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Javier Ricardo Guzmán González
Universidad Antonio Nariño, Colombia

Grace Judith Vesga Bravo
Universidad Antonio Nariño, Colombia

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Javier Ricardo Guzmán González, Grace Judith Vesga Bravo

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Abstract

The TPACK model is an essential framework for appropriately integrating technology in the classroom. The present study aimed to categorize and establish the main research findings around TPACK between 2017 and 2022, specifically in practicing teachers at the secondary education level. A systematic literature review guided by the PRISMA statement was conducted. The search for papers was carried out in the Scopus, Web of Science, Sage Journal, and SciELO databases in September 2022. 37 articles were selected for review. The review of the studies made it possible to establish that the papers were mainly grouped into two categories: the first related to teachers' perception of TPACK, which includes research with self-perception questionnaires, case studies and relationships of self-perception with other variables such as barriers to technology integration in the classroom, pedagogical beliefs, and online education; and the second to developing training courses based on TPACK, complemented with self-perception questionnaires in the form of pretest-posts, classroom observations, and interviews. The results of the first category are dissimilar since TPACK levels differ from one study to another in variables such as gender and teaching experience. From the second, it is established that teacher professional development courses favor improving technological integration in the classroom.

Introduction

Technology integration in classrooms has been a widely addressed topic in recent years. Diverse research has established the advantages presented by technological tools in the teaching-learning processes of students in terms of skills development (Novita & Herman, 2021), reinforcement of competencies and overcoming learning difficulties (Sampaio & Almeida, 2016), problem-solving (Monjelat et al., 2020) and active participation in their educational process (Villarreal-Villa et al., 2019). As for teachers, they are presented as tools of an innovative nature (Sampaio & Almeida, 2016), which allow generating motivation in students (Villarreal-Villa et al., 2019) and which pose challenges to teachers (Njiku et al., 2021; Saltan & Arslan, 2017) for the integration of resources such as virtual classrooms, social networks and some others that facilitate the teaching-learning processes (Granados et al., 2020).

However, certain studies establish that some teachers do not have sufficient training to integrate technology into the classroom adequately since it is not enough to include technological tools in a specific session, but that technology should be encouraged to penetrate all pedagogical aspects of the educational process (Barroso et al, 2019; Cejas-León & Navío, 2018). Concerning teacher training in the use of technology, the TPACK model has gained relevance (Alrwaished et al., 2017; Dalal et al., 2021; Kim & Lee, 2018).

TPACK (Technological, Pedagogical and Content Knowledge) is an important framework for the proper integration of technologies in the classroom developed by Mishra and Koehler (2006), in which technological knowledge (TK) interacts with those already established by Shulman (1986), pedagogical (PK), content (CK) and pedagogical content (PCK). Thus, technological pedagogical knowledge (TPK) arises, referring to the knowledge of the potential of the multiple technologies used in the teaching-learning processes; as well as technological knowledge of content (TCK), concerning the knowledge of how technology can generate new representations for specific topics; and technological and pedagogical knowledge of content (TPACK), which coordinates the previous knowledge to facilitate students' learning through the use of ICT (Cabero et al., 2017).

About the TPACK model, different research types have been developed with pre-service (Scherer et al., 2018; Thohir et al., 2021) and in-service teachers (Da Silva et al., 2021; Njiku et al., 2021), for specific knowledge areas (Bustamante, 2019; Juanda et al., 2021; Ozturk, Kinik, & Ozturk, 2023; Pratumsala & Nuangchalerm, 2023), for the development and validation of perceived self-efficacy questionnaires (Graham et al., 2009; Schmidt et al., 2009), for in-depth knowledge of the incorporation of technologies in the classroom (Tiba & Condy, 2021; Walan, 2020), for technology integration during Covid-19 (Adipat, 2021; Kartimi et al., 2021), for comparing knowledge levels by gender (Gómez-Trigueros & De Aldecoa, 2021), age, level of academic background (Tanucan et al., 2021), and knowledge areas (Bingimlas, 2018), for critiques or modifications to the original model (Koh et al., 2014), and the development of professional development courses (Dalal et al., 2021).

