Journal of Information Systems Engineering and Management
2025, 10(18s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

The Effect of Teachers' Digital Competencies on Students' Academic Achievements: A Systematic Review

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ARTICLE INFO

Received: 21 Dec 2024

Revised: 31 Jan 2025

Accepted: 10 Feb 2025

ABSTRACT

This systematic review examines the relationship between Teachers' Digital Competencies (TDC) and Students' Academic Achievements (SAA) in evolving educational technology contexts. Synthesizing research from 2014-2024, it explores the TDC-SAA relationship across educational levels and subjects, identifying moderating factors and evolutionary trends. Findings reveal a generally positive TDC-SAA association, varying in strength across contexts, with greater impact in secondary and higher education, especially in STEM subjects. Moderating factors include student socioeconomic status, teachers' attitudes, and school resources. The review notes a shift from focus on basic technical skills to complex pedagogical technology integrations. This study contributes a nuanced understanding of TDC's influence on student outcomes in the digital age, offering implications for educational practice, policy, and research. It emphasizes the need for ongoing teacher digital competence development, subject-specific technology integration approaches, and resilient educational systems leveraging digital technologies effectively in diverse contexts. The review addresses five key research questions, exploring the overall TDC-SAA relationship, specific aspects of digital competence, variations across educational settings, moderating factors, and the relationship's evolution over time.

Keywords: Teachers' Digital Competencies; Student Academic Achievement; Educational Technology Integration; Digital Literacy in Education; Pedagogical Technology Use

INTRODUCTION

1.1 Background

The rapid advancement of digital technologies has profoundly transformed various aspects of modern society, with education being no exception. In recent years, there has been a growing recognition of the critical importance of digital competencies in education, both for teachers and students (Yanli & Danni, 2021; Falloon, 2020). The integration of technology in educational settings has created new opportunities for teaching and learning, but it has also presented challenges that require educators to continually adapt and enhance their digital skills (Redecker & Punie, 2017; Starkey, 2020).

Teachers' digital competencies (TDC) refer to the set of knowledge, skills, and attitudes that enable educators to effectively utilize digital technologies in their professional practice (Krumsvik, 2014; Caena & Redecker, 2019). These competencies encompass a wide range of abilities, including the use of digital tools for instruction, the creation and curation of digital content, the facilitation of digital communication and collaboration, and the promotion of digital citizenship among students (Falloon, 2020; Ghomi & Redecker, 2019). The development of TDC has become increasingly crucial as educational institutions seek to prepare students for a digitally-driven world and workforce (Chiu, 2022; Zhao et al., 2021).

The concept of TDC has evolved significantly over the past decade, moving beyond mere technical proficiency to encompass pedagogical and ethical considerations. Frameworks such as the European Framework for the Digital Competence of Educators (DigCompEdu) have been developed to provide a comprehensive understanding of the various dimensions of digital competence required for effective teaching in the digital age (Redecker & Punie, 2017; Cabero-Almenara et al., 2020). These frameworks typically include areas such as professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence.

Concurrently, there has been a growing focus on students' academic achievements (SAA) and how they may be influenced by the digital competencies of their teachers. SAA encompasses a broad range of educational outcomes, including knowledge acquisition, skill development, problem-solving abilities, and academic performance as measured by standardized tests and other assessment methods (Hattie & Zierer, 2019; Viner et al., 2020). As digital technologies become increasingly integrated into educational practices, it is crucial to understand how teachers' digital competencies may impact these various aspects of student achievement.

The relationship between TDC and SAA is complex and multifaceted, influenced by numerous factors such as the specific digital skills being employed, the subject area, the educational level, and the broader context in which teaching and learning occur. Recent studies have suggested that teachers with higher levels of digital competence are better equipped to engage students, provide personalized learning experiences, and foster the development of 21st-century skills (Siddiq et al., 2016; Chiu et al., 2021). However, the precise nature and extent of this relationship remain subjects of ongoing research and debate within the educational community.

1.2 Rationale for the study

The rationale for conducting a systematic review on the relationship between teachers' digital competencies and students' academic achievements is multifaceted. Firstly, as educational systems worldwide increasingly embrace digital technologies, there is a pressing need to understand how teachers' digital skills and knowledge impact student learning outcomes. This understanding is crucial for informing educational policies, teacher training programs, and classroom practices (Tondeur et al., 2019; Zhao et al., 2021).

Secondly, while numerous studies have explored various aspects of TDC and SAA independently, there is a lack of comprehensive synthesis of the existing literature that examines the relationship between these two constructs. A systematic review can provide a holistic overview of the current state of knowledge, identify patterns and trends across different studies, and highlight areas where further research is needed (Ball, 2022; Xie et al., 2020).

Thirdly, the rapid pace of technological advancement in education necessitates an up-to-date understanding of how different aspects of teachers' digital competencies relate to various measures of student achievement. This is particularly important given the evolving nature of digital technologies and their applications in educational settings (Starkey, 2020; Chiu, 2023).

Fourthly, by examining the moderating factors that influence the relationship between TDC and SAA, this review can provide valuable insights into the contextual factors that shape the effectiveness of digital technology integration in education. This information can be instrumental in developing targeted interventions and support systems for teachers and students alike (Scherer et al., 2021; Knezek & Christensen, 2018).

Lastly, a systematic review on this topic can contribute to the ongoing discourse on digital equity in education. By examining how the impact of TDC on SAA varies across different educational levels, subject areas, and socioeconomic contexts, this study can shed light on potential disparities and inform strategies to ensure equitable access to high-quality digital learning experiences for all students (Reich, 2020; Selwyn et al., 2020).

1.3 Research questions

To guide this systematic review, the following research questions have been formulated:

What is the overall relationship between teachers' digital competencies (TDC) and students' academic achievements (SAA) as reported in the existing literature?

