improved self-regulatory behaviors and increased confidence in learning.

3.3.2. Students' learning engagement

Evidence from the reviewed literature of single research methods consistently showed that TDC positively affects various dimensions of students' LE, including behavioral, emotional, and cognitive engagement. Bawa et al.[48] suggested that the integration of digital game content largely supports students' LE. Hazzam and Wilkins[32] indicated that technology use significantly improves students' behavioral engagement. Rugh et al.[49] stated that TDC significantly predicts students' digital engagement. Studies employing both qualitative and quantitative approaches emphasized that digital competence enables teachers to create a learning environment with more interactivity, student-centered instruction, and personalized assessment[41]. This, in turn, leads to higher participation rates, sustained attention, and increased interest in learning tasks. LE is particularly enhanced when digital tools are used to support collaborative learning, multimedia presentations, and immediate feedback[50,51]. In quasi-experiments, Lin et al.[43] applied mapping strategies + mobile instructional systems, which significantly increase students' LE. Ostrovska et al.[46] emphasized the important role of teachers' digital skills in shaping students' LE. Some other research particularly, made an effort to investigate the indirect effect of TDC on students' LE. For example, Chiang[42] proved that the designed tasks with multimodal features indirectly influence students' LE through ASE. Czok et al.[34] used AR teaching tools to improve students' LE indirectly. Habibi et al.[35] thought that the ICT of teachers, in an indirect way, impacts students' LE.

A few studies, however, were not consistent with the positive result. Beirnes[47] explained the limited role of the virtual format on students' LE. Baroudi and Shaya[52] found that online teachers in the Arab world are still confused about ways to increase students' LE. Similarly, DeCoito and Estaiteyeh[53] showed that the impact of online teaching on students' learning outcomes is generally considered negative. The opposite research findings suggest that, as a new auxiliary tool, technology alone is insufficient in pedagogy, which needs educators to design and develop digital instructional activities that adapt to various students at all education levels.

3.3.3. Other student-related outcomes

In addition to ASE and LE, several studies explored other student-related outcomes associated with TDC. Generally speaking, the TDC can significantly upgrades students' learning outcomes[34,41]. Specifically, first of all, the technology integration in the teaching environment has a positive effect on students' academic achievement[37,54,55] and language proficiency[45]. Second, Gunawan and Shieh[40] and Ostrovska et al.[46] pointed out that teachers with higher digital competence can enhance the teaching content, which increases students' motivation and performance. Meanwhile, Hazzam and Wilkins[38] figured out that technology use is significantly related to students' learner satisfaction. Third, TDC is shown to directly or indirectly influence students' learning effectiveness in a positive way[35,42]. Fourth, a few studies confirmed the important role of TDC in constructing students' behavior intentions[44,56]. At last, teachers' instructional design and task assignment through modern information technology is one of the strongest predictors of students' learning skills, including computational thinking, creativity, self-directed learning and speaking skills[43,56,57].

The findings suggest that high levels of TDC are often linked to improvements in student autonomy, goal orientation, and enjoyment of learning. In particular, digital pedagogical strategies that align with learners' needs are found to enhance learning satisfaction and foster greater motivation. However, it should be noticed that these studies are not all in agreement. Beirnes[47] supposed that the virtual format limited the ability for students, and DeCoito and Estaiteyeh[53] believed that online teaching on student achievement was generally considered negative by most teachers. This may stem from the fact that digital teaching approaches

are different and students are at diverse levels of psychological development, making the acceptance of TDC inconsistent.

In summary, the effect of TDC has been discussed from three aspects: the effect on students' ASE, the effect on students' LE and the effect on other student-related outcomes. When it came to the students' ASE and LE, four dimensions, including single method, mixed method, quasi-experiment and contradictory findings, were refined to clarify the effect of TDC from reported literature. In addition, except for the direct effect, a few studies also mentioned the indirect effect of TDC on LE through ASE. At last, the other student-related outcomes associated with TDC were summarized in accordance with students' academic achievement, motivation, satisfaction, learning effectiveness, behavior intentions and learning skills. The above discussion provides a multi-angle generalization of the effect of TDC on students' learning, which is conducive to affording a comprehensive perspective for future studies.

