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TPACK and Teachers' Self-Efficacy: A Systematic Review

TPACK et l'auto-efficacité des enseignants: une revue systématique

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Abstract

Technological Pedagogical Content Knowledge (TPACK) studies have surged over the past few years, however, there is a lack of studies that have comprehensively reviewed and synthesized data on teachers' TPACK self-efficacy. The present review aimed to provide data on research methods, study samples, subject domains, and evaluation approaches used in the TPACK studies to date. The review also aimed to analyze teachers' TPACK self-efficacy, self-efficacy beliefs, computer self-efficacy, and technology support concerning professional development. Five best bets (most searched databases) were selected on the Electronic Business Source Complete (EBSCO) host platform. An abstract level screening was conducted for 136 peer-reviewed articles, and 75 articles were selected for the detailed screening. The analyses were focused on year-wide appearance of TPACK studies, research methods, study samples, subject domains, and evaluation approaches used. The growth and development of TPACK self-efficacy was examined using the narrative approach. Results indicated that professional development interventions were effective in improving teachers' TPACK self-efficacy. Also, TPACK-based argumentation practices helped participants strengthen their perceptions toward the integration of technology in classrooms. The implications of the findings for teacher preparation programs and other professional development activities were presented.

Keywords: TPACK; self-efficacy; instructional technology; professional development

Résumé

Les études sur les connaissances du contenu pédagogique technologique (TPACK, par ses sigles en anglais) ont augmenté au cours des dernières années, cependant, il y a un manque d'études qui ont examiné et synthétisé de manière exhaustive des données sur l'auto-efficacité TPACK des enseignants. La présente revue de literature visait à fournir des données sur les méthodes de recherche, les échantillons de l'étude, les domaines d'études et les approches d'évaluation utilisées dans les études TPACK à ce jour. La revue visait également à analyser l'auto-efficacité TPACK des enseignants, les croyances d'auto-efficacité, l'auto-efficacité en matière informatique et le soutien technologique

concernant le développement professionnel. Cinq meilleurs paris (les bases de données les plus recherchées) ont été sélectionnés sur la plateforme hôte d'Electronic Business Source Complete (EBSCO). Une sélection à partir du résumé a été effectué pour 136 articles évalués par des pairs, et 75 articles ont été sélectionnés pour un examen détaillé. Les analyses se sont concentrées sur l'apparition, à travers l'année, des études sur le TPACK, des méthodes de recherche, des échantillons d'étude, des domaines d'études et des approches d'évaluation utilisées. La croissance et le développement de l'auto-efficacité TPACK ont été examinés en utilisant une approche narrative. Les résultats ont indiqué que les interventions de perfectionnement professionnel ont été efficaces pour améliorer l'auto-efficacité TPACK des enseignants. En outre, les pratiques d'argumentation basées sur le TPACK ont aidé les participants à renforcer leurs perceptions vers l'intégration de la technologie dans les salles de classe. Les implications des résultats pour les programmes de perfectionnement des enseignants et d'autres activités de perfectionnement professionnel ont été présentées.

Mots-clés : TPACK ; auto-efficacité ; technologie d'enseignement ; perfectionnement professionnel

Background and Introduction

Technology can play a crucial role in transforming teaching-learning pedagogy. New classroom technologies such as tablet computers, interactive whiteboards (IWBs), social media, online simulations, and smartphones allow teachers to radically transform the ways they can help their students to learn new content and skills (Cennamo et al., 2010; DeSantis, 2013). More technologies are becoming readily available and these constantly evolving technologies are now part of the everyday life experiences of the digital natives (Ito et al., 2010). These technological advancements perhaps helped in flipping the role of the teacher from the curriculum designer to the content delivery facilitator who chooses an appropriate technology along with the pedagogy to do that (Kereluik et al., 2010). Teachers dealing with the learners of this century need to be skilled in integrating technology with the classroom activities as the appropriate use of technology has proven to enhance learning environments. Consequently, this brings changes in instructional strategies, classroom management, and tech-based classroom interventions (Kazu & Erten, 2014). Studies indicated that technological literacy and technological competence were the vital components for the integration of technology into teaching. Such skills help instructors have control over the instructional design and development in this age of technology (Kereluik et al., 2010).

The Technological Pedagogical Content Knowledge (TPACK) framework was one of the frequently used frameworks for understanding the integration of technology with pedagogy and content, which was built upon Shulmans' (1986) analysis of pedagogical content knowledge. As per Shulman, pedagogy and content were inseparable components of learning. Shulman further described that the efficacy of integrating pedagogical skills with the content was of considerable importance in education (Shulman, 1987). The TPACK framework integrated the knowledge of technology with the content and the pedagogy (Harris et al., 2009; Koehler et al., 2007; Koehler & Mishra, 2005; Koehler & Mishra, 2008; Mishra & Koehler, 2006; Schmidt et al., 2009). TPACK helped conceptualize the complex relationships between content and the integration of technology with the content, and helped

teachers improve classroom effectiveness (Baka et al., 2020; Kilic et al., 2019; Schmid et al., 2021). Such integration of technology into learning strategies was used to improve classroom practices in the digital century (Rocha et al., 2011).

Evaluation of TPACK

TPACK has evolved as one of the powerful frameworks addressing the successful integration of technology into classroom instruction (Koehler & Mishra, 2008). TPACK was evaluated in numerous studies using diverse samples and approaches to explore the framework further (Koehler et al., 2014). TPACK's widespread impact was criticized for inaccurate and insufficient definitions of knowledge domains as well as the integration of the technology domain into the model (Anderson et al., 2001; Cox & Graham, 2009; Graham, 2011). Nevertheless, TPACK has been applied to various tech-based academic settings, which, consequently, has helped TPACK grow as a useful framework for analyzing self-efficacy (Angeli & Valanides, 2009; Baran et al., 2011; Mishra & Koehler, 2006; Polly, 2011). Despite the ample attention that TPACK has received, it was rarely applied in studies incorporating ongoing activities in order to strengthen performance in teaching and professional development interventions (Willermark, 2017).