Systematic literature reviews are a type of research that allow establishing research gaps in the field in which they are developed, locating new activities, and helping to generate new hypotheses (Kitchenham, 2004). This study seeks to answer how they have been developed and the main research findings about TPACK in practicing secondary education teachers between 2017 and 2022.

Methodology

The purpose of the study was to categorize and establish the main research findings around TPACK between 2017 and 2022, specifically in practicing teachers and at the high school level. The paper was guided by the PRISMA statement (Page et al., 2021) for systematic reviews. The databases selected were Scopus and web of Science for their international prestige (Carter-thuillier & Gallardo-fuentes, 2021), SciELO, and Sage Journal. The search was performed in September 2022, using the equations and filters in each database, as shown in Table 1. The search yielded a total of 189 full-text studies. Three duplicated studies were eliminated, so the inclusion and exclusion criteria shown in Table 2 were applied to 186 articles by reading the title, abstract and key words. 38 articles remained to be read after applying the inclusion and exclusion criteria. Figure 1 describes the complete process.

Table 1. Search Equations and Filters

Database Search	Search equation	Applied filters
Scopus	TPACK AND (“profesores en servicio” OR “in service teachers”) AND (secundaria OR secondary)	Publication status: final. Type of document: article. Open Access. From 2017 to 2022.
Web of Science	TPACK AND (“profesores en servicio” OR “in service teachers”) AND (secundaria OR secondary)	Open Access. Type of document: article. From 2017 to 2022.
SciELO	TPACK	From 2017
Sage Journal	TPACK AND (“profesores en servicio” OR “in service teachers”) AND (secundaria OR secondary)	Open Access. From 2017

Source: own elaboration

Table 2. Inclusion and Exclusion Criteria

Inclusion criteria	Exclusion criteria
The acronym TPACK must be present in the title, abstract or key words. The research had to be developed totally or partially with in-service and high school teachers. The studies should be empirical papers. Papers published between 2017 and 2022.	The acronym TPACK is not present in the title, abstract or keywords. Other type of participants or at another educational level. Systematic review or meta-analysis. Published in another period.

Source: own elaboration.

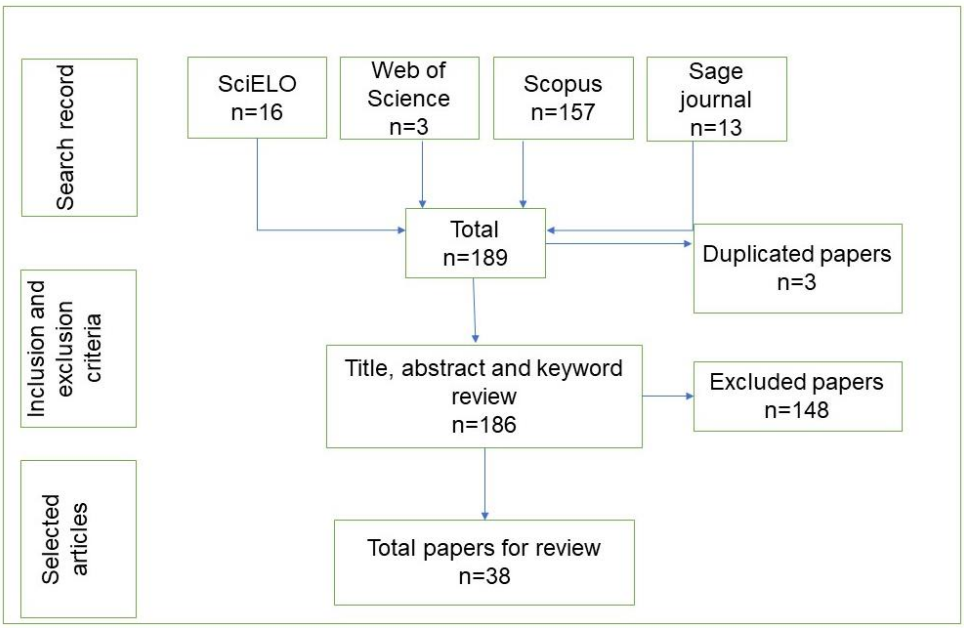

Figure 1. Flow Chart. Source: own elaboration.

