SIGNIFICANT EFFECT OF THE TPACK FRAMEWORK ON TEACHERS' SELF-EFFICACY: A SYSTEMATIC LITERATURE REVIEW

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The empirical evidence demonstrates that teachers' self-efficacy is influenced by their knowledge of technological pedagogical content, especially in schools where technology is frequently used. However, few systematic reviews have investigated how TPACK affects teachers' self-efficacy. This review investigates the effects of teachers' knowledge of technological pedagogical content (TPACK) on teachers' self-efficacy. To investigate the theoretical basis and the practical use of TPACK, it uses a rigorous Systematic Literature Review (SLR) technique, with thirty-four high-quality studies published between 2017 and 2021 fulfilling the stringent selection criteria. Each study was categorized based on four features: (a) concept development of the TPACK framework, (b) technology integration, (c) TPACK and teachers' self-efficacy, and (d) strategies development on TPACK practices and teachers' self-efficacy. Implications are discussed across the theoretical underpinnings and practical uses of TPACK that influence teachers' self-efficacy. By interpreting the results of the review, recommendations are provided for practitioners, policymakers, and researchers focusing on teacher technology training.

Keywords: *TPACK, Teachers' Self-Efficacy, Systematic Literature Review*

INTRODUCTION

Teachers face several challenges due to the ever-changing educational environment and the increasing availability of digital devices and Internet access (O'Neal et al., 2017; Qian & Lehman, 2018). Ineffective and frequent attempts to overcome these hurdles have a negative impact on teachers' self-efficacy (Saienko et al., 2020). Recent observations indicate that most teachers do not provide students with opportunities to use technology for rich learning (Gonzalez & González-Ruiz, 2017). Instead, teachers often use technology to improve the efficiency of teacher-centred instruction (Kao et al., 2020; Kim & Lee, 2018). However, school closures as a result of COVID-19 are an important point in global history, forcing us to re-evaluate the way education works in each of our countries. Among the many changes brought about by this issue is that digital technology has become the mediator of all education (Pozo et al., 2021). In addition, the teaching profession has also changed. Teachers' knowledge and abilities must be updated to meet the needs of students and businesses. Teachers face several challenges due to the ever-changing educational

environment and technological advances. Ineffective and repeated attempts to overcome these barriers negatively impact teachers' self-efficacy (Saienko et al., 2020).

Current technology use by the teacher is still mostly a replication of traditional and administrative practices to studies, most teachers lack the pedagogies required for effective educational technology integration. Greater knowledge of what inspires instructors' distinctive methods, as well as how teachers' approaches grow conceives that can be considered effective pedagogies for the use of technology. To put it succinctly, what is required is a thorough grasp of the developmental process through which teachers conceptualize the link between technology and pedagogy (Prestridge, 2017). Effective technology integration into education continues to be a serious concern. A critical aspect of this difficulty is the relationship between teachers' pedagogical views and how digital devices are employed in classrooms (Vidal-Hall et al., 2020). Integrating technology, in which teachers play a critical role, is a lengthy process (Suárez-Rodríguez et al., 2018). The widespread use of technology in elementary education has not been related to good pedagogical practice in classrooms. While schools use technology in a variety of ways as cognitive tools of instruction, the impact of teachers' self-efficacy on their pedagogical use of technology is unclear (Mlambo et al., 2020).

An all-inclusive construct based on this research posits that teachers' technology use is influenced by their expertise, confidence, beliefs, and culture. However, just a few empirical research have backed up this theory. Additionally, even though elementary and secondary school teachers have varied situations and responsibilities, few studies have examined the diverse relationships between teacher-related attributes and technology integration (Jung et al., 2019). There is a substantial corpus of research on elementary and secondary school teachers' technology integration and their self-efficacy and attitudes about technology. Nevertheless, little investigation has been performed to look into the consequences of teachers' self-efficacy and attitudes toward their intention to incorporate technology into their instructional strategies (Kao et al., 2020). As a result, the goal of this research is to investigate the connection between TPACK and teacher self-efficacy in the context of teachers who seek to utilize technology. The fundamental research question that prompted this review was, how to develop TPACK and self-efficacy for teachers?