Small- and large-scale reviews, incorporating distinct scopes and foci, have been published in the past (Chai et al., 2013; Voogt et al., 2013; Wu, 2013). The literature review conducted by Willermark in 2017 focused on how TPACK was categorized in research. According to Willermark (2017), the studies published between 2011 and 2016 followed two major approaches: self-report and performance on the activity. Self-report and performance in teaching activities were further sub-categorized into general and specific, experienced and planning - implementing and evaluating teaching activities, respectively (Willermark, 2017). Other reviews focused on empirical studies incorporating survey analysis, content analysis, facilitation activities, and TPACK-based argumentation practices comprising experimental training.

Study Rationale, Purpose, and Research Questions

Previous studies have indicated that TPACK-savvy teacher-taskforce can fulfill learners' classroom expectations better as the students from the digital age feel confident about their learning with tech-savvy instructors (Alotumi, 2020; Buss et al., 2018; Ca et al., 2019). Since its inception, TPACK, as a framework, was evaluated in different educational settings on various platforms. However, a study presenting data about research methods, study samples, subject domains, and evaluation approaches used in all the TPACK studies to date was not available. Further, a study analyzing teachers' TPACK self-efficacies, self-efficacy beliefs, computer self-efficacy, technology support, and associated derivative variables concerning professional development interventions has been missing. Therefore, it was proposed to analyze research methods, study samples, subject domains, and evaluation approaches used in the TPACK studies to date. It was also proposed to analyze teachers' TPACK self-efficacies, self-efficacy beliefs, computer self-efficacy, technology support, and associated derivative variables concerning professional development interventions.

The specific aim of the present study was to answer the following research questions:

RQ1: To what extent has the TPACK Framework expanded in terms of research methods, study samples, subject domains, and evaluation approaches?

RQ2: What is the impact of tech-based professional development interventions on teachers' TPACK self-efficacy?

Significance to the Field

The outcomes of this study could serve as a guiding document for the researchers and policymakers for conducting future research concerning TPACK, technology self-efficacy, and tech-based pedagogical innovations both in online and in-person modes of instructional design and delivery. The outcomes could also help researchers incorporate more empirical settings and methods into future studies, which could provide a new perspective on the integration of TPACK into teacher professional development. In addition, the outcomes could help provide insight into the relationship between the knowledge domains within the framework, which could benefit tech-based professional development interventions, both for pre-service and in-service teachers.

Validating the outcomes of previous TPACK studies may be one of the key interests of future researchers, especially at K-12 and K-16 levels. The outcomes of this study could help researchers compare and critically analyze research settings, study samples, research methods, and evaluation approaches used in previous studies. Such analyses can be used for studies concerning the impact of developmental processes on teachers' TPACK-21CL design confidence, argumentation-based TPACK studies, and design-based scaffolding.