Results and Discussion

Two categories were established through an open coding process (Strauss & Corbin, 2002), that grouped the different investigations (n=38): perception of the use of TPACK; and teacher training courses for the appropriate integration of technology based on the TPACK framework.

Perception of TPACK Use

It was further divided into three subcategories: the first was defined as perceived self-efficacy around TPACK, characterized by using Likert-type questionnaires applied to teachers to establish their levels of acceptance of statements concerning TPACK knowledge. The second is called the perception of classroom practices using TPACK. Through interviews and classroom observations, the researchers inquired deeply into how teachers integrate technology in their classrooms. The third one, which was designated as self-reported complemented TPACK, refers to research that not only inquires into teachers' self-perception of their TPACK levels but also related topics such as online education (Juanda et al., 2021), motivational beliefs, and appropriated lesson planning with technology (Backfisch et al., 2020), barriers to ICT integration (De Freitas & Spangenberg, 2019), technology integration in the classroom (Chieng & Tan, 2021; Muhaimin et al., 2019), and also as a means of contrast between the stated and the observable (Rahmawati et al., 2021).

Perceived Self-efficacy

This subcategory is where most studies were found (n=19), in which self-perceived TPACK questionnaires are applied, adapted from existing questionnaires, or self-developed. The results are predominantly quantitative, which makes it possible to establish relationships between the domains with the highest and lowest levels of TPACK, gender, experience, and age of the teachers. The questionnaire developed by Schmidt et al. (2009), was adapted and used by Akun & Mohamad (2021), Ibrohim et al. (2022), Li (2022), Tanucan et al. (2021), Tapia (2021) and Zeng (2022). While Bingimlas (2018), Guggemos & Seufert (2021), Hsu & Chen (2019), Paidi et al. (2021) and Rodríguez-Muñiz et al. (2021) developed a questionnaire on their own. In the research conducted by Bakar et al. (2020), Baturay et al. (2017), Chen & Hsu (2021), Chen & Jang (2019), López-Vargas et al. (2017), Ramakrishnan et al. (2020), Saltan & Arslan (2017) and Uslu (2018), they used adaptations of other questionnaires.

The results obtained for the levels of the core knowledge (TK, PK, and CK) that make up the TPACK framework were not homogeneous. While in the research conducted by Akun & Mohamad (2021), Baturay et al.(2017), Li (2022), the TK construct was one of those with the highest scores. In those conducted by Bakar et al. (2020), Chen & Jang (2019), Paidi et al. (2021), Saltan & Arslan (2017), and Tapia (2021) it was at the lowest or moderate levels. Contrary to what happened in CK (Akun & Mohamad, 2021; Chen & Jang, 2019; López-Vargas et al., 2017; Paidi et al., 2021) and in the PK (Akun & Mohamad, 2021; Paidi et al., 2021) where high and only moderate scores were obtained in the study of Bakar et al. (2020).