4. Discussion

4.1. Summary of key findings

This systematic review aimed to synthesize empirical evidence on the influence of TDC on students' ASE, LE, and other student-related outcomes. Based on 25 studies published between 2015 and 2025, several notable patterns and trends were identified. First, in terms of the first research question 1, the number of studies about this topic has been increasing after COVID-19, reaching a peak in 2023, and research in this field was mainly concentrated in developed regions. Besides, most of this research has been conducted at the higher education level, and the samples in these studies encompassed teachers and students from elementary school to university levels. Second, concerning research question 2, TPACK, SCT, SDT, and TAM were often used as theoretical foundations. Quantitative research and mixed-method research were the most commonly used research methods in this field, with questionnaires being the most frequently used measurement tool. In addition, the relationship between ASE and other outcomes was the most frequently studied topic in this field, but there was limited research on the impact of TDC on student learning.

Third, regarding research question 3, the core of this review, most studies reported a positive correlation between TDC and students' ASE. Teachers with higher digital competence were better able to create interactive, adaptive, and personalized learning environments, which in turn helped students build confidence in their learning abilities. Particularly, the integration of innovative technologies—such as augmented reality, mobile learning, and AI-based tools—was associated with increases in student autonomy and perceived learning control. This aligns with principles from Social Cognitive Theory, which identifies ASE as a key driver of academic success. Besides, TDC was consistently linked with students' LE, covering behavioral, emotional, and cognitive aspects. When teachers used digital tools to facilitate collaborative tasks, real-time feedback, and multimedia instruction, students were more likely to express interest and participate actively in learning activities. Evidence from both qualitative and quantitative studies supported this relationship, particularly in contexts where digital technologies were integrated in a student-centered manner. In addition, beyond ASE and LE, TDC also contributed to a range of other student outcomes, including academic achievement, motivation, learner satisfaction, and skill development. Notably, teachers who demonstrated strong digital competence were able to deliver more relevant and effective instructional designs that catered to students' needs and improved learning effectiveness.

However, not all studies reached the same conclusions. A few studies reported neutral or negative effects, especially in cases where digital tools were used without proper pedagogical strategies or where students lacked adequate support in online learning environments. These inconsistencies suggest that digital

competence alone is not sufficient. Moreover, how teachers apply digital skills in their instructional design and classroom practice is equally critical.

4.2. Critical reflection and research gaps

While this review provides strong evidence supporting the positive effects of TDC, several key limitations and gaps in the current literature were identified.

1) Geographical and socioeconomic bias. Most of the reviewed studies were conducted in developed countries, such as the United States, South Korea, and European nations. Only a few studies involved underdeveloped or low-income regions, even though these areas often face greater educational inequalities. The lack of context-specific research from such regions (e.g., rural China or Southeast Asia) limits the global applicability of current findings.

2) Neglect of primary and vocational education contexts. A significant number of studies focused on higher education, with limited attention to K–12 or vocational schools. Yet, the development of students' ASE and LE begins early in the lower education level. More empirical research is needed to explore how TDC affects students in basic education settings, especially in early grades, where foundational skills and motivation are formed.

3) Insufficient methodological diversity. The field still relies heavily on cross-sectional survey designs, with self-reported data appearing frequently. While it's useful for identifying trends, these designs are limited in establishing causality. Only a minority of studies adopted quasi-experimental or intervention designs. There is a clear need for longitudinal, experimental, and mixed-methods research to better understand the dynamic and long-term effects of TDC on student outcomes.

4) Inconsistent theoretical application. Although theories such as TPACK, SCT, and TAM were mentioned in several studies, many did not provide a clear or consistent theoretical framework. This limits the ability to explain how TDC operates in different educational settings or through which mechanisms it influences students. Future research should strengthen the integration of theory into study design and data interpretation.

5) Inconsistent and single measurement tools. Many instruments were self-developed or adapted, often without thorough validation. This poses challenges for comparing findings and building cumulative knowledge. There is a pressing need to develop reliable, valid, and widely accepted instruments to measure TDC and its related constructs. Besides, A wide range of measurement tools used in the reported review were questionnaires, and the qualitative research was just presented with a small proportion. There is no doubt that the single research method is difficult to obtain comprehensive results, and questionnaires do not provide as in-depth perspectives as interviews or other qualitative measurement tools. Future research should ideally combine qualitative and quantitative tools to make findings more convincing.