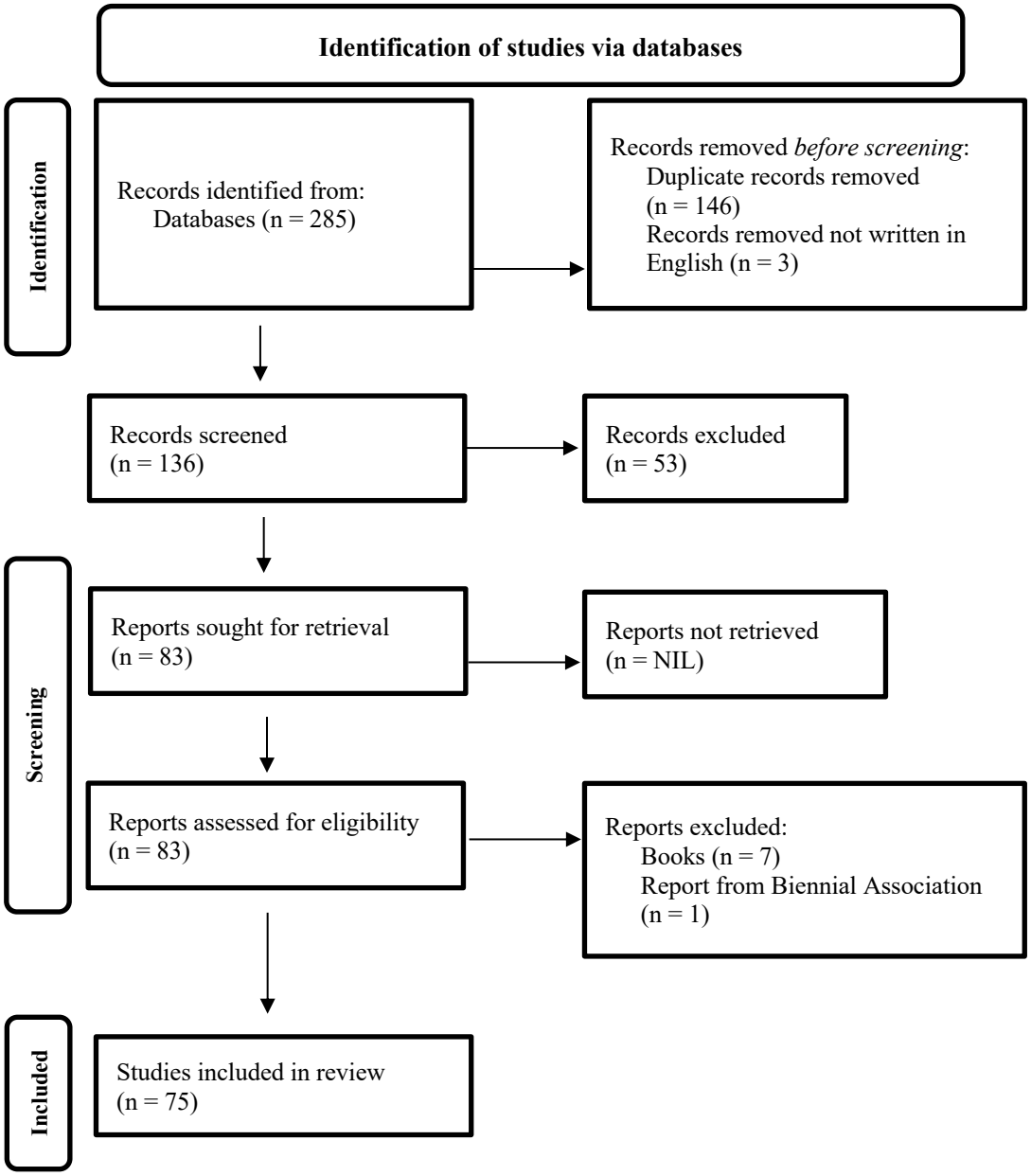
Methodology

Search Procedures, Data Collection, and Data Management

A systematic search was conducted using five popular databases, ERIC, Education Source, Child Development and Adolescent Studies, Psyc INFO, and Academic Search Ultimate (McDaniel, n.d.). Keywords "Self-Efficacy" and "Technological pedagogical content knowledge" were used on the EBSCO host platform to identify scholarly peer-reviewed articles published between 2006 and 2021. Searches were limited to peer-reviewed journal articles published in English, which excludes book chapters, conference proceedings, and published or unpublished dissertations. The title, abstract, and keywords of each article from the initial search, which resulted in 285 articles (75 in Social Sciences Citation Index, 81 in Education Resources Information Center, and 129 in Scopus), were read carefully. Finally, 136 non-overlapping articles comprising empirical studies were selected for further investigation. After screening all 136 results, 75 articles were selected for the present study (Figure 1). The article categorization, inclusion, and exclusion criteria are presented in the forthcoming sections.

Figure 1

Flow Diagram ("PRISMA 2020 statement: An updated guideline for reporting systematic reviews," 2021)



Article Categorization

The content analysis approach (Bryman, 2015), which comprises qualitative and quantitative methods, was adopted for a critical screening of the 75 peer-reviewed studies (Figure 1). Content analysis steps included shortlisting articles with the title "Technological pedagogical content knowledge" or "TPACK" or "TPCK", screening abstracts to confirm empirical studies with appropriate

methods, and finally reading whole articles. Articles were double-scanned for the identifying approaches used (self-report or skill performance-based), subject domains, and grade levels.

The protocol developed for examining article characteristics included the year of publication, author(s), research methodology (quantitative, qualitative, and mixed methods), subject domains, selected samples (pre-service teacher, in-service teachers, and others), approaches used (self-report and skill performance-based), and the title of the study.

Inclusion and Exclusion Criteria

After reading the abstracts of all 136 peer-reviewed articles, 75 relevant articles were selected to include in the study.

The following inclusion criteria were used:

1. Peer-reviewed journal articles focusing on teachers' self-efficacy in developing and implementing TPACK as a framework.
2. Articles examining the impact of professional developmental practices on TPACK self-efficacies and on teacher effectiveness.
3. Articles investigating teachers' TPACK literacy, perception, and belief.
4. Article published in English.

The following exclusion criteria were used:

1. Editorial, letters, opinions, conference papers, and dissertations.
2. Articles not published in English.

Results

This section could provide data on research methods, study samples, subject domains, and evaluation approaches used in the TPACK studies to date.

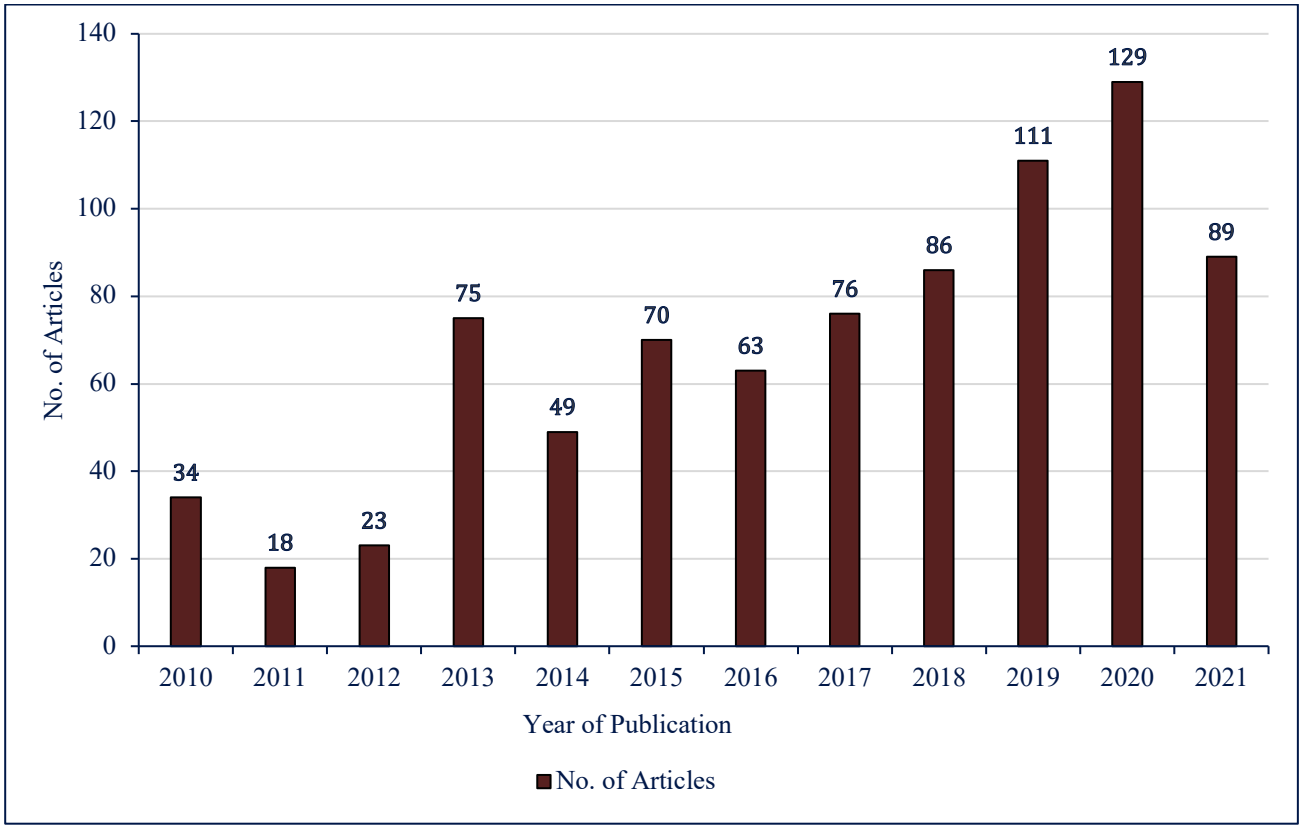
Year-Wide Appearance of TPACK and Self-Efficacy and Self-Efficacy Studies

TPACK framework caught the attention of researchers since its inception in 2005, but there was a noticeable upsurge in the appearance of empirical TPACK studies during 2010, which was around a 21% increase in the total TPACK studies published between 2005-2009 (Figure 2). This sudden rise in numbers went down in the year 2011, however, kept rising after 2012. This rising trend showed that the TPACK framework was discussed well in the last decade and continues to be an interesting framework for researchers.