Composite knowledge (PCK, TPK, TCK, and TPACK) showed that the construct with the best levels of self-perception was PCK (Akun & Mohamad, 2021; Ramakrishnan et al., 2020; Tapia, 2021), although moderate in the Bakar et al. (2020) research. TPACK obtained adequate levels in the studies of Baturay et al. (2017), Rodríguez-Muñiz et al. (2021) and Ramakrishnan et al. (2020) in contrast to the findings of Akun & Mohamad (2021), Li (2022), Chen & Jang (2019), López-Vargas et al. (2017) and Paidi et al. (2021) in which the results for this construct were low. TCK only obtained high values in the research of Saltan & Arslan (2017) in a similar way to what happened with TPK in the study of Baturay et al. (2017), while they presented low results in the studies of Akun & Mohamad (2021), Bakar et al. (2020), Li (2022) and Paidi et al. (2021). In the study of Zeng (2022) technology-based constructs (TK, TCK, TPK and TPACK) obtained lower scores than non-technology-based constructs (CK, PK, PCK).

Concerning gender, Ibrohim et al. (2022) and Rodríguez-Muñiz et al. (2021) established that, in general, TPACK self-efficacy levels of males were better than that of females; Uslu (2018) and Tanucan et al. (2021) reported the opposite. Baturay et al. (2017) and Bingimlas (2018) found higher levels in favor of men on the TK construct, although the former further indicates that women's TCK was higher than men's. In the study of Bakar et al. (2020), no significant differences between men and women were reported. Regarding teaching experience and its relationship with TPACK self-efficacy levels, several studies found that there is an inversely proportional relationship between age and the levels of the constructs that include technology (TK, TCK, TPK, and TPACK) (Akun & Mohamad, 2021; Bingimlas, 2018; Guggemos & Seufert, 2021; Ibrohim et al., 2022; López-Vargas et al., 2017; Tanucan et al., 2021; Tapia, 2021). Meanwhile, Rodríguez-Muñíz et al. (2021) found no significant differences in terms of the age of the participants.

Perception of Classroom Practices

Three research belong to this subcategory (n=3). In the study of Walan (2020) was developed through a case study with two participants, the objective was to determine what happens in a natural science class when teaching is almost completely based on digital technologies. The results showed that the use of digital technologies was positive for teachers since it had improved their science teaching, they had more tools for planning, evaluation, personalized teaching, and also identified greater motivation in students. The participants showed high levels of technological knowledge (TK).

On the other hand, the research developed by Aniq et al. (2022) sought to establish the beliefs of three English teachers with respect to the TPACK framework. They developed a case study in which they used interviews and classroom observations. The results indicated that there are similarities among teachers in terms of their beliefs about TPACK, such as the importance of choosing a good technological medium to develop classroom lessons and the motivation that the inclusion of technology in the classroom generates among students.

In the research of Pamuk (2022), the main objective was to gain an in-depth understanding of the experiences in practice with Tablet PCs and integrated whiteboards of 54 teachers in different Turkish cities. For this purpose, a case study was conducted using classroom observations, semi-structured interviews, and a focus group with

teachers from different areas of knowledge. The results indicated that teachers were limited by a lack of technical knowledge and pedagogical experience in teaching with technologies. Additionally, it was established that teachers were more opposed to working with the tablet PCs than with the integrated whiteboards.

Complemented Self-reported TPACK

These studies (n=7), in addition to inquiring about teachers' self-perceived TPACK levels, also did so with other related topics such as online education, motivational beliefs, barriers to ICT integration, technological integration in the classroom, pedagogical beliefs, and to contrast the declared with the observable. For this, they used, in addition to, the perceived self-efficacy questionnaires, classroom observations, lesson plans, and semi-structured interviews. Juanda et al. (2021) inquired about the preparation of biology teachers in Indonesia in the framework of online education according to their TPACK knowledge. Using a self-perception questionnaire and open-ended questions, they concluded that teachers had sufficient skills. However, they needed to improve technological competencies since biology requires activities such as laboratory practices, which, in online education, should be developed using simulators.