METHODOLOGY

This section discusses the importance of systematically examining the theoretical foundations and practical applications of TPACK on teachers' self-efficacy. Meanwhile, in comparison, the following part covers the strategies used to obtain answers to the research question stated in the current study. We used PRISMA, which included systematic review resources (Scopus and Web of Science), eligibility and exclusion criteria, review stages (identification, screening, eligibility), data abstraction and analysis, and data abstraction.

PRISMA

The PRISMA Statement guided the review (Preferred Reporting Item for Systematic reviews and Meta-Analyses) and is frequently used in social science research. It has three distinct advantages, according to Mohamed Shaffril et al. (2021): 1) It creates simple research questions that allow systematic research; 2) It identifies inclusion and exclusion criteria, and 3) It aims to investigate a huge database of scientific literature in a specific time frame. The PRISMA Statement allows for a comprehensive search of terms related to TPACK and their impact on teachers' technology self-efficacy (see Fig. 1).

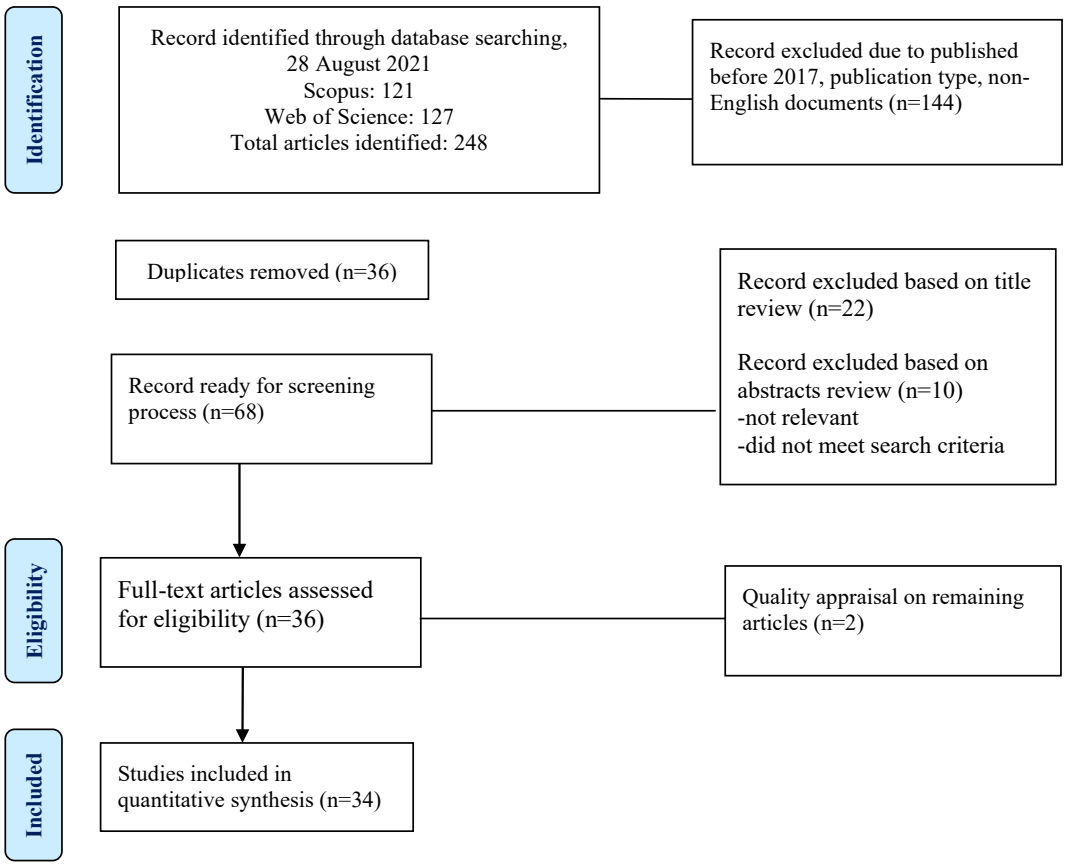

Fig. 1 PRISMA flow diagram (Moher et al., 2009)

Systematic review process

We used systematic searching techniques to investigate the effect of technological pedagogical content knowledge (TPACK) on teachers' self-efficacy. Three subprocesses of systematic searching strategies were conducted to execute an exhaustive and systematic search: identification, screening, and eligibility.