The largest number of TPACK articles was published in 2020 with the volume expected to rise in 2021 as 89 articles were already published by the time this study was conducted. These rising trends have been crucial for the establishment of TPACK as a framework.

Figure 2

Year-Wide Distribution of Empirical TPACK Publications

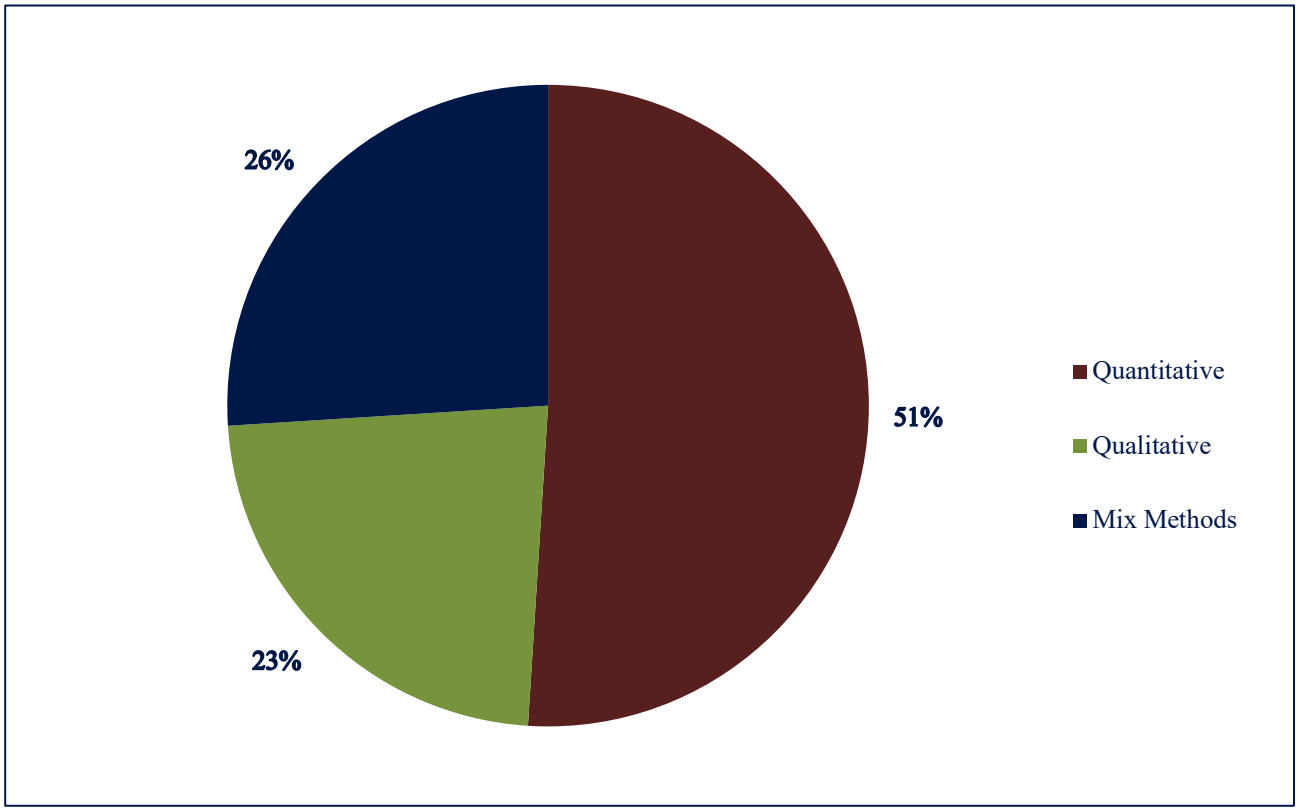


Research Methods Used in TPACK and Self-Efficacy Studies

In previous TPACK studies, quantitative, qualitative, and mixed-methods were adopted. As shown in Figure 3, more than half of the studies have adopted the methods based on quantitative design. These studies have used surveys, polls, and questionnaires for data collection. Of the studies, 23% have adopted the methods based on qualitative design. These studies have used interviews, group discussions, group activities, observations, and content analyses. The remaining 26% of the studies have adopted the methods based on mixed design.