Backfisch et al. (2020) conducted research with in-service and pre-service mathematics teachers. They first contrasted the levels of content knowledge, pedagogical content knowledge, and technological knowledge between in-service and pre-service teachers through different questions related to the Pythagorean theorem and strategies for its teaching and a test on the use of different technologies used in the teaching of mathematics. The results revealed significant pedagogical and content knowledge differences in favor of in-service teachers. In technological knowledge, no differences were established between the groups. In a second phase, they found that in-service teachers perceived themselves as having higher levels of TPACK than pre-service teachers. Finally, the participants had to plan a class using technology; the researchers found that the more experienced teachers designed lesson plans with higher instructional quality and higher levels of technology use than the pre-service teachers.

De Freitas & Spangenberg (2019) conducted a study to identify TPACK levels and barriers to the ICT integration of mathematics teachers. They applied a self-perception questionnaire to 93 teachers and conducted interviews with 10 of them. The results showed adequate levels of teachers in CK, PK, and PCK, but low levels in TK, TPK, TCK, and TPACK. In addition, they identified six barriers to technology integration: relationship with the curriculum, poor technological infrastructure, negative perception of ICT in learning, short professional development courses, incorrect pedagogical beliefs, and poor school leadership. Chieng & Tan (2021) explored perceptions of ICT integration according to the TPACK framework with science teachers. They applied a self-perception questionnaire to 228 teachers and interviewed 3 of them in depth. They concluded that teachers had high expectations regarding their understanding of TPACK and the relationship between TPACK and technology integration in the classroom. However, the technology component (TK) scored the lowest.

Muhaimin et al. (2019) measured TPACK levels of science teachers seeking to establish differences concerning participants' age, gender, and teaching experience. They also sought to learn about teachers' perceptions of

technology integration in classrooms viewed from the lens of the TPACK framework. For this purpose, they applied a self-perception questionnaire and selected 8 teachers to be interviewed. The results showed that technology-based knowledge was generally the lowest, although higher in males than in females, except for TCK, where there was no difference. The TK and TPK knowledge levels showed significant differences in favor of teachers between 25 and 35 years of age. On the other hand, the interviewees agreed that peer collaboration helps to improve their technological skills and knowledge.

In their research, Rahmawati et al. (2021) replace content knowledge CK with vocational knowledge VK; therefore, they establish the TPAVK framework. They used a self-perception questionnaire of TPAVK levels and an analysis of lesson planners and field observations. The results indicated that PK was the highest among the base knowledge, followed by TK and VK. In the composite knowledge in the TPK, better levels of the participants were observed. By contrasting the questionnaire results with the lesson plans and field observations, it is established that teachers self-report knowledge related to technological integration; however, they rarely implement it in their teaching-learning processes.

Finally, Wu et al. (2022) in their study sought to establish the correlation between pedagogical beliefs and self-perceived levels of TPACK framework of secondary school teachers who used video-based flipped classroom (VFL) methodology. For this purpose, they developed a self-efficacy questionnaire called TPACK-VFL and adapted a questionnaire of pedagogical beliefs. The results indicated that the constructs CK, PCK, PK, TPK, and TCK were associated with teachers who identified with student-centered pedagogical beliefs, whereas the constructs TCK, TPK, and TPACK correlated with teachers with teacher-centered pedagogical beliefs.

Teacher Training Courses based on the TPACK Framework

The review yielded (n=9) papers in which teacher training courses on the appropriate integration of technologies in the classroom are developed. Some studies apply multiple-choice questionnaires (Chaipidech et al., 2022) or TPACK self-perception questionnaires as a pre-test/post-test (Alrwaished et al., 2017; Dalal et al., 2021; Kim & Lee, 2018; Njiku et al., 2021), accompanied by classroom observations and interviews (Bustamante, 2019) or with the review of classroom plans (Dalal et al., 2021). For their part, Da Silva et al., (2021) applied a technology integration questionnaire before starting the course and a TPACK self-perception questionnaire at the end of the course, in addition to analyzing classroom plans developed by teachers. The study by Sari et al. (2021) conducted interviews, classroom observations and analyzed field diaries before and after the workshops. Similarly, the research by Harron et al. (2022) was a case study using observational notes, group interviews and surveys. The following briefly describes each course, followed by the results.

Course Description

Chaipidech et al. (2022) conducted a course for science teachers, in which they relied on an artificial intelligence system for personalized teacher training called KKU SMART TPACK. The course took place over two days with 6 hours of work on each day. During the course, teachers recognized the training system, developed activities

aimed at learning to learn and learning to teach, developed skills in the constructs of the TPACK framework, and finally socialized the final results estimated by the KKU SMART TPACK.

The course developed by Alrwaished et al. (2017) involved some in-service teachers who obtained low scores on the self-perception questionnaire. The course workshop was developed during six days, in which the introduction to the TPACK framework was conducted. Its effects on the development of skills in students were exposed, emphasis was made on the role of introducing technological tools in lesson plans, and groups were formed that designed a lesson plan based on the TPACK framework. The course implemented by Dalal et al. (2021) had an extension of 10 sessions, each lasting 3 hours. They addressed topics such as learning theory, digital technology, internet safety, web-based communication, assessment, and mobile learning. Participating teachers completed individual and group assignments such as creating online presentations, teaching a particular topic through digital stories, and designing an online portfolio.

Kim & Lee (2018) conducted 2 courses, one for an experimental group and one for a control group, each lasting 15 hours. For the experimental group, the training was based on coding by including the Scratch program, while the control group focused on ICT tools such as Zoomit, Excel, and PowerPoint. Similarly, three groups of teachers were established for the professional development course designed by Njiku et al. (2021). The first group developed all the activities; another group only developed the last two activities, and a third group served as a control group that did not participate in any of them. The course lasted two months and developed five types of activities: the selection of a specific topic for the teaching of mathematics; analysis of the available digital resources; discussion about the incorporation, in the classroom lessons, of the previously analyzed resources; then work teams were assembled to plan lessons with digital resources, and finally the execution of the designed task.

Bustamante (2019) implemented a 16-week online professional development course for Spanish teachers in which activities were developed using Web 2.0 tools such as blogs, wikis, creating posters and comics, and video editing. Da Silva et al. (2021) course was a 130-hour blended course emphasizing maker spaces using educational videos, open educational resources, design and production of objects with 3D printers, and virtual and remote laboratories. Sari et al. (2021) developed two 90-minute workshops for secondary school English teachers. The first is about theoretical aspects of multimodality in English language teaching and reflective teaching practices. The second focused on the practical aspects of developing a lesson plan using TED-Ed (educational video library). Harron et al. (2022) conducted three workshops for mathematics teachers in which they used digital tools such as laser cutters and 3D printers to make materials such as Voronoi stained glass, origami jaws, non-circular gears, Mercator projection, among others.

Results obtained from the Courses

The results of the previous studies indicated significant improvements, when comparing the findings between pre-test and post-test, in the levels of technology-based knowledge (TK, TCK, TPK and TPACK) in the papers of Alrwaished et al. (2017), Chaipidech et al. (2022), Dalal et al. (2021), Kim & Lee (2018) and Njiku et al. (2021). Also was found that science teachers perform better than their mathematics counterparts (Alrwaished et al., 2017).

Additionally, there were no significant differences between the experimental and control groups (Kim & Lee, 2018), and TPACK levels improved in the three groups into which the teachers participating in the study were grouped (Njiku et al., 2021).

On the other hand, in research by Da Silva et al. (2021), it was established that teachers consider that they know how to use technologies but present weaknesses in using them to be effective in the teaching and learning processes. After the course, teachers reported higher levels of CK and PK and lower levels of TCK and TK. Nevertheless, the study concludes that the training course was effective, given that the teachers learned to use the technology and reflect on their educational practices. This is similar to the findings of Dalal et al. (2021), who found that teachers explored new educational technologies, improved their integration skills, and incorporated them into their teaching strategies.

In the research developed by Bustamante (2019), the results indicated that pedagogical knowledge and content knowledge were