Identification of source

Identification is the process of identifying synonymous phrases with similar meanings or variations of the study's primary keywords: technological pedagogical content knowledge and teachers' self-efficacy. Next, we give the selected databases, WOS and Scopus, more alternatives for locating relevant articles to evaluate. Finally, we identified appropriate keywords using an online thesaurus, keywords from previous studies, and phrases suggested by Scopus (refer to Table 1).

The search process is carried out on the primary database. Support is provided selectively based on the primary keyword and encryption, either through the use of advanced search techniques i.e., through the use of Boolean operators, phrase search, truncation, wildcard, and field code functions separately or the combination of these search techniques into a whole search string (Table 2). As Gusenbauer and Haddaway (2020) proposed, Scopus and Web of Science were selected as the primary databases because both databases have advanced search options, are broad (indexing over 5000 publishers), control article quality, and are multidisciplinary, cover education studies.

Table 1: Result of the identification process

Section	**Main keywords**	**Enriched keywords**
The effects of teachers' self-efficacy on their technological pedagogical content knowledge (TPACK).	Influences	Influences = impact, effect
	TPACK	TPACK = Technological pedagogical content knowledge, teacher technological beliefs, technology integration
	Teacher self-efficacy	Teachers' self-efficacy = teacher beliefs, teachers' effectiveness, teachers' competence

Table2 Full search string used in selected databases

Database	**String**
Scopus	TITLE-ABS-KEY((Influence* OR impact* OR effect*) AND (tpack OR "Technolog* pedagog* content knowledge" OR "teacher* technolog* belief*"OR "technolog* integration") AND ("Teacher* self-efficacy" OR "teacher* belief*" OR "teacher* effective*" OR "teacher* competence*")
Web of Science	TS=((Influence* OR impact* OR effect*) AND (tpack OR "Technolog* pedagog* content knowledge" OR "teacher* technolog* belief*"OR "technolog* integration") AND ("Teacher* self-efficacy" OR "teacher* belief*" OR "teacher* effective*" OR "teacher* competence*"))

According to the search results, there are 121 Scopus records and 127 Web of Science records.

Screening

We screened all 248 articles using a database sorting tool. Okoli (2015) suggests that researchers impose a time restriction for reviewing all published articles. However, Deeks et al. (2019) show that timetable limits should be chosen when the use of a study is limited. As a result, only empirical studies published in journals are functionally represented. Furthermore, the query only included English-language publications (Table 3), and 144 articles were excluded owing to not meeting the procedure's criteria. On the other hand, we eliminated 36 records owing to duplication, 22 records were released due to title review, and ten records were removed due to abstract review. In comparison, another 36 articles were reviewed while evaluating eligibility.

Table 3: Inclusion and exclusion criteria.

Criterion	Inclusion	Exclusion
Timeline	2017 to 2021	Before 2016
Publication Type	Article	Conference proceeding, review, book, book chapters, etc.
Language	English	Non-English

Eligibility criteria

The third procedure is eligibility, in which we confirm that all remaining articles fit the requirements after the screening process. Only articles that examined the effects of TPACK and teachers' self-efficacy were included. The research methods under consideration are quantitative, qualitative, or a mix. Here, we are concerned with the study samples, as well as the teachers. After reading the title and abstract, we analyze the article's content for relevance to the study.