Figure 3

Method-Wide Distribution of Empirical TPACK Studies



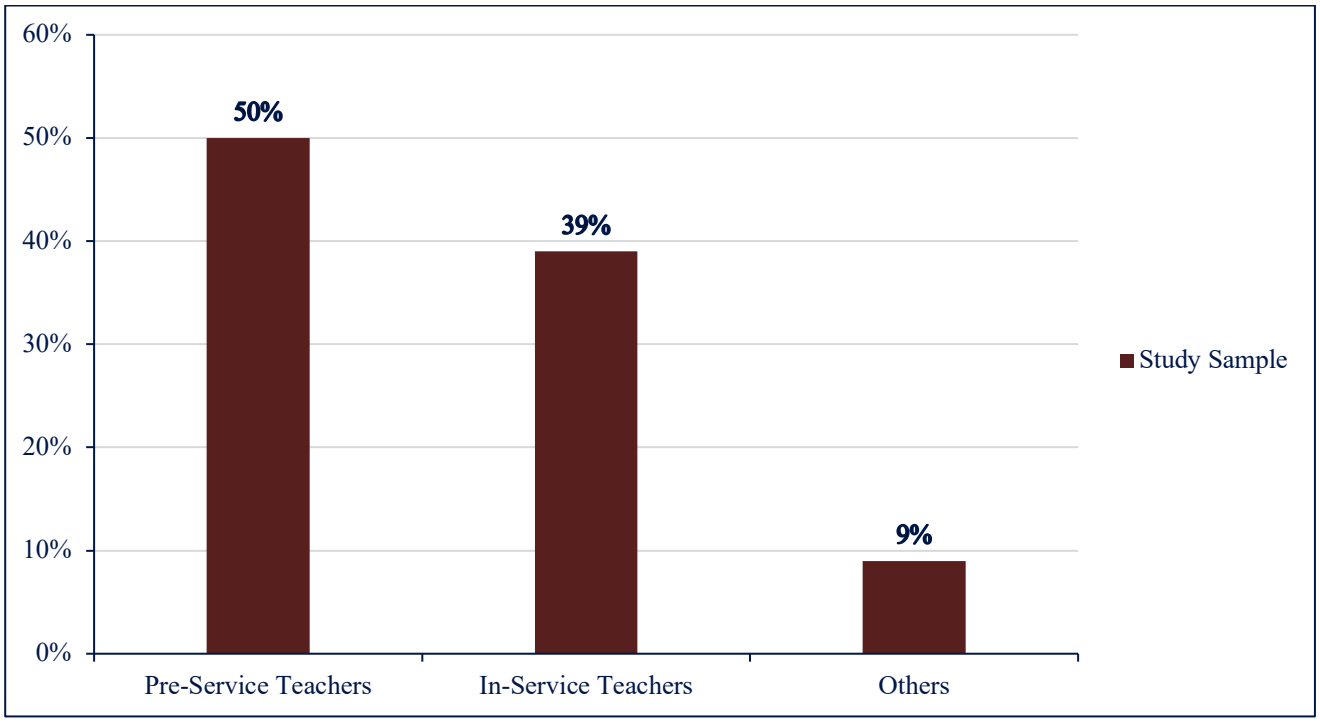
Study Samples Used in TPACK and Self-Efficacy Studies

Study samples included pre-service teachers, in-service teachers, and other academics. From all the TPACK studies, 50% have recruited pre-service teachers, 39% have recruited in-service teachers, and 2% have recruited both pre-and in-service teachers. Of the studies, 9% recruited samples from other groups of academics such as school principals, school representatives, tutors, engineering students, high school students, and graduate and undergraduate students.

From pre-service teachers, 26% of the samples were recruited from elementary schools (grades 1-6), 46% from high schools (grades 7-12), and 21% were recruited from colleges and universities. The remaining 7% were recruited from a non-teaching background. From in-service teachers, 26% of the samples were recruited from elementary schools (grades 1-6), 56% from high schools (grades 7-12), and 18% were recruited from colleges and universities.

Figure 4

The Sample-Wide Distribution of Empirical TPACK Studies

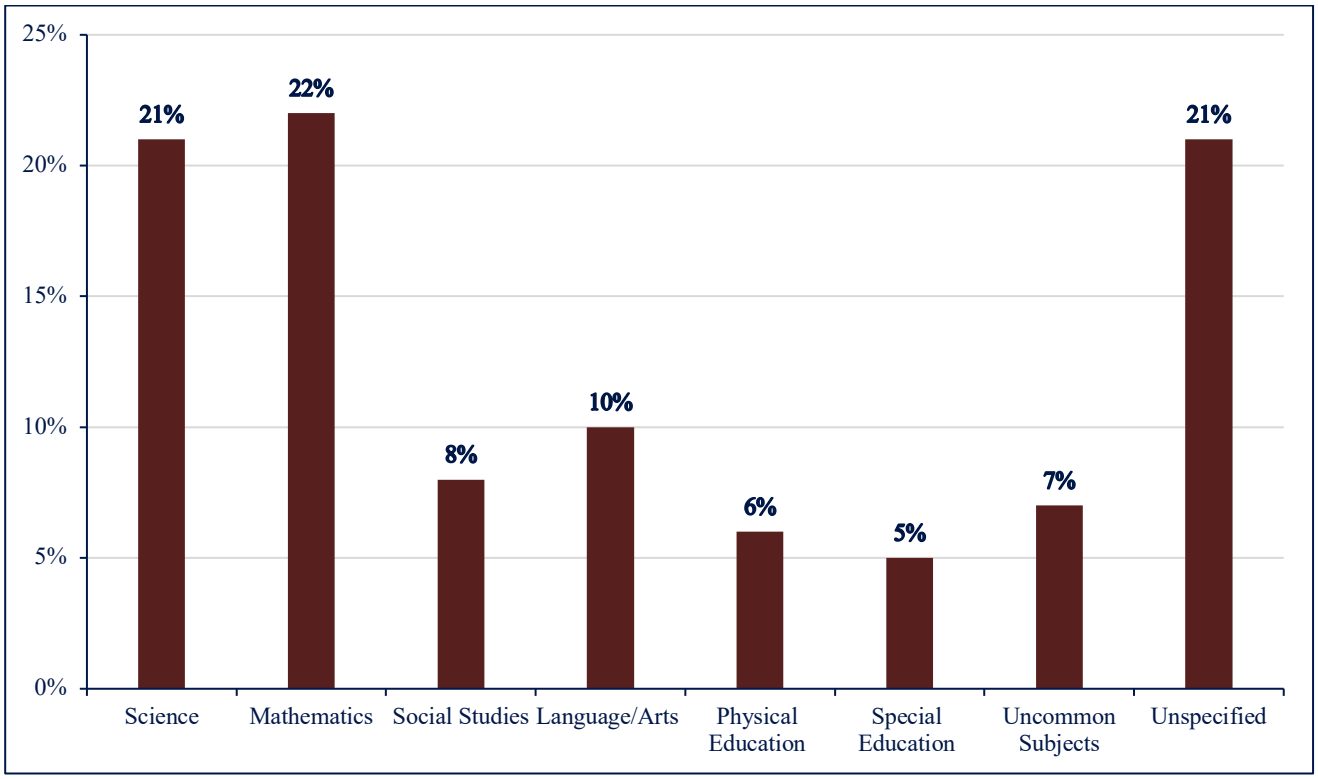


Subject Domains Used in TPACK and Self-Efficacy Studies

TPACK was administered as a framework in various subject domains. These subject domains were science (21%), mathematics (22%), social studies (8%), language/arts (10%), physical education (6%), and special education (5%). Of the studies, 7% have analyzed TPACK for the subject areas such as jewelry technology, music, tech integration courses, educational technology course, engineering, and education. Among these subject domains, jewelry technology, music, and education were the uncommon subject domains, which appeared in one or two studies. The subject areas were unspecified in the remaining 21% of the TPACK studies.