6) Lack of multi-variable and mediated models. Few studies investigated how TDC influences multiple variables simultaneously (students' ASE, LE and other related outcomes), or how its effects might be mediated by variables such as ASE or moderated by contextual factors like digital infrastructure or student characteristics. For example, only two studies examined the joint impact of TDC on ASE, LE, and learning achievement within a single framework. This reflects a missed opportunity to understand the complex interplay between teacher competence and student learning behavior.

4.3. Implications for future research and practice

4.3.1. Implications for research

This systematic review synthesized findings from 25 empirical studies of TDC and students' learning outcomes. First, the current literature exhibits a geographical and contextual bias toward well-resourced settings. Future studies should intentionally investigate TDC in economically undeveloped regions and rural educational contexts, where infrastructure limitations, access issues, and sociocultural factors may shape unique digital pedagogical practices and outcomes. Second, the heavy reliance on cross-sectional surveys limits causal inference. To better understand how TDC develops and influences students' outcomes over time, researchers should employ longitudinal, experimental, or quasi-experimental designs. Furthermore, adopting analytical approaches from complex systems theory—such as network analysis or latent growth modeling—could help capture the dynamic and reciprocal relationships between teachers' competence, students' motivation, and learning behaviors. Third, future work would benefit from stronger theoretical integration. Rather than applying isolated frameworks, researchers should test multilevel models that explicitly link TDC to student-centered learning processes, such as self-efficacy, cognitive engagement, and self-regulated learning. In particular, studies should investigate mediated and moderated pathways to clarify how—and for whom—TDC influences academic outcomes. Fourth, to enable meaningful cross-study comparisons and synthesis, the field urgently requires harmonized measurement instruments. We encourage the development and validation of standardized scales for assessing TDC and its downstream outcomes, drawing on established frameworks like DigCompEdu and TPACK while ensuring cultural and contextual adaptability.

4.3.2. Implications for practice

The consolidated evidence from this review offers feasible insights for educators, administrators, and policymakers. Teacher professional development should move beyond technical skills training to emphasize pedagogical design for technology integration. Programs should prepare teachers to use digital tools in ways that directly support students' self-efficacy, engagement, and achievements. Schools, particularly in under-resourced settings, must provide ongoing institutional support in the form of mentoring communities and reliable digital infrastructure. Such supports are critical for translating teacher competence into sustainable classroom practice. Policymakers should develop incentive structures and evaluation frameworks that link TDC to tangible improvements in student engagement and self-efficacy, rather than focusing solely on tool availability or teacher certification. This shift would promote greater equity in digital education reforms.

5. Conclusion

This systematic review examined 25 empirical studies published between 2015 and 2025 to explore how TDC influences students' ASE, LE, and other learning outcomes. When summarizing existing evidence, this review makes several important contributions to the field. First, it provided a comprehensive and structured synthesis that integrated findings across different countries, educational levels, sample features, research designs, theoretical frameworks, measurement tools and variable focus. Unlike many previous reviews that focused only on teacher training or technology use, this study highlighted the student-centered outcomes of TDC, emphasizing how students' psychological and behavioral responses are shaped by digitally competent teaching.

Second, when it came to the variable relations, the findings confirmed that TDC, when meaningfully integrated into teaching practice, is generally associated with improvements in students' learning beliefs,

motivation, participation, and achievement. This relationship was especially evident in studies using quasi-experiments and mixed-methods approaches, indicating both direct and indirect pathways of influence.

Third, the review identified critical gaps in the literature—geographical imbalances, limited focus on K–12 education, insufficient methodological diversity, inconsistent theoretical grounding, a lack of various and validated measurement tools and few multivariable and mediated models. These findings are not merely descriptive but offer strategic guidance for future research, pointing to areas where empirical efforts can yield the greatest impact. For example, further investigation is needed in economically underdeveloped areas, where digital inequalities may amplify or mitigate the effects of TDC.