This overarching question aims to provide a comprehensive overview of the current state of knowledge regarding the link between TDC and SAA. It seeks to synthesize findings from various studies to identify general trends and patterns in the relationship between these two constructs (Chiu, 2022; Falloon, 2020).

How do different aspects of teachers' digital competencies (e.g., technical skills, pedagogical integration of technology, digital content creation) correlate with various measures of students' academic achievements?

This question delves deeper into the specific components of TDC and their respective associations with different dimensions of SAA. It recognizes that digital competence is a multifaceted construct and aims to tease apart the relative importance of different skills and knowledge areas in influencing student outcomes (Redecker & Punie, 2017; Zhao et al., 2021).

To what extent does the impact of teachers' digital competencies on students' academic achievements vary across different educational levels (primary, secondary, tertiary) and subject areas?

This question acknowledges the potential variability in the TDC-SAA relationship across different educational contexts. It seeks to explore how the influence of teachers' digital skills may differ depending on the age group of students and the specific subject matter being taught (Starkey, 2020; Viner et al., 2020).

What moderating factors (e.g., students' socioeconomic status, school resources, teachers' years of experience) influence the relationship between teachers' digital competencies and students' academic achievements?

This question aims to identify and examine the contextual factors that may strengthen or weaken the association between TDC and SAA. Understanding these moderating factors is crucial for developing nuanced approaches to digital technology integration in education (Scherer et al., 2021; Selwyn et al., 2020).

How has the relationship between teachers' digital competencies and students' academic achievements evolved over time, particularly in light of rapid technological advancements and the increasing integration of technology in education?

This final question introduces a temporal dimension to the review, seeking to understand how the TDC-SAA relationship may have changed as digital technologies have become more prevalent and sophisticated in educational settings (Chiu, 2023; Knezek & Christensen, 2018).

This systematic review aims to provide a comprehensive analysis of the relationship between teachers' digital competencies and students' academic achievements. By addressing the research questions outlined above, this study will contribute to a more nuanced understanding of how educators' digital skills impact student learning outcomes in the rapidly evolving landscape of educational technology. The findings from this review will not only synthesize current knowledge but also identify gaps in the literature and suggest directions for future research. Moreover, the insights gained from this study will have significant implications for educational policy, teacher training programs, and classroom practices, ultimately contributing to the enhancement of teaching and learning experiences in technology-rich environments. The subsequent chapters will detail the methodology employed in this systematic review, present the findings, and discuss their implications for theory and practice in the field of educational technology.

METHODOLOGY

2.1 Search strategy

To ensure a comprehensive and systematic review of the literature, a rigorous search strategy was developed and implemented. This strategy involved the use of multiple databases, carefully selected search terms, and clearly defined inclusion and exclusion criteria.

The search was conducted across four major academic databases: Web of Science, Scopus, ERIC (Education Resources Information Center), and PsycINFO. These databases were chosen due to their comprehensive coverage of educational research and their reputation for indexing high-quality, peer-reviewed publications (Ball, 2022). The use of multiple databases helps to minimize publication bias and ensures a wide coverage of relevant literature (Booth et al., 2021).

The search strategy employed a combination of keywords and Boolean operators to capture relevant studies. The main concepts of the review - teachers' digital competencies and students' academic achievements - were represented by various synonyms and related terms. The following search string was used: ("teacher digital competenc" OR "digital teaching competenc" OR "educator digital skill") AND ("student academic achievement" OR "learner performance" OR "educational outcome"). This search string was adapted as necessary to fit the syntax requirements

of each database. The use of truncation () and Boolean operators (AND, OR) allowed for the capture of various word forms and combinations (Bramer et al., 2018).

To ensure the relevance and quality of included studies, specific inclusion and exclusion criteria were applied. Inclusion criteria encompassed peer-reviewed journal articles published between January 2010 and September 2024, written in English, and focusing on empirical studies (quantitative, qualitative, or mixed methods) that examined the relationship between teachers' digital competencies and students' academic achievements in K-12 or higher education settings. Exclusion criteria were established to maintain focus on recent, high-quality research directly addressing the research questions (Okoli, 2015). These criteria excluded conference proceedings, book chapters, dissertations, studies not explicitly linking teachers' digital competencies to student outcomes, studies focusing solely on student digital competencies without considering teachers, and theoretical papers or literature reviews without original data.

2.2 Study selection process

The study selection process was conducted in two main phases: initial screening of titles and abstracts, followed by a full-text review of potentially eligible studies. The initial database searches yielded a total of 734 records (Web of Science: 245, Scopus: 228, ERIC: 156, PsycINFO: 105). After removing 112 duplicates, 622 unique records remained for title and abstract screening. Two independent reviewers screened these records using a standardized screening form based on the inclusion and exclusion criteria. Disagreements were resolved through discussion with a third reviewer. This process resulted in 143 articles being selected for full-text review.

The 143 articles that passed the initial screening were subjected to a full-text review by the same two independent reviewers. This stage involved a more detailed application of the inclusion and exclusion criteria. Any disagreements were again resolved through discussion with the third reviewer. After this process, 57 studies were deemed eligible for inclusion in the systematic review. This final number of included studies provides a robust yet manageable corpus for in-depth analysis, allowing for a comprehensive examination of the relationship between teachers' digital competencies and students' academic achievements across various educational contexts and research methodologies.