Figure 5

Subject-Wide Distribution of Empirical TPACK Studies

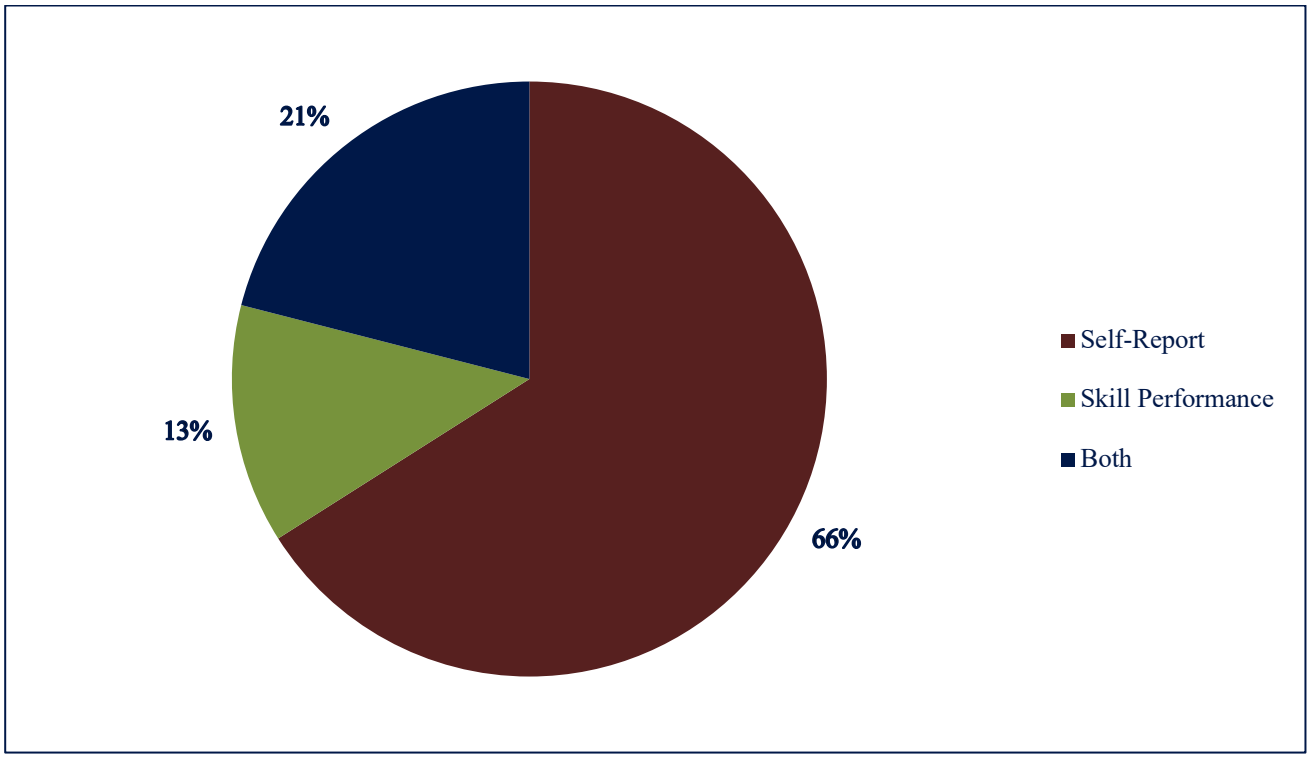


Evaluation Approaches Used in TPACK and Self-Efficacy Studies

The evaluation approaches were analyzed in terms of two categories: self-report and skill performance (performance on teaching activity), as described by Willermark (2017). From all the TPACK studies, 66% of the studies have employed self-report, 13% of the studies have employed skill performance activities, and 21% of the studies have employed both approaches. The use of self-report measures decreased in the last five years (2016 - 74%; 2021 - 58%) whereas the use of skill performance measures was increased (2016 - 12%; 2021 - 14%). Further, the use of combined approaches was reduced substantially (2016 - 28%; 2021 - 14%).

Figure 6

Evaluation Approaches Used in the Empirical TPACK Studies



Discussion

The outcomes of this study could be described in clusters, guided by specific themes. The first cluster could describe the growth of TPACK in terms of research methods, study samples, subject domains, and evaluation approaches. Other clusters (5.2 – 5.8) could describe research-based findings from TPACK-based professional development opportunities. These clusters could also explain best practices that were employed while implementing TPACK into teaching-learning and professional development practices, which could help educators improve their technology self-efficacy.

Growth of TPACK

The results of this study indicated that TPACK has grown tremendously in the last decade in terms of research methods, study samples, subject domains, and evaluation approaches. The number of empirical studies has increased over the years and these results align with the outcomes from previous studies (Willermark, 2017). Quantitative, qualitative, and mixed methods were used for analyzing the impact of tech-based professional development on teachers' self-efficacy. The samples included pre-service and in-service teachers, however, professionals from the administration were also recruited as samples in some of the studies. There was a wide range of subject domains in which TPACK was examined such as science, mathematics, social studies, language/arts, physical education, special education, jewelry technology, music, tech integration courses, educational technology course,

engineering, and education. In these studies, TPACK was evaluated using two key approaches: self-report and skill performance (performance on teaching activity). Such analysis provided fascinating data about the growth and development of TPACK approaches, which could serve as a guiding document for the researchers. Also, the analyses in terms of research methods, study samples, subject domains, and evaluation approaches could guide researchers in choosing the appropriate study variables for future studies. A comparative analysis of self-report and skill performance-based studies holds promise in directing researchers to adopt factual approaches for future TPACK studies.