Quality assessment

Three reviewers evaluated 36 papers utilizing qualitative, quantitative and mixed methods of research appraisal. The articles would be included in the review only if all reviewers agreed. The manuscript was sent to a fourth reviewer for evaluation if there were any disagreements. After critical review, two papers were excluded. Thirty-four studies (19 quantitative, nine qualitative, and six mixed methods) were chosen and re-evaluated to assure total agreement. SPSS version 26 was used to enter the reviewer's critical evaluation ratings for each study (IBM Corp., Armonk, NY, USA). According to the statistical analysis, Cohen's kappa value was 0.87 for papers that reviewers critically appraised. Thus, the kappa value suggested a significant agreement between the reviewers (Gravetter et al., 2018).

Data abstraction and analysis

Each publication included in the study was examined and summarized by at least three research team members. Disagreements were discussed until a solution was reached. Sub-themes were discovered by comparing and contrasting the summaries from different studies. As a result, the following sections elaborate on the major themes. For example, the theoretical foundations of TPACK and teachers' self-efficacy were addressed through the following sub-themes: concept development of the TPACK domain, technology integration, TPACK and teachers' self-efficacy and strategies for developing TPACK and teachers' self-efficacy. All reviewers led to the cross-article analysis, which the study team deliberated until they agreed on. After a literature search and data is extracted, 34 papers were synthesized (Fig. 1).

RESULTS

The search results and data extraction resulted in identifying 34 papers that meet the requirements for answering research questions. Therefore, the articles included in this review are listed in Table 4 (see Appendix 1).

Concept development of the TPACK framework

The development of the TPACK framework is discussed in 18 publications from the Scopus and WOS databases. These publications added to our understanding of TPACK for certain subject domains. Interestingly, these findings highlight the strong relationship between TPACK and PCK. Later, we used these publications' ideas to examine how this concept has grown over time.

In the educational field, the Technological, Pedagogical, and Content Knowledge (TPACK) framework, which proposes a set of knowledge domains required for effective technology-assisted instruction, has attracted much interest. However, recent studies have demonstrated that access to technology does not inherently imply a higher level of integration or a higher quality of integration. Instead, teachers' views also play a significant role in determining how teachers integrate technology into the classroom (Vongkulluksn et al., 2018).

Explanation of TPACK for a specific context of education stressed the technological Pedagogical Content Knowledge (TPACK) framework as a lens to view online education (Eichelberger & Leong, 2019). They make two arguments supporting the TPACK framework's impact on teachers' beliefs. First, they recognized that teachers' perceptions of pupils significantly impact teaching and technology integration. However, they investigated teacher perspectives on technology integration, focusing on the impact of a teacher's ideas on how frequently students use a single tool, such as Facebook, to signify that they will be proficient with other learning resources. In the same study by Eichelberger and Leong (2019), recognition of the interaction between content, pedagogy, and technology was established. However, this interaction made it difficult to tie themes to the different TPACK elements definitively due to frequent overlap.

The connection between pedagogy, content, and technology, as outlined by Sadik (2021), is crucial for educating future teachers in technology integration, and all education courses. In addition, Gonzalez and González-Ruiz (2017) discovered that pre-service teachers' behavioural intention to include technology in their classroom delivery was connected with a preponderance of TPACK. However, the findings revealed a significant gap between pre-service teachers' behavioural intentions and their mastery of technological pedagogical content. Furthermore, even when participants expressed positive intentions, the data they utilized to select technology-supported tasks was unrelated to TPACK and insufficient to identify technology's instructional potential.

Apart from that, Huang and Lajoie (2021) emphasized the relevance of Self-Regulated Learning (SRL) in obtaining technological pedagogical content knowledge (TPACK), which is a fundamental component of effective technology use by instructors. This study discovered many regulatory procedural patterns that teachers employ with their TPACK accomplishments. While the positive role of Facebook and teacher-directed use of Chemistry Learning Facebook Groups (CLFG) were studied from the perspectives of instructors' TPACK and teachers' self-efficacy views on the usage of technology Blonder and Rap (2017). These authors discovered that while the definition of what constitutes learning in the CLFG did not alter during the trial, teachers better understood how to assist with this learning. Additionally, they improved the integration of connections to films and visuals that aided in comprehending abstract chemistry ideas.