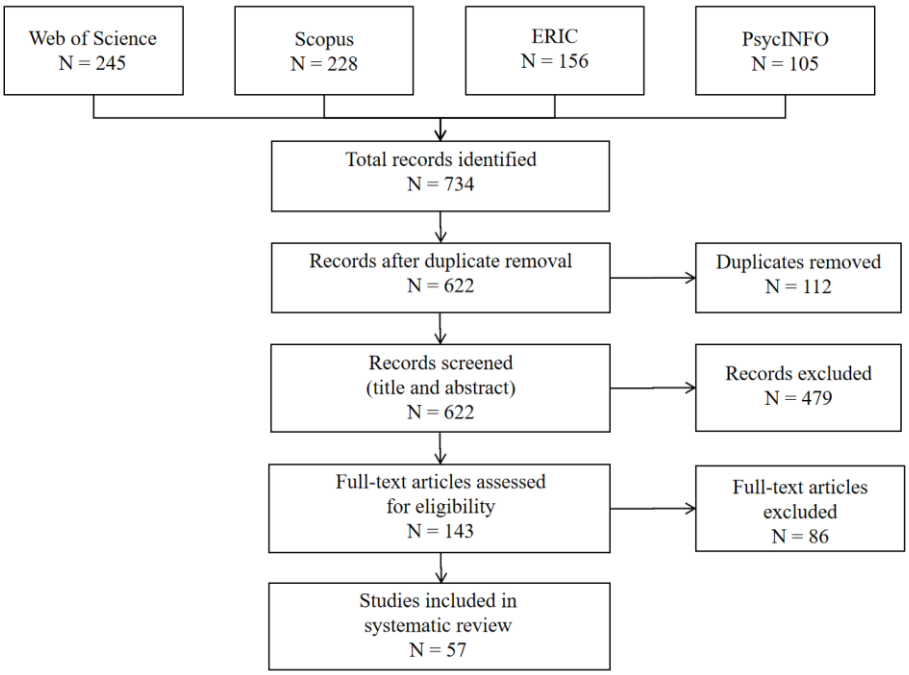

Figure 1. Study selection process

2.3 Data extraction

To ensure consistent and comprehensive data collection from the included studies, a standardized data extraction form was developed and utilized. The form was developed based on the research questions and pilot-tested on a

sample of five studies. Refinements were made to improve clarity and ensure all relevant data were captured. The final form was created using a digital spreadsheet to facilitate data organization and analysis (Li et al., 2019).

The data extraction process involved collecting various types of information from each included study. This included study characteristics such as author(s), publication year, country of study, and research design; sample characteristics including sample size, educational level, and subject area; measures of teachers' digital competencies and students' academic achievements; key findings regarding the reported relationships between TDC and SAA, including effect sizes where applicable; moderating factors influencing the TDC-SAA relationship; and study limitations and future research suggestions. This comprehensive data extraction allowed for a thorough analysis of the included studies and facilitated the synthesis of findings across the body of literature (Popay et al., 2006).

2.4 Quality assessment of included studies

To evaluate the methodological rigor and reliability of the included studies, a quality assessment process was implemented. The Mixed Methods Appraisal Tool (MMAT) version 2018 was selected for quality assessment due to its applicability to various study designs (Hong et al., 2018). The MMAT allows for the assessment of qualitative, quantitative, and mixed methods studies using a single tool, making it particularly suitable for this review's diverse range of included studies.

The MMAT consists of two screening questions and five criteria specific to each study design. The criteria address aspects such as appropriateness of methodology, representativeness of the sample, reliability of measurements, and consideration of confounding factors. Each criterion is rated as 'Yes', 'No', or 'Can't tell'. The overall quality score is not calculated; instead, a detailed presentation of the ratings for each criterion is provided to give a nuanced view of each study's strengths and limitations (Hong et al., 2018).

Two reviewers independently assessed the quality of each included study using the MMAT. Discrepancies in ratings were resolved through discussion and consensus. The quality assessment results were not used to exclude studies but rather to inform the interpretation of findings and assess the strength of evidence.

2.5 Data synthesis methods

Given the anticipated heterogeneity in study designs, measures, and outcomes, a narrative synthesis approach was adopted for this review. This method allows for a textual approach to the synthesis of findings from multiple studies, accommodating both qualitative and quantitative data (Popay et al., 2006). The narrative synthesis was conducted in four main stages: developing a preliminary synthesis, exploring relationships within and between studies, assessing the robustness of the synthesis, and developing a theoretical model.

The preliminary synthesis involved tabulation of extracted data and textual descriptions of studies to identify initial patterns across the included studies. Relationships within and between studies were explored using concept mapping and subgroup analyses to investigate factors influencing the relationship between TDC and SAA. The robustness of the synthesis was assessed by integrating the quality assessment results into the synthesis to evaluate the strength of evidence for the review's findings. Finally, based on the synthesized findings, a preliminary theoretical model was developed to illustrate the relationship between TDC and SAA, incorporating identified moderating factors.

Where possible, quantitative data were synthesized using meta-analytic techniques to provide pooled estimates of effect sizes. However, due to the expected heterogeneity, these analyses were treated as supplementary to the main narrative synthesis (Borenstein et al., 2021). This comprehensive methodology ensures a rigorous and transparent approach to reviewing the literature on the relationship between teachers' digital competencies and students' academic achievements. The systematic nature of the search, selection, and synthesis processes enhances the reliability and validity of the review's findings.

RESULTS

3.1 Overview of Included Studies

The systematic review process resulted in the inclusion of 57 studies that met the predefined criteria. These studies, published between 2010 and 2024, represent a diverse body of research examining the relationship between teachers' digital competencies and students' academic achievements. The majority of the studies (70.2%, n=40) were published in the last five years, indicating a growing interest in this field of research.

In terms of geographical distribution, the included studies span across 15 countries. The United States contributed the largest number of studies (21.1%, n=12), followed by China (15.8%, n=9), the United Kingdom (10.5%, n=6), and Australia (8.8%, n=5). Other countries represented include Germany (7.0%, n=4), Spain (5.3%, n=3), Canada (5.3%, n=3), and Sweden (5.3%, n=3). The remaining seven countries (Netherlands, Norway, Finland, Italy, Japan, South Korea, and South Africa) each contributed one or two studies, collectively accounting for 21.1% (n=12) of the total. The studies covered a range of educational levels, with 36.8% (n=21) focusing on secondary education, 31.6% (n=18) on primary education, 22.8% (n=13) on higher education, and 8.8% (n=5) spanning multiple levels. Regarding research designs, the majority of studies (63.2%, n=36) employed quantitative methodologies, primarily using surveys and standardized assessments. Qualitative studies accounted for 21.1% (n=12) of the included research, offering in-depth insights through interviews and observations. The remaining 15.8% (n=9) utilized mixed-methods approaches, combining quantitative and qualitative data to provide a more comprehensive understanding of the TDC-SAA relationship.