Fourth, this review contributed to both research and practice. On a research level, it calls for more longitudinal designs and multi-variable models to study how TDC affects students' learning from various aspects in a long-term digital instructional environment. On a practical level, it urges teacher training programs and education systems to treat digital competence as not only a technical skill, but a pedagogical and psychological tool for empowering students.

Fifth, there are some research novelties that need to be articulated. As for the scientific novelty, while previous reviews have examined self-efficacy or learning engagement, this is the first systematic review to integrate findings from empirical studies that specifically explore the relationship between academic self-efficacy, learning engagement as well as other learning outcomes and TDC. Besides, our synthesis moves beyond direct-effect models and offers a novel, mediating conceptual model that reveals the psychological and behavioral pathways (i.e., TDC → self-efficacy → engagement). Concerning practical novelty, we uniquely identify that students in economically underdeveloped regions may benefit much from TDC development. The practical insight can help policymakers direct resources and training where they are needed to address educational inequality.

In conclusion, as education systems continue to adapt to a rapidly digitized world, ensuring that teachers possess the knowledge, skills, and mindset to use digital tools effectively becomes essential. This review demonstrates that improving TDC is not an end in itself—it is a means to enhance student development, engagement, and achievement. Future research should continue to explore how TDC operates in diverse settings and interacts with various student-level and contextual variables, in order to build more inclusive, effective, and learner-centered digital education environments. Generally speaking, this review affirms the development potential of TDC in an education-informatization society and calls for deeper, broader, and more contextualized studies to fully understand and realize its educational benefits.

Author contributions

Conceptualization, Ruizhu, Luo.; methodology, Ruizhu, Luo.; software, Ruizhu, Luo.; validation, Ruizhu, Luo., Hazrati Binti Husnin. and Mohammad Hafiz Bin Zaini.; formal analysis, Ruizhu, Luo.; investigation, Ruizhu, Luo.; resources, Ruizhu, Luo.; data curation, Ruizhu, Luo.; writing—original draft preparation, Ruizhu, Luo.; writing—review and editing, Hazrati Binti Husnin.; visualization, Hazrati Binti Husnin.; supervision, Mohammad Hafiz Bin Zaini.; project administration, Ruizhu, Luo. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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Appendix A

Examples of Data Extraction Form

Author (Year)	Country	Education Level	Theoretical Framework	Teacher DC Scale	Self-Efficacy Scale	Engagement Scale	Other Outcomes Scale	Sample	Research Method	Key Findings	Appendix
Al-khresheh, M. H. Alkursheh, T. O. (2024)	Saudi Arabian	University	TPACK SCT	Blackboard—as a language-learning instrument—provides teachers with a flflexible platform for developing interactive and engaging language lessons.	6-item questionnaire;	Blackboard use; 16 targeted questions to gauge students' engagement with Blackboard in English-language learning.	35-item questionnaire to evaluate students' English proficiency	Universities were deliberately selected using a purposive selection;590 students were stratified random sampled.	Quantitative correlational design	"Blackboard", "self-efficacy" positively inflfluences "English profificiency" ; "Blackboard", "self-efficay" positively inflfluences "achievement" ; "English proficiency" positively influences "achievement.	Blackboard and self-efficacy are independent variables, while achievement is a dependent variable; proficiency is both a dependent variable and a mediating variable.
Baroudi, S. Shaya, N.(2022)	six Arab countries	K-12 teachers	N/A	Teachers' Sense of Efficacy Teaching Scale with 32 items (online teaching)	N/A (There is no scale, but other tools have been used to study this variable.)	N/A	N/A	150 K-12 teachers	Mixed methods design: queationnaire and interview	Student engagement had the weakest correlation between the four scales with the overall self-efficacy;teachers in the Arab world are still confused about ways to increasing students' engagement in the lesson and the extent that this would have on their online TSE.	This study examined teachers' self-efficacy in online teaching, but the findings were inconsistent with previous research conclusions.
Bawa, P. Watson, S. L. Watson, W.(2018)	United States	University	Self-determination Theory	N/A	N/A	N/A Interview and focus group	N/A	95 students	Qualitative research	Teachers' ability to screen, evaluate, and integrate digital game content largely influences the effectiveness of these resources in supporting student motivation and engagement.	