Moreover, studies of the TPACK concept are discussed in a specific education context: programming (Kim & Lee, 2018), ICT (Seifu, 2020), and chemistry (Blonder & Rap, 2017). Teaching programs based on programming is an effective way of developing TPACK among teachers (Kim & Lee, 2018). They proposed a study that TPACK standards and indicators for instructors, which they divided into two TPACK training programs: Information and Communication Technology (ICT) and programming. In their findings, teaching programs based on programming were demonstrated to influence Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and TPACK. As shown in previous studies, TPACK uses a sophisticated approach. In the development of TPACK among teachers, important information is acquired. The TPACK-forming construct can be used to construct teachers' TPACK. Developing the teacher's TPACK can also be done independently on each TPACK component.

Technology integration

Technology integration is discussed in detail in 19 publications. According to their definition, emerging technologies are not transparent or pervasive in a given setting (i.e., education).

While emergent technologies are frequently digital, this is not always true. As a result, technology integration is limited to digital technologies sometimes addressed as ICTs (Sadik, 2021). Several of these 19 studies include various technologies, while others concentrate on specialized ones, such as the web (Kao et al., 2020). Shulman's concept of pedagogical content knowledge (PCK) encompassed the appropriate use of technology when teachers are required to consider representations of the subject being taught to students (Shulman, 1986). Nonetheless, given technology's widespread significance in our society and its rapid advances, Mishra and Koehler (2006) proposed that technology knowledge (TK) be included as a third category of knowledge. The TPACK framework is based on the idea that technology integration in a specific educational context benefits from the careful alignment of content, pedagogy, and technological potential (Andyani et al., 2020; Chand et al., 2020; Suárez-Rodríguez et al., 2018). Therefore, teachers who want to integrate technology into their teaching practice must be competent in all three domains.

The merging of several technologies is referred to as technology integration. When we analysed the type of technology integration, we discovered that effective technology integration required technological support (O'Neal et al., 2017), professional learning ((Hall & Trespalacios, 2019; Vidal-Hall et al., 2020), and educational innovation (Prestridge, 2017) to improve teaching and learning and helps 21st century skill for students' success. Technology use helps students develop reading, math, and other academic skills (O'Neal et al., 2017). Additionally, in this study discovered that a lack of technological support and resources influenced technology integration and affected teachers' attitudes about directly controlling pedagogy in the classroom and their competency with its use. They concluded that more positive attitudes toward technology's role in teaching and learning result in more teachers integrating computing across the curriculum and assisting students in developing the necessary abilities for the twenty-first century.

Moreover, observed the effects of tailored professional learning on teachers' degrees of comfort and self-efficacy concerning ICT (Hall & Trespalacios, 2019). According to their findings, individualised professional development made a big difference in teachers' self-efficacy about their ICT skills and how confident they were about using ICT in their classrooms. Vidal-Hall et al. (2020) revealed how her intervention led to the teacher shifting from skepticism about the significance of digital media for early childhood education to developing effective techniques for using digital media in her child-centred pedagogy. This transformation in the pedagogical approach enabled the teacher's shifting attitudes about the importance of digital tools in early childhood education. Furthermore, Prestridge (2017) has explored how teachers use game-based technologies in their classrooms. A rich narrative of teaching innovation was related to teachers' pedagogical views and practised surrounding technologies.

Finally, in 19 publications, the understanding of technology integration is presented describing conceptual should be implemented in the long term and current. Nevertheless, teachers are often engaged in everyday activities, such as lesson planning, delivery, evaluation, and classroom organisation. They may find the introduction of technology into instruction an additional task. Due to the numerous concerns and demands connected with integrating devices, such as classroom management and pedagogical practice modifications, not all teachers are interested in doing so.