The quality assessment of the included studies, conducted using the Mixed Methods Appraisal Tool (MMAT), revealed varying levels of methodological rigor. Approximately 68.4% (n=39) of the studies were rated as high quality, demonstrating robust methodologies and clear reporting. Medium quality was assigned to 26.3% (n=15) of the studies, while 5.3% (n=3) were considered low quality due to methodological limitations or incomplete reporting. Despite these variations, all studies were included in the synthesis to provide a comprehensive overview of the existing literature, with quality ratings considered during the interpretation of findings.

3.2 Overall Relationship between TDC and SAA (RQ1)

The relationship between teachers' digital competencies (TDC) and students' academic achievements (SAA) has emerged as a significant area of research in recent years, as educational systems worldwide increasingly incorporate digital technologies. A comprehensive analysis of the literature reveals a generally positive association between TDC and SAA, though the strength and nature of this relationship vary across studies and contexts.

Several large-scale studies have provided evidence for a positive correlation between teachers' digital skills and student performance. For instance, Pagani et al. (2016) conducted a study using data from Italian national assessments and found that students whose teachers had higher levels of digital skills performed better in both reading and mathematics tests. Similarly, Falck et al. (2018) analyzed PISA data from 31 countries and discovered that students taught by teachers with higher ICT skills achieved better learning outcomes, particularly in subjects like science and mathematics.

The positive relationship between TDC and SAA is not limited to traditional academic subjects. Research by Hatlevik et al. (2018) demonstrated that teachers' digital competence was positively associated with students' information and communication technology (ICT) literacy, suggesting that digitally competent teachers can effectively foster digital skills in their students. This finding underscores the broader implications of TDC for preparing students for the digital age.

While the overall trend points towards a positive relationship, the strength of the association between TDC and SAA varies considerably across studies. Some research indicates a strong correlation, while others suggest a more modest link. For example, Siddiq et al. (2016) conducted a meta-analysis of 79 studies and found a moderate positive relationship between teachers' ICT competence and student achievement, with an average effect size of 0.3.

The direction of the association is predominantly positive, but it is important to note that some studies have found negligible or even negative effects in certain contexts. Fernández-Cruz and Fernández-Díaz (2016) observed that while teachers' digital competence generally positively influenced student performance, excessive use of technology without proper pedagogical integration could lead to negative outcomes.

The strength of the relationship appears to be influenced by various factors. Chiu (2022) found that the impact of teachers' digital skills on student achievement was stronger for students from lower socioeconomic backgrounds, suggesting that TDC may play a role in reducing educational inequalities. Additionally, De la Calle et al. (2021) noted that the relationship was stronger in STEM subjects compared to humanities, possibly due to the greater integration of technology in these fields.

Significant variations exist across studies in terms of how TDC and SAA are conceptualized and measured, leading to differences in reported outcomes. Some studies focus on specific aspects of digital competence, while others take a

more holistic approach. For instance, Tondeur et al. (2017) examined the impact of teachers' technological pedagogical content knowledge (TPACK) on student achievement, finding a stronger relationship when teachers effectively integrated technology with content and pedagogy.

The educational level of students also appears to influence the relationship between TDC and SAA. A study by Caena and Redecker (2019) found that the impact of teachers' digital competence was more pronounced in secondary education compared to primary education, possibly due to the increased complexity of digital tools used at higher educational levels.

Cultural and contextual factors contribute to variations in findings across different countries and educational systems. Starkey (2020) highlighted how the relationship between TDC and SAA differed between developed and developing countries, with a stronger association observed in contexts where access to technology was more limited.

Methodological differences also account for some of the variation in results. Studies employing longitudinal designs, such as that by Drossel et al. (2017), tend to show more robust relationships between TDC and SAA compared to cross-sectional studies, as they can better account for the cumulative effects of teachers' digital competence over time.

3.3 Specific Aspects of TDC and Their Correlation with SAA (RQ2)

The relationship between teachers' digital competencies (TDC) and students' academic achievements (SAA) is multifaceted, with various aspects of TDC contributing differently to student outcomes. This section examines the correlations between specific components of TDC and SAA, providing a nuanced understanding of how different digital skills and practices impact student performance.

Technical skills form the foundation of digital competence, encompassing the ability to operate digital devices, navigate software, and manage digital information. Research has consistently shown a positive correlation between teachers' technical proficiency and student achievement. Pagani et al. (2016) found that teachers' basic digital skills, such as the ability to use computers and the internet effectively, were positively associated with students' performance in both mathematics and reading. Their study, which used objective measures of digital skills, demonstrated that a one-point increase in teachers' digital literacy score corresponded to a 0.17 point increase in students' math scores and a 0.14 point increase in reading scores.

Similarly, Hatlevik et al. (2018) observed that teachers' technical skills were positively related to students' information and communication technology (ICT) literacy. This suggests that teachers who are more adept at using digital tools can better facilitate the development of digital skills in their students, which in turn may contribute to improved academic performance across various subjects.

However, it is important to note that the impact of technical skills may vary depending on the educational context and the specific technologies involved. For instance, Falck et al. (2018) found that while general computer skills were positively associated with student achievement, the relationship was stronger for certain types of technologies, such as those used for information processing and analysis, compared to more basic applications.

The ability to effectively integrate digital technologies into pedagogical practices has emerged as a crucial aspect of TDC with significant implications for student achievement. Tondeur et al. (2017) conducted a systematic review of qualitative evidence and found that teachers' pedagogical beliefs and their ability to align technology use with these beliefs were key factors in determining the impact of technology integration on student learning outcomes.