TPACK evolved as one of the useful frameworks addressing the successful integration of technology into classroom instruction (Koehler & Mishra, 2008). TPACK was measured in numerous studies using diverse samples and approaches to explore the framework further (Altun, 2019; Bingimlas, 2018; Cai et al, 2019; Fathi & Yousefifard, 2019; Koehler et al., 2014; Zahwa et al., 2021). TPACK's widespread impact was criticized for inaccurate and insufficient definitions of knowledge domains as well as the integration of the technology domain into the model (Anderson et al., 2001; Cox & Graham, 2009; Graham, 2011). Nevertheless, TPACK has grown into an influential framework through diverse educational settings and interventions (Angeli & Valanides, 2009; Baran et al., 2011; Oda et al., 2020; Polly, 2011; Young et al., 2019). Despite the ample attention that TPACK has received, it was rarely applied in studies incorporating ongoing activities in order to strengthen performance in teaching and professional development interventions (Willermark, 2017).

The Impact of Tech-Based Professional Development Interventions on Teachers' TPACK Self-Efficacy

Technology Interventions and TPACK Self-Efficacy

Technology-based professional development interventions had a huge impact on teachers' self-efficacy. Well-developed design and skill performance-based interventions were found to be helpful for teachers in building their TPACK self-efficacies. Professional development programs using technologies such as interactive whiteboards and geographic information systems played a crucial role in determining TPACK and other derivative variables (DeSantis, 2013; Oda et al., 2020). TPACK served as a guiding theory in analyzing the impact of individual knowledge domains, i.e., content, pedagogy, and technology. TPACK was assessed through qualitative studies using staples from elementary language-arts and it was concluded that teachers' approach toward pedagogy was aligned with the use of the iPad in their classrooms (Anderson et al., 2017). Anderson et al. (2017) also found that teachers' pedagogical knowledge and teaching experience strongly influenced the use of mobile technology in the classrooms.

Professional Development Interventions and Self-Efficacy

The participants of the designed-based professional development interventions were likely to build technology self-efficacy and TPACK self-efficacy as the interventions were effective in determining and developing TPACK and other tech-based frameworks such as Instructional Technology Outcome Expectations and Technology Integrated Self-Efficacy (Cengiz, 2014). Teachers' attitudes toward the integration of technology in different subject areas helped them approach the

pedagogy in these subjects (Simsek & Sarsar, 2019; Simsek & Yazar, 2019). Moreover, teachers' understanding of pedagogy and teaching strategy influenced decision-making toward the use of technology in the classrooms. The relationship between TPACK knowledge and self-efficacy was identified as dynamic as this relationship varied with the content and setting (Cengiz, 2014). The qualitative methodology may be a good fit to assess some of the TPACK variables. However, the data collection techniques such as questionnaires may pose some limitations to the qualitative studies.

Professional development interventions from technology integration courses had a statistically significant impact on the TPACK self-efficacy beliefs of pre-service teachers and individual dimensions such as content knowledge (CK), pedagogical content knowledge (PCK), and technological pedagogical knowledge (TPK) predicted the outcomes for their overall TPACK (Abebe et al., 2022). Despite the huge benefit of technology integration into classrooms, teacher practitioners had limited use of it in English as a foreign language (EFL) courses. While investigating issues with technology integration, Zhang and Chen (2022) discovered that affective attitudes of teachers were unrelated to their technology use. However, both TPACK and evaluative attitudes had a positive impact on the actual technology use in both online and face-to-face classes. Teachers from other language courses such as Chinese as a second language (CSL) also reported problems with the integration of technology into the curriculum as they were least confident about their technology use (Qiu et al., 2022). Further, the CSL teachers were not able to distinguish the boundaries between the dimensions such as TPK, TCK, and overall TPACK. However, the TPACK proficiency and skills of teachers from engineering courses were found to be good (Ferdiansyah et al., 2022). These studies warranted a need for examining TPACK self-efficacy across subjects. In conclusion, professional development interventions had a positive impact on teachers' TPACK self-efficacies and helped teachers to get a better understanding of the existing content, pedagogy, and technology knowledge by focusing on key areas, which further helped fulfill the needs of the 21st century classrooms.

TPACK as the Predictor of Self-Efficacy

TPACK knowledge was found to be one of the predictors of self-efficacy beliefs in the empirical articles reviewed in this study (Birisci & Kul, 2019; Cankaya, 2018; Kan & Yel, 2019). However, participants were not confident in their ability to design and implement content-based materials using technology (Abbitt, 2011; Cengiz, 2014; Saudelli & Ciampa, 2016; Wetzel et al., 2014). TPACK-based courses in natural sciences (science education and math) and literature were helpful in improving teachers' self-efficacies (Tokmak & Incikabi, 2013). It was interesting to know that there was a significant difference between the self-efficacies of teachers teaching natural science and social science toward their teaching and technology-content knowledge. However, this difference was not significant for the TPACK. The TPACK for 21st century learning program (TPACK-21CL) professional developmental processes were found to be generally effective for enhancing teachers' TPACK-21CL confidence and their confidence in design (Koh et al., 2016). This study had limitations such as school level (elementary), single-cycle lesson redesign, and construct validation of the survey instrument. These limitations make the study results restricted on one hand but open doors for future research on the other hand. Focusing on coherent groups, time duration, and an absence of timely follow-up may be the additional limitations to all the studies reviewed.

Skill-Performance Interventions and TPACK

TPACK-based argumentation practices were also found to be effective in increasing participants' TPACK self-efficacy in addition to changing participants' views toward the argument statements (Çoban et al., 2016). TPACK for 21st century learning program was found to be effective in enhancing technology self-efficacy of both students and teachers (Koh et al., 2016). The process included 37 primary school teachers' (from subject areas English, Mathematics, and Science) and described their prolonged engagement with peers and researchers within the teams for one school year. Another training program that was based on TPACK-based argumentation interventions had a noticeable positive impact on the participants (Çoban et al., 2016). Such skill-performance-based interventions may help fill the gap between the theory and the practice. In all the studies reviewed, participants were able to connect with the TPACK components toward the end of the intervention.