TPACK and teachers' self-efficacy

Six research in our database examined the relationship between teachers' TPACK and their efficacy. First, teachers' self-efficacy is examined from two perspectives: pedagogical beliefs (Andyani et al., 2020; Atar et al., 2019; Prestridge, 2017) and technological beliefs (Basaran & Yalman, 2020; Chand et al., 2020; Jung et al., 2019). Because knowledge and beliefs are inextricably linked in a teacher's mind, both are frequently considered essential elements of teacher knowledge (Chand et al., 2020). Recent studies (in both databases) contributed to our understanding of how TPACK affects teacher self-efficacy. Notably, this research highlights the close relationship between technology integration and teacher self-efficacy. Furthermore, Suárez-Rodríguez et al. (2018) defined pedagogical belief as teachers' knowledge and abilities in using ICT in their teaching and learning processes (e.g., curriculum design, and planning). They also considered several ICT-based classroom organisations, communication with the educational community (for example, parents and students), participation in ICT-based initiatives and innovations, and ICT-related ethical and legal issues.

Teachers' pedagogical beliefs serve as a filter, screening new knowledge and experiences for meaning and relevance (Kagan, 1992). This also applies to teachers' technological experience. We have proposed that, as a result of the frequent use of technology in the classroom, teachers frequently shift their classroom practises and, as a result, adopt more student-centred views (Chai et al., 2019). This, however, does not apply to all teachers. This could be because teachers' individual experiences, beliefs, emotions, knowledge, self-efficacy, skills, and motivations can all be influenced by their teaching situations (Stoll, 1999). As a result, teachers' judgments of good teaching and effective learning are based on what they think is good teaching and effective learning (Cheng & Xie, 2018).

Although each teacher defined self-efficacy differently, it changed in Hall and Trespalacios (2019). External initiatives, such as training programmes and social support, can boost teachers' confidence in adopting technology. In addition, technology has changed the demands placed on K-12 teachers (O'Neal et al., 2017). Teachers are increasingly expected to better prepare kids with 21st-century abilities (Jung et al., 2019), so it is critical to understand their views on technology in education and their pupils' skills to succeed. Cheng et al. (2021) also demonstrated that competence assumptions and traditional pedagogical beliefs interact synergistically. They indicated that when competence perceptions are extremely low, traditional pedagogical attitudes have a greater negative impact on technology integration. Besides that, Andyani et al. (2020) added to the evidence for teacher beliefs by demonstrating that technological pedagogical content knowledge, mediated by teachers' self-efficacy, did not affect ICT use in pedagogy. In contrast, as mediated by teachers' self-efficacy, the innovative organisational climate affects ICT use in pedagogy. They also stated that teachers' continual usage of e-teaching is beneficial and significant.

Use of these technological resources is similar to the study of Suárez-Rodríguez et al. (2018), in which the essential concept of teacher integration of ICT as teachers' ICT technological and pedagogical competencies were investigated. In contrast, pedagogical beliefs influence personal-professional usage and classroom use, while technological competencies affect both. Suárez-Rodríguez et al. (2018) aim to gain a better understanding of the difficult process of incorporating ICT into classrooms by emphasizing the link between ICT competencies and classroom use. As a result, this paradigm guides ICT teacher training. In addition, Joo et al. (2018) discovered that pre-service teachers' TPACK substantially affected teacher self-efficacy. Furthermore, teachers' TPACK had a favourable impact on their perceptions of the

ease with which they could adopt the technology. Additionally, they revealed that teacher self-efficacy influenced teachers' intentions in utilising technology.

The realization that technology can impact pleasurable incorporation into educational practices, the constructivist perspectives stated that intrinsic and extrinsic motivation, perceived ease of use, and behavioural intention, among other cognitive and motivational aspects, contributed to technology's success (Limone et al., 2019). Furthermore, Barni et al. (2019) finds that teachers' self-efficacy had a significant impact on ICT integration. They discovered that the use of technology by teachers varies depending on the school level. This is except pedagogical ideas, supportive culture, and teachers' self-efficacy and expertise, all of which have a substantial impact on teachers' technology integration. In addition, Kao et al. (2020) discovered that self-efficacy toward web-based professional development is the main determinant of primary school teachers' perceptions of integrating technology into their lessons.