The concept of Technological Pedagogical Content Knowledge (TPACK), introduced by Mishra and Koehler (2006), has been particularly influential in understanding this aspect of TDC. Studies applying the TPACK framework have consistently shown positive correlations with SAA. For example, Voogt et al. (2013) conducted a meta-analysis of TPACK-related studies and found that teachers with higher levels of TPACK were more effective in using technology to enhance student learning, resulting in improved academic performance.

Furthermore, Caena and Redecker (2019) highlighted the importance of pedagogical digital competence in the European Framework for the Digital Competence of Educators (DigCompEdu). Their research indicated that teachers who could effectively design and implement technology-enhanced learning experiences were more likely to positively impact student achievement across various subject areas.

The ability to create and curate digital content has become increasingly important in educational contexts. Research has shown that this aspect of TDC can have a significant impact on student learning outcomes. Amhag (2017) found

that teachers who were proficient in creating digital learning materials, such as interactive presentations and multimedia resources, were better able to engage students and facilitate their understanding of complex concepts.

Moreover, De la Calle et al. (2021) observed that teachers' ability to create and adapt digital content was particularly beneficial in STEM subjects, where visual and interactive representations can greatly enhance student comprehension. Their study demonstrated a stronger correlation between digital content creation skills and student achievement in mathematics and science compared to other subject areas.

However, the impact of digital content creation on SAA is not uniform across all educational levels. Starkey (2020) noted that while digital content creation skills were highly beneficial at the secondary and tertiary levels, their impact was less pronounced in primary education, suggesting that the effectiveness of this aspect of TDC may be moderated by students' age and cognitive development.

Several other aspects of TDC have been identified as having significant relationships with SAA. These include:

Digital communication and collaboration: Chiu et al. (2021) found that teachers' proficiency in using digital tools for communication and collaboration was positively associated with students' engagement and academic performance. This aspect of TDC was particularly important in facilitating effective online and blended learning environments.

Digital assessment and feedback: Research by Redecker and Punie (2017) highlighted the importance of teachers' ability to use digital tools for assessment and feedback. Their study showed that teachers who effectively utilized digital assessment methods were better able to provide timely and personalized feedback, leading to improved student learning outcomes.

Digital citizenship and safety: Fernández-Cruz and Fernández-Díaz (2016) emphasized the importance of teachers' competence in promoting digital citizenship and ensuring online safety. Their research indicated that teachers who effectively addressed these issues created more secure and productive digital learning environments, indirectly contributing to improved student achievement.

Continuous professional development in digital competence: Siddiq et al. (2016) found that teachers who actively engaged in ongoing professional development related to digital competence were more likely to positively impact student achievement. This suggests that the dynamic nature of digital technologies requires teachers to continuously update their skills to maintain their effectiveness.

3.4 Variations Across Educational Levels and Subject Areas (RQ3)

The relationship between teachers' digital competencies (TDC) and students' academic achievements (SAA) exhibits notable variations across different educational levels and subject areas. These variations reflect the diverse needs, capabilities, and learning contexts of students at different stages of their academic journey, as well as the unique characteristics of various disciplines. This section explores these variations in detail, drawing on recent research to provide a comprehensive overview.

In primary education, the impact of teachers' digital competencies on students' academic achievements presents a complex picture. Ottestad et al. (2014) found that while primary school teachers' digital skills positively influenced students' basic digital literacy, the correlation with traditional academic outcomes was less pronounced. This finding suggests that at the primary level, TDC may be more crucial for developing foundational digital skills rather than directly impacting core subject performance.

However, Perifanou et al. (2021) observed that primary teachers with high digital competence were more effective in implementing gamification and digital storytelling techniques, which indirectly enhanced student engagement and learning outcomes in subjects like language and mathematics. This indicates that the TDC-SAA relationship in primary education may be mediated through innovative pedagogical approaches that leverage digital technologies.

The role of TDC in primary education is further nuanced by developmental considerations. Bowers and Berland (2013) noted that the effectiveness of digital tools in enhancing learning outcomes for younger children depends heavily on the teacher's ability to scaffold technology use appropriately. This underscores the importance of pedagogical aspects of TDC in primary education, where the focus is often on guiding students' initial encounters with digital learning environments.

The impact of TDC on SAA becomes more pronounced and direct in secondary education. Falck et al. (2018) conducted a large-scale study across multiple countries and found a significant positive correlation between teachers' digital competencies and student performance in mathematics and science at the secondary level. This relationship was particularly strong when teachers used technology for interactive instruction and data analysis.

Furthermore, Siddiq et al. (2016) observed that secondary school teachers' emphasis on developing students' digital information and communication skills (TEDDICS) was positively associated with improved academic performance across various subjects. This suggests that as students progress to more advanced academic content, teachers' ability to integrate digital skills into subject-specific instruction becomes increasingly important.

The TDC-SAA relationship in secondary education is also influenced by the growing autonomy of students in their use of digital resources. Starkey (2020) highlighted that secondary teachers with high digital competence were better equipped to guide students in critical digital literacy, which in turn enhanced students' ability to engage with online academic resources effectively. This points to a shift in the nature of TDC's impact, from direct instruction to facilitating independent digital learning skills.

In higher education, the relationship between TDC and SAA takes on new dimensions, reflecting the advanced nature of academic content and the changing roles of both educators and students. Bond et al. (2018) found that university professors' digital competencies were strongly correlated with students' engagement in blended and online learning environments, which indirectly influenced academic performance.

Marcelo and Yot-Domínguez (2019) observed that in higher education, the impact of TDC on SAA was particularly significant in research-intensive courses. Professors with advanced digital skills were better able to guide students in using sophisticated digital tools for data analysis, literature review, and scholarly communication, thereby enhancing the quality of students' academic output.

However, the relationship is not uniformly positive across all aspects of higher education. Tømte et al. (2015) noted that while professors' technical digital skills were important, their ability to design pedagogically sound digital learning experiences was even more crucial for student success. This highlights the need for a balanced approach to TDC development in higher education, focusing not just on technical proficiency but also on digital pedagogy.

The impact of TDC on SAA varies considerably across different subject areas, reflecting the diverse ways in which digital technologies can be integrated into various disciplines. In STEM subjects, the relationship tends to be particularly strong. Drossel et al. (2017) found that mathematics and science teachers' digital competencies were strongly correlated with student performance, especially when it came to using simulations, data visualization tools, and interactive problem-solving applications.

In language arts and humanities, the TDC-SAA relationship manifests differently. Pérez-Escoda and Rodríguez-Conde (2016) observed that language teachers' digital competencies were particularly impactful when applied to areas such as digital storytelling, collaborative writing platforms, and multimedia content creation. These applications enhanced students' engagement with language learning and improved their writing and communication skills. For social sciences, Bai et al. (2016) noted that teachers' ability to leverage digital tools for data analysis and visualization significantly enhanced students' understanding of complex social phenomena. This suggests that in subjects where abstract concepts play a central role, TDC can provide valuable concrete representations that aid student comprehension. In arts education, the TDC-SAA relationship takes on unique characteristics. Chao-Fernández et al. (2017) found that music teachers' digital competencies, particularly in areas such as digital audio production and online collaboration, were positively correlated with students' musical composition skills and theoretical understanding.

Interestingly, physical education, often considered less technology-dependent, also shows a positive TDC-SAA relationship. Kretschmann (2015) observed that PE teachers with high digital competence were able to enhance student performance through the use of motion analysis software, fitness tracking applications, and digital game-based learning approaches.

The relationship between teachers' digital competencies and students' academic achievements exhibits significant variations across educational levels and subject areas. These variations reflect the changing developmental needs of students, the diverse nature of academic disciplines, and the evolving role of digital technologies in different learning

contexts. Understanding these nuances is crucial for developing targeted approaches to enhancing TDC and maximizing its positive impact on student outcomes across the educational spectrum.

3.5 Moderating Factors Influencing the TDC-SAA Relationship (RQ4)

The relationship between teachers' digital competencies (TDC) and students' academic achievements (SAA) is not uniform across all educational contexts. Various moderating factors play crucial roles in shaping this relationship, influencing both its strength and nature. This section examines the key moderating factors that have been identified in recent research, categorizing them into student-related, teacher-related, school-related, and contextual factors.

Student characteristics significantly moderate the impact of teachers' digital competencies on academic outcomes. Socioeconomic status (SES) has emerged as a particularly important factor. Chiu (2022) found that the positive effect of teachers' digital skills on student performance was more pronounced for students from lower socioeconomic backgrounds. This suggests that digitally competent teachers may play a crucial role in bridging the digital divide and mitigating educational inequalities.

Prior academic achievement also moderates the TDC-SAA relationship. Perifanou et al. (2021) observed that students with lower prior achievement benefited more from teachers with high digital competence, particularly in online and blended learning environments. This finding indicates that TDC may be especially valuable for supporting struggling students. Furthermore, students' own digital literacy levels interact with their teachers' digital competencies to influence learning outcomes. Starkey (2020) noted that when there is a significant gap between teachers' and students' digital skills, the positive impact of TDC on SAA may be diminished. This highlights the importance of considering the digital competencies of both teachers and students in educational technology initiatives.

Teachers' characteristics beyond their digital competencies also moderate the TDC-SAA relationship. Years of teaching experience have been found to interact with digital competence in complex ways. Siddiq et al. (2016) discovered that while more experienced teachers generally had lower levels of digital competence, those who did possess high digital skills had a stronger positive impact on student achievement compared to their less experienced counterparts.

Attitudes towards technology play a crucial role in moderating the effectiveness of TDC. Chiu et al. (2021) found that teachers with positive attitudes towards technology were more likely to effectively leverage their digital skills to enhance student learning. Conversely, even highly digitally competent teachers who held negative attitudes towards technology were less likely to positively impact student achievement through digital means.

Professional development specific to digital pedagogy has also been identified as a significant moderating factor. Tondeur et al. (2019) observed that teachers who received targeted training in integrating technology into their subject areas showed a stronger positive relationship between their digital competencies and student outcomes.

The school environment plays a critical role in moderating the TDC-SAA relationship. Access to digital resources and infrastructure is a primary factor. Falloon (2020) highlighted that the impact of teachers' digital competencies on student achievement was significantly enhanced in schools with robust digital infrastructure and readily available technological resources. Leadership support for technology integration has emerged as another crucial moderating factor. Bond et al. (2021) found that in schools where leadership actively promoted and supported the use of digital technologies, the positive relationship between TDC and SAA was stronger. This underscores the importance of a supportive organizational culture in maximizing the benefits of teachers' digital skills. Collaborative practices within schools also moderate the TDC-SAA relationship. De la Calle et al. (2021) observed that schools fostering collaborative technology integration practices among teachers saw a more substantial positive impact of TDC on student outcomes. This suggests that the collective digital competence of a school's teaching staff may be as important as individual teacher competencies.

Broader contextual factors also play a significant role in moderating the TDC-SAA relationship. The urban-rural divide has been identified as a particularly important factor. Xie et al. (2020) found that the impact of teachers' digital competencies on student achievement was more pronounced in rural areas, where access to technology outside of school might be more limited. This highlights the potential of digitally competent teachers to compensate for environmental limitations. Cultural aspects also moderate the TDC-SAA relationship. Chiu (2023) observed that in cultures with high power distance and strong hierarchical structures, the impact of teachers' digital competencies on student outcomes was less pronounced. This suggests that cultural norms around education and authority may

influence how effectively digital competencies translate into improved student performance. The level of digital integration in the broader society also moderates the TDC-SAA relationship. Caena and Redecker (2019) noted that in highly digitalized societies, the impact of teachers' digital competencies on student achievement was more substantial, likely due to the increased relevance of digital skills in students' daily lives and future careers. Lastly, the COVID-19 pandemic has emerged as a significant contextual factor moderating the TDC-SAA relationship. Scherer et al. (2021) found that during periods of remote learning necessitated by the pandemic, the impact of teachers' digital competencies on student achievement was amplified. This underscores the increased importance of TDC in contexts where digital technologies become the primary medium of instruction.