Computer Literacy and TPACK Self-Efficacy

Computer literacy played a key role in performance development interventions as the computer self-efficacy of teachers was closely associated with cognitive style and TPACK self-efficacy (López-Vargas et al., 2017). Computer literacy also played a significant role in assessing the integration of technology into pedagogy as the self-efficacy of computer literate teachers was predominantly higher in using technology in classrooms (Bakar et al., 2020; Coyne et al., 2017). However, the perceptions of teacher self-efficacy and academic self-efficacy changed with different variables such as gender, age, grade point average, and subject areas (Berkant & Baysal, 2018). Factors such as perceived ease of use and perceived usefulness of technology in classrooms also affected teachers' intentions to use technology (Joo et al., 2018). Self-efficacy was sometimes misunderstood with overconfidence as there was a difference between self-perception of teachers' content knowledge and teaching abilities to the perception of their supervisors (Dassa & Nichols, 2019). Nevertheless, the self-efficacy beliefs of teachers were closely associated with their attitudes about computer-assisted instructions (Kan & Yel, 2019), which was an indication of improved computer literacy.

Sustainability of TPACK-Based Professional Development Interventions

TPACK was evaluated for the sustainability of professional development interventions fostering one-to-one technology support (Kerry, 2019). The study was based on Bandura's (1997) self-efficacy theory and found that "content-driven professional development, clear expectations for technology use in classrooms, and the availability of school-based instructional coaches can impact the sustainability of a one-to-one computing initiative" (p. 17). Factors such as school climate and teachers' attitude were the key components for the integration of technology in classrooms (Raygan & Moradkhani, 2020). Teachers' attitudes in technology integration strengthened the association between technology competency and TPACK competency (Yulisman et al., 2019). Moreover, teachers' attitudes toward the use of technology played a moderating role between technology competency and TPACK competency. Professional development interventions helped mathematics teachers from urban schools improve their perceptions of PK, TK, PCK, and TCK (Young et al., 2020). However, pre-service teachers "considered themselves to have the high-level ability in both digital nativity and TPACK competency"

(Kabakci-Yurdakul, 2018, p. 267). Nevertheless, the notion of TPACK development was different for both pre-service and in-service teachers, and prior experience of technology influenced their use of technology in classrooms (Akapame et al., 2019).

Research-Based Practices to Improve Technology Self-Efficacy

Research indicated that computer literacy played a key role in improving teachers' self-efficacy. Teachers with well-informed computer knowledge have had higher technology self-efficacy than teachers with low computer knowledge. Therefore, reinforcing robust computer literacy in educational institutions could be the basic research-based professional development practice to improve the technology self-efficacy of teachers. TPACK-based classroom practices helped both teachers and learners improve their self-efficacy toward the integration of technology into the curriculum. On one hand, such practices helped teachers improve their self-confidence toward the use of technology in day-to-day teaching-learning. On the other hand, these practices helped students develop confidence in the appropriate integration of technology by teachers into the curriculum. Therefore, reinforcing TPACK-based technology integration into classrooms could prove to be another useful practice, which could help improve teachers' self-efficacy. Teachers using self-developed technology-based instructional materials as a teaching strategy are more likely to develop technology self-efficacy than teachers who do not use such materials. Therefore, subject-based professional development practices for the integration of technology into the curriculum should help teachers improve their technology self-efficacy.

Skill performance-based and practice-based technological interventions can be one of the most influential practices to improve teachers' technology self-efficacy as these practices helped teachers in building their TPACK self-efficacies. Professional development programs providing hands-on technologies such as interactive whiteboards, smartboards, classroom tablets, Listserv, learning management systems, online quiz makers, PowerPoint slideshows and games, online grading systems, geographic information systems, etc. can be highly useful. Designed-based professional development interventions and TPACK-based argumentation practices helped teachers become classroom tech-savvy and improve their technology self-efficacy, therefore, can be highly useful. Professional development practices based on existing technological frameworks and argumentation practices can help teachers improve their technology self-efficacy as these frameworks provide a strong research-based design for the implementation of technology into the curriculum.

Limitations

This study presented a detailed analysis of the TPACK and its acceptance as a framework, however, may contain some limitations. The first limitation was the keyword combination that was used for the literature search. The database search with the keyword "technological pedagogical content knowledge" provided a large number of outcomes, but these numbers were reduced when another keyword "self-efficacy" was included with the previous keyword. The second limitation was posed by the study inclusion criteria. This systematic review included only empirical studies focusing on the

variables such as tech-based professional development, self-efficacy, and TPACK. The third limitation may be the databases. This study was conducted using databases such as ERIC, Education Source, Child Development, and Adolescent Studies, Psyc INFO, Academic Search Ultimate, and Scopus. The empirical studies beyond the scope of these databases were automatically excluded.

Implication For Future Research

The outcomes of this study indicated that there is a strong need to conduct follow-up studies using contemporary technological tools that can support existing findings concerning TPACK. Extending the studies using new variables would explore new dimensions of TPACK. Professional developmental activities focusing on teacher proficiency, teaching methods, and assessment techniques would help participants understand the TPACK domains better. Qualitative studies using different settings and methods might help both participants and researchers to look at the framework from a different perspective. Studying the relationship between the knowledge domains within the framework for different settings could assist academics to devise an empowered mechanism for implementing tech-based practices. Strategies developed from the TPACK-aligned interventions may be useful for many faculty-leadership programs as well as for tech-based professional development programs.

One of the key areas for future research would be validating the existing outcomes in other schools/levels, colleges, and tertiary institutions. The school leadership culture and its impact on implementing the professional development process could be further examined. In future research, the prolonged effects of developmental processes on teachers' TPACK-21CL design confidence can be examined across multiple redesigned cycles. Further work in the areas of design-based scaffolding can be done to enhance teacher learning in school-based contexts.

Teacher preparation programs can have the usefulness of the relationship that pedagogical knowledge has with the knowledge evolution of the participants when they switch from preservice to in-service. Understanding various uses of technology in the educational arena may help teachers better prepare for their classrooms. Scaffolding during training programs could assist teachers in developing a sound technical background and tech self-efficacy. Design-based TPACK studies could enhance teachers' basic technology skills and might be evidence for future TPACK studies. Argumentation-based TPACK studies promote understanding the deep epistemology of the framework. Furthermore, future plans include studying the impact of online or face-to-face content delivery on students' TPACK self-efficacies using pre-test-post-test design.

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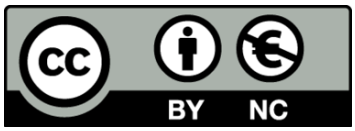

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