However, Cheng et al. (2021) described how the usefulness of value beliefs substantially influenced technological integration. Their data reveal that pedagogical belief and perceived cost are not important predictors. According to these authors, teachers' self-efficacy regarding technology integration, may be more effective targets for future intervention work than pedagogical beliefs. While, Andyani et al. (2020) found that while teachers' technological pedagogical subject knowledge has no direct effect on their self-efficacy, it substantially affects their use of ICT in pedagogy. Similarly, Blonder and Rap (2017) discovered that teachers' ideas about the utility of specific technologies, specifically Social Networking Sites (SNS), influence how they integrate technology into their instruction. Their three case studies offer insight into how instructors learn to use SNS with their pupils as part of their professional development. When teachers adopted new media, they kept their preconceptions about learning. Instead, they built TPACK unique to teachers by understanding how to assist this learning in the subject.

These findings suggest that teachers' knowledge influences their self-efficacy regarding technology integration. Furthermore, the TPACK framework can assess teachers' ability to select and apply appropriate technology for content and pedagogy. The TPACK framework is presented as a means of assisting instructors in increasing their self-efficacy to execute effective technology-based learning. As a result, teachers can adapt the technology they apply to their students' requirements and the available technology in their schools.

Strategies development on TPACK and teachers' self-efficacy

Nine research in both databases examined ways for enhancing teachers' TPACK and self-efficacy. Across the training program, the primary strategy was active involvement in technology-enhanced lessons, followed by modelling how to teach in a technology-rich setting.

Vidal-Hall et al. (2020), proposed that professional development cover practitioner perspectives on digital media and early childhood education, as well as time and space for teacher reflection. At the same time, Qian and Lehman (2018) recommended that teacher education programmes emphasized the development of teachers' technological pedagogical content knowledge (TPACK), or the knowledge necessary for effective technology-based instruction.

Additionally, Mlambo et al. (2020) advocated for continual ICT integration and educator development, with an emphasis on how to integrate ICT tools as creative thinking tools. These strategies have the potential to boost educators' self-efficacy with ICT in resource-constrained settings. In elementary education, educator training programmes should be revised to emphasise practical lesson planning that uses ICTs as seamless classroom resources. According to Mukminin et al. (2019), secondary school teachers' opinions regarding ICT and its integration into education, were primarily focused on student engagement and practical learning, with a diversified use of ICT in terms of grades and content (behavioural beliefs). His findings about the level of teachers' self-efficacy are high for using ICT and access to learning materials (control beliefs), as well as the demands of digital-age pupils and the expectations of authorities, administrators, and colleagues (normative beliefs).

Barton and Dexter (2020) argued that the relationship between formal professional development and informal and autonomous learning emphasized by these claims warrants leaders' commitment of limited financial and human resources to this attempt to scale up Teacher Self-Efficacy (TSE). They make recommendations for leaders to act on these results, as leaders are accountable for setting the conditions necessary for teachers to integrate technology effectively and for further study to expand generalizability and depth of understanding. According to the literature, there are various strategies for developing TPACK and self-efficacy through professional development, teacher education programs, and the financial commitment of human resources to support continual development. Furthermore, while various research studies on TPACK have been conducted in concept development, technological integration, and development strategies, researchers should also explore limited financial and leadership commitment.

DISCUSSION AND CONCLUSION

This review examined the impact of TPACK on teachers' self-efficacy. We know from our work with practising teachers that TPACK is an intuitive and communicable idea. However, as this literature study revealed, TPACK is a complex topic that sparks scholarly dispute (Chai et al., 2019). The review revealed three interpretations of the concept. T(PCK) represents extended PCK, TPCK represents a different body of knowledge, and TP(A)CK represents the interaction of three knowledge domains. TP(A)CK stresses the link between the three knowledge areas and their intersections, unlike the preceding two conceptualizations. Our findings show that TPCK is derived from (Shulman, 1986) PCK. Two features of PCK are apparent: PCK is about (1) representations of domain knowledge and (2) particular learning challenges and student perceptions connected to teaching specific domain topics. Based on these PCK characteristics, we believe TPACK should be considered as a separate body of knowledge. In this light, our review found just a few studies that examined TPACK for a given subject domain. The added value of TPACK is the potential for students to learn conceptual and procedural information through the use of technology (Eichelberger & Leong, 2019). Therefore, TPACK is a knowledge foundation, not technology integration.