The relationship between teachers' digital competencies and students' academic achievements is moderated by a complex interplay of factors at the student, teacher, school, and broader contextual levels. Understanding these moderating factors is crucial for developing effective strategies to leverage TDC for improved student outcomes. Future research should continue to explore these moderating factors, particularly in light of rapidly evolving educational technologies and changing global contexts.

3.6 Evolution of the TDC-SAA Relationship Over Time (RQ5)

The relationship between Teachers' Digital Competencies (TDC) and Students' Academic Achievements (SAA) has undergone significant evolution over the past decade. This section examines the chronological development of this relationship, the impact of technological advancements, and the changes in its nature and strength over time.

The study of the TDC-SAA relationship has seen a marked progression in both focus and methodology over the years. In the early 2010s, research primarily centered on establishing the existence of a link between teachers' digital skills and student outcomes. Tondeur et al. (2017) conducted a comprehensive review of studies from this period, noting that while a positive correlation was generally observed, the strength and consistency of this relationship varied widely across different contexts and educational levels.

As the decade progressed, research became more nuanced, exploring specific aspects of digital competence and their individual impacts on student achievement. Siddiq et al. (2016) introduced the concept of Teachers' Emphasis on Developing Students' Digital Information and Communication Skills (TEDDICS), marking a shift towards examining how teachers' digital competencies translated into specific instructional practices that benefit students. The latter half of the 2010s saw an increased focus on the pedagogical aspects of digital competence. Starkey's (2020) review of research from this period highlighted a growing emphasis on how teachers' ability to integrate technology meaningfully into their teaching practices, rather than mere technical proficiency, influenced student outcomes. More recently, the COVID-19 pandemic has spurred a new wave of research into the TDC-SAA relationship. Chiu (2022) examined how teachers' digital competencies influenced student engagement and achievement in online learning environments, finding that the relationship became more pronounced in this context.

Technological advancements have significantly shaped the evolution of the TDC-SAA relationship. The rapid development of educational technologies has continually redefined what constitutes digital competence for teachers. In the early 2010s, research often focused on basic technological skills. However, as noted by Redecker and Punie (2017), the concept of digital competence expanded to include more complex skills such as digital content creation, data literacy, and online collaboration. This expansion has led to a more multifaceted understanding of how teachers' digital skills impact student learning. The advent of mobile technologies and cloud computing has also influenced the TDC-SAA relationship. Crompton and Burke (2020) observed that teachers' ability to leverage mobile learning technologies effectively was increasingly correlated with positive student outcomes, particularly in terms of engagement and motivation. More recently, emerging technologies such as artificial intelligence and virtual reality have begun to play a role in shaping the TDC-SAA relationship. Chiu et al. (2021) explored how teachers' competencies in AI-enhanced education correlated with student achievement, finding that teachers who could effectively integrate AI tools into their instruction saw improved student outcomes, particularly in STEM subjects.

The nature and strength of the TDC-SAA relationship have evolved considerably over time. Early studies often reported modest correlations between teachers' digital skills and student achievement. However, as both the conceptualization of digital competence and research methodologies have become more sophisticated, stronger and more consistent relationships have been observed.

Falloon (2020) proposed a comprehensive framework for teacher digital competency (TDC), which helped to clarify the multidimensional nature of the TDC-SAA relationship. This framework highlighted how different aspects of digital competence (e.g., technical skills, pedagogical integration, digital citizenship) may impact student outcomes in distinct ways.

The strength of the TDC-SAA relationship has also been influenced by broader educational trends. The increasing emphasis on 21st-century skills has amplified the importance of teachers' digital competencies. Caena and Redecker (2019) noted that as digital literacy became a core educational objective, the impact of teachers' digital skills on student outcomes became more pronounced across various subject areas.

Furthermore, the nature of the relationship has shifted from a focus on direct effects to a more nuanced understanding of how TDC influences student learning. De la Calle et al. (2021) observed that recent research increasingly examines how teachers' digital competencies shape the learning environment and instructional practices, which in turn affect student outcomes.

The COVID-19 pandemic has further altered the nature and strength of the TDC-SAA relationship. Scherer et al. (2021) found that during periods of remote learning, the impact of teachers' digital competencies on student achievement was amplified, highlighting the critical role of TDC in ensuring educational continuity and quality in crisis situations.

Looking towards the future, emerging research suggests that the TDC-SAA relationship may become increasingly context-dependent. Xie et al. (2020) proposed a person-centered approach to examining this relationship, emphasizing the need to consider individual student characteristics and learning preferences when assessing the impact of teachers' digital competencies.

In summary, the evolution of the TDC-SAA relationship reflects the dynamic nature of educational technology and its integration into teaching practices. From initial explorations of basic correlations to sophisticated analyses of multifaceted competencies, research in this field has progressively unveiled the complex interplay between teachers' digital skills and student outcomes. As technology continues to advance and educational paradigms shift, it is likely that the nature and strength of this relationship will continue to evolve, necessitating ongoing research and adaptation of educational practices.

DISCUSSION

The systematic review of literature examining the relationship between Teachers' Digital Competencies (TDC) and Students' Academic Achievements (SAA) has revealed a complex and evolving landscape. This discussion aims to synthesize the key findings, compare them with existing literature, and explore their implications for educational practice, policy, and future research.

The review has uncovered a generally positive relationship between TDC and SAA, albeit with significant variations across educational levels, subject areas, and contexts. At the primary education level, the impact of TDC on SAA appears to be more indirect, primarily influencing students' foundational digital skills rather than traditional academic outcomes (Ottestad et al., 2014). However, innovative pedagogical approaches leveraging digital technologies have shown promise in enhancing student engagement and learning outcomes even at this early stage (Perifanou et al., 2021).

In secondary education, the relationship between TDC and SAA becomes more pronounced and direct. Studies have consistently shown positive correlations between teachers' digital competencies and student performance, particularly in STEM subjects (Falck et al., 2018; Siddiq et al., 2016). The impact extends beyond academic achievement to include the development of critical digital literacy skills, which are increasingly important for students' future academic and professional success (Starkey, 2020). At the higher education level, the TDC-SAA relationship takes on new dimensions, with a strong focus on advanced digital skills and their application in research-intensive settings. The ability of professors to guide students in using sophisticated digital tools for data analysis, literature review, and scholarly communication has been shown to significantly enhance the quality of students' academic output (Marcelo & Yot-Domínguez, 2019).

The review has also identified several key moderating factors that influence the TDC-SAA relationship. Student-related factors, such as socioeconomic status and prior achievement, play a significant role, with evidence suggesting

that digitally competent teachers may have a more pronounced positive impact on students from disadvantaged backgrounds (Chiu, 2022). Teacher-related factors, including years of experience and attitudes towards technology, also moderate the relationship, highlighting the importance of ongoing professional development and fostering positive attitudes towards digital integration (Siddiq et al., 2016; Chiu et al., 2021). School-related factors, such as access to digital resources and leadership support, have emerged as crucial moderators. Schools with robust digital infrastructure and supportive leadership see a stronger positive relationship between TDC and SAA (Falloon, 2020; Bond et al., 2021). Broader contextual factors, including the urban-rural divide and cultural aspects, also play a role in shaping the TDC-SAA relationship (Xie et al., 2020; Chiu, 2023).

The chronological analysis of findings revealed an evolution in the focus of research, from establishing basic correlations to exploring more nuanced aspects of the TDC-SAA relationship. Recent studies have increasingly emphasized the pedagogical aspects of digital competence and their impact on student outcomes (Starkey, 2020). The COVID-19 pandemic has further accelerated research in this area, highlighting the critical role of TDC in ensuring educational continuity and quality in crisis situations (Scherer et al., 2021).

The findings of this review largely align with and extend previous research in the field. The positive relationship between TDC and SAA corroborates earlier studies that have pointed to the potential of digital technologies to enhance learning outcomes (Tondeur et al., 2017). However, this review provides a more nuanced understanding of how this relationship varies across different educational contexts and subject areas.

The identified moderating factors echo previous research on the digital divide and educational inequalities. The finding that TDC may have a more pronounced impact on students from disadvantaged backgrounds aligns with studies highlighting the potential of technology to bridge educational gaps (Reich & Ito, 2017). However, this review extends these findings by providing a more comprehensive picture of how various factors interact to shape the TDC-SAA relationship.

The evolution of the TDC-SAA relationship over time, as revealed in this review, reflects broader trends in educational technology research. The shift from a focus on basic technical skills to more complex pedagogical integrations of technology aligns with the development of frameworks such as TPACK (Mishra & Koehler, 2006) and more recent models like DigCompEdu (Redecker & Punie, 2017).

The findings of this review have several important implications for educational practice and policy. Firstly, they underscore the need for comprehensive and ongoing digital competence development for teachers at all educational levels. This development should go beyond basic technical skills to encompass pedagogical applications of technology and the ability to foster students' digital literacy (Caena & Redecker, 2019). Secondly, the varied impact of TDC across different subject areas suggests the need for subject-specific approaches to digital integration. Educational policymakers and curriculum developers should consider how digital competencies can be most effectively leveraged in different disciplines, particularly in STEM subjects where the impact appears to be most pronounced (Drossel et al., 2017). Thirdly, the identified moderating factors highlight the importance of a holistic approach to digital integration in education. Policymakers should consider not only the provision of technology and teacher training but also the broader ecosystem of support, including school leadership, infrastructure, and community engagement (De la Calle et al., 2021). The amplified importance of TDC during the COVID-19 pandemic underscores the need for resilient and flexible educational systems. Policies should be developed to ensure that teachers are prepared to leverage digital technologies effectively in both face-to-face and remote learning contexts (Scherer et al., 2021).

This review also points to several promising avenues for future research. Firstly, there is a need for more longitudinal studies to better understand the long-term impacts of TDC on student outcomes. Such studies could provide insights into how the benefits of digitally enhanced teaching accrue over time and across different stages of education. Secondly, the review highlights the need for more research into the specific mechanisms through which TDC influences SAA. While a positive relationship has been established, more work is needed to understand precisely how different aspects of digital competence translate into improved learning outcomes. Thirdly, the emerging importance of advanced technologies such as AI and virtual reality in education suggests a need for research into how teachers' competencies in these areas impact student learning. As these technologies become more prevalent in educational settings, understanding their effects on the TDC-SAA relationship will be crucial (Chiu et al., 2021). Finally, the review underscores the importance of context in shaping the TDC-SAA relationship. Future research should adopt

more nuanced, context-sensitive approaches to studying this relationship, taking into account the various moderating factors identified in this review (Xie et al., 2020).

CONCLUSION

In conclusion, this systematic review has provided a comprehensive overview of the current state of knowledge regarding the relationship between teachers' digital competencies and students' academic achievements. The findings highlight the complex and multifaceted nature of this relationship, influenced by a wide range of factors at the individual, institutional, and societal levels. As digital technologies continue to evolve and reshape educational landscapes, ongoing research and adaptive policies will be crucial to ensuring that digital competencies are leveraged effectively to enhance student learning outcomes. The challenge for educators, researchers, and policymakers is to navigate this dynamic landscape, continually refining our understanding of how best to harness the potential of digital technologies in education while addressing the associated challenges and inequalities.

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