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Beirnes, S.(2022)	United States	Elementary school	Engagement Theory	N/A	N/A (There is no scale, but journals have been used.)	N/A Videos	N/A Reflective journals	11 students	Qualitative research	The virtual format also limited the ability for students to receive help and for the music teacher to use implicit teaching strategies to easily correct improper technique.	Student-centered teaching enhances students' self-efficacy and engagement, but virtual teaching formats limit the use of certain teaching strategies, contradicting some research findings.
Bi, J. Izadpanah, S. Mohammadi, Z. Rezaei, Y. M.(2024)	Zanjan City	High school	N/A	N/A (Teachers participated in teaching activities, but there were no scales or qualitative assessments.)	Lent et al.'s self-efficacy questionnaire with 27 items	N/A	Harter's AM questionnaire with 33 items; Benishek et al.'s AP questionnaire with 40 items	52 male students	Quantitative research: Quasi-experimental design.	The use of technology in education has benefited these significant facets of students' learning experiences, including AM (academic motivation), AP (perseverance) and ASE.	The teacher utilized a variety of technology instruments to enhance the teaching process, including smart boards, data projectors, the Internet, social networks, CDs, Microsoft Word, and PowerPoint.
Cheung, G. Wan, K. Chan, K.(2018)	Hong Kong	University	TPACK UTAUT（Unified Theory of Acceptance and Use of Technology）	A questionnaire with 50 items designed based on TPACK and UTAUT; focus group interviews	N/A	N/A	N/A	17 teachers	concurrent mixed method design	Teachers' digital competencies (especially the multiple dimensions of TPACK) significantly impact student learning outcomes, engagement, and learning self-efficacy by improving instructional interactivity, assessment accuracy, and classroom	Although this article does not measure student performance, two theoretical models explore the efficiency of teachers' use of clickers (students' response systems, or SRS)

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										engagement.	and analyze the impact of teachers' technical abilities on teaching and student learning. This article does not directly measure teachers' digital competence, but provides feedback from the students' perspective. Through two questionnaires and interviews, it is clear that teachers' DST teaching designs can enhance students' digital literacy, writing efficacy, and engagement.
Chiang, M. H. (2022)	Taiwan	College	DST (digital storytelling)	N/A (Digital Teaching Design by Teachers - DST)	Self-Efficacy of Using English as International Language; open ended survey and a group interview	N/A	Digital Literacy Scale	18 students	mixed case-study approach	Teachers designed tasks with multimodal features through DST, and this design directly enhanced students' motivation, digital literacy, and writing confidence (academic self-efficacy). Teachers' digital competence was shown to indirectly and positively influence students' learning effectiveness and affective engagement.	
Czok, V. Krug, M. Müller, S. Huwer, J. Weitzel, H.(2023)	Germany	University	TPACK DiKoLAN	N/A (An AR teaching environment based on games designed by teachers)	Motivation Scale; Computer Self-Efficacy Scale (CSE)	User Engagement Scale (Short Form)	Technology Acceptance Scale; Cognitive Load Scale; Knowledge Test; ESD Motivation and Action Scale	203 pre-service teachers	Quantitative research: A quasi-experimental design	Teacher-designed AR teaching environments based on the TPACK and DiKoLAN frameworks significantly increased students' motivation, user engagement, and self-efficacy, exemplifying the indirect impact of teachers' digital	2×2 experimental design (with/without AR × with/without games); Total sample of 203 new university teacher education students;Three

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										competence on students' learning outcomes.	measurements (pre-test/mid-test/post-test), multiple scales.
DeCoito, I. Estaiteyeh, M.(2022)	Canada	Elementary and secondary	TPACK; Self-efficacy theory	Questionnaire: 24-item scale and 5 open-ended questions	N/A	N/A (Describe it from the teacher's perspective)	N/A	75 Grade 1–12 science/STEM teachers	Mixed research: questionnaire survey included quanti data and quali data	The impact of online teaching on student outcomes was generally considered negative by most teachers,including student-student engagement,student-teacher engagement,students achievement.	This finding is inconsistent with previous research conclusions that online teaching has a positive impact on students.
Gerick, J. Eickelmann, B. Bos, W.(2017)	Australia, Germany, Norway and the Czech Republic	Secondary school	SCT; Educational Effectiveness Research, EER	Teacher Questionnaire	N/A	N/A	Computer and Information Literacy (CIL) Test	9500 students and their teachers.15 teachers each school.	Quantitative research	students' computer and information literacy (CIL) was significantly associated with school-level aggregates of teachers' ICT-related attitudes and self-efficacy. In particular, teachers' positive views of ICT had a positive impact on students' CIL outcomes, suggesting that a digitally supportive teaching culture can enhance students' digital competence development.	This paper used a multilevel linear model for data analysis. Although there was no direct test of the impact of teachers' ICT on students, the ICT attitudes of teachers throughout the school reflected the school's technological culture (ICT-enriched teaching climate), which influenced the overall benefits to students.
Gunawan, S. Shieh, C. J.(2023)	Taiwan	University	Multiple Intelligences Theory;Self-Efficacy	N/A (There was no direct measurement of teachers, but there was	Self-Efficacy Scale	N/A	Learning Confidence Scale;Teaching with	276 students	Quantitative research	Technology + Multiple Intelligences (MI) instructional design is effective in increasing	

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			Theory;Technology Integration in Education	measurement of teachers' technology integration behavior.)			Multiple Intelligences Approach Scale			student self-efficacy,motivation, and performance, with high teacher expectations and contextualized technology integration playing a central role.	
Habibi, A. Mukminin, A. Sofyan, Setiono, P.(2019)	Indonesia	Vocational technical high school	Theory of Planned Behavior, TPB	Behavioral Beliefs Scale;Normative Beliefs Scale;Control Beliefs Scale	N/A	N/A (No scale, but assessed through interviews)	N/A	765 teachers for scale,10 teachers for interview	Mixed research	In quanti:strong behavioral beliefs toward ICT's benefits for student learning;In quali:ICT is widely recognized by teachers as improving learning, stimulating student engagement, and meeting diverse learning needs.	While the study did not directly assess student outcomes, it indicated that teachers' digital competence—particularly beliefs and confidence—indirectly impacts student engagement and learning effectiveness.
Hazzam, J. Wilkins, S.(2023)	United States	University	Engagement Theory	Lecturer technology use scale	Self-efficacy four-item scale	Sun and Rueda's (2012) five-item scale	Hosen et al.'s (2021) five-item scale for learning performance; Six-item student satisfaction scale	659 students	Quantitative research(SEM)	Lecturer charismatic leadership and technology use are each significantly related to student engagement, which predicts students' learning performance and satisfaction. Further, lecturer charismatic leadership and technology use significantly improves students' behavioral engagement.	
Hu, B. Li, Y.(2025)	China	University	Technology Acceptance Model; Unified	N/A	N/A	N/A	N/A	100 art students for survey and 30 students for	Mixed research	A 19-week Intervention Design and Implementation (IDI)	This paper conducts quantitative

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			Theory of Acceptance and Use of Technology;Theory of Planned Behavior					intervention		confirms the positive role of systematic guidance and training of digital drawing tool in significantly improving students' perceived enjoyment, self-efficacy, effort expectancy, and behavioral intentions.	research in the first phase, using questionnaires to study students' internal and external motivations for using digital tools. The second phase is qualitative + quantitative, finding that teachers' teaching interventions can enhance students' sense of efficacy and behavior.
Kim, J. Kim, V.(2024)	South Korea	University	Self-Determination Theory;Self-Efficacy Theory;Sociocultural Theory	N/A (Mentioned the use of online platforms for teachers)	academic writing motivation questionnaire (AWMQ)	N/A Open-ended questionnaire	students' class experience questionnaire(SCEQ)	126 students	Mixed research	The impact of teachers' digital competence was not directly explored in the study, but the importance of teacher feedback and use of technology (e.g., the Piazza platform) on student motivation and engagement was emphasized. Teachers need to be able to design effective online activities and provide targeted support, especially for beginning students.	