We offer the following study directions for further work on the TPACK framework's development. First, if TPACK is understood as the knowledge basis that a teacher requires to teach successfully with technology, we must have a deeper understanding of what that knowledge base looks like for certain topic domains. It is suggested that a PCK framework (Andyani et al. 2020; Blonder & Rap 2017) be used to create this knowledge base for specific

areas and that consensus among scholars and practitioners be sought using Delphi-type surveys. Reviewing the existing research on using technology to assist students in understanding complicated ideas is a good place to start in a given topic domain. Honey (2018) and Mlambo et al. (2020) provide valuable examples in scientific education.

Secondly, because teachers' knowledge and beliefs are inextricably linked, additional study on the complicated interaction between TPACK (teacher knowledge), teacher practical knowledge, and teacher efficacy is also needed. Additionally, this method will emphasize the dynamic aspect of TPACK. Hence, we believe that knowledge may be helpful for professional development initiatives to increase student-teachers TPACK. Thirdly, by understanding what TPACK means for various subject domains, we will measure a teacher's TPACK more accurately. Along with more targeted self-assessments, there is a need for accurate and trustworthy tools that allow teachers to demonstrate TPACK. Lastly, having technical resources in the classroom encourages teachers to use ICT in the school and improve their ICT skills, which positively impacts ICT integration (Chand et al., 2020; Hall & Trespalacios, 2019).

Appendix 1 Overview of the selected articles.

Authors	Study design	Concept development of the TPACK framework	Technology integration	TPACK and teachers' self-efficacy	Strategies for developing TPACK and teachers' self-efficacy
Andyani et al. (2020)	Structural equality model	×		×	×
Atar et al. (2019)	Survey	×		×	
Barton and Dexter (2020)	Case study	×			×
Basaran and Yalman, (2020)	Structural equality model		×	×	
Blonder and Rap (2017)	Mixed methods		×		
Chai et al. (2019)	Survey		×		
Chand et al. (2020)	Quasi-experimental		×	×	
Cheng et al. (2021)	Structural equality model	×			×
Eichelberger and Leong (2019)	Study case	×			×
Er and Kim (2017)	Mixed methods	×			
Gonzalez and Gonzalez-Ruiz (2017)	Case study	×			
Hall and Trespalacios (2019)	Quasi-experimental		×		
Honey (2018)	Action research		×		
Huang and Lajoie (2021)	Theoretical study	×			

Authors	Study design	Concept development of the TPACK framework	Technology integration	TPACK and teachers' self-efficacy	Strategies for developing TPACK and teachers' self-efficacy
Joo et al. (2018)	Structural relationship	×			
Jung et al. (2019)	Structural equation modelling	×	×	×	
Kao et al. (2020)	Correlation study	×			
Kim and Lee (2018)	Quasi-experimental	×	×		
Krause (2017)	Quasi-experimental				
Limone et al. (2019)	Quasi-experimental	×	×		
Mlambo et al. (2020)	Correlation study		×		×
Mukminin et al. (2019)	Mixed methods		×		×
O'Neal et al. (2017)	Qualitative study		×		
Pozo et al. (2021)	Survey		×		
Prestridge (2017)	Case study		×	×	
Qian and Lehman (2018)	Mixed methods		×		×
Sadik (2021)	Design-based research	×			
Saienko et al. (2020)	Mixed methods			×	
Scherer et al. (2017)	Evaluation study	×			

Authors	Study design	Concept development of the TPACK framework	Technology integration	TPACK and teachers' self-efficacy	Strategies for developing TPACK and teachers' self-efficacy
Seifu (2020)	Mixed methods	×			
Suarez-Rodriguez et al. (2018)	Survey	×	×		
Vidal-Hall et al. (2020)	Case study		×		×
Vongkulluksn et al. (2018)	Theoretical study	×			×
Zipke et al. (2019)	Case study		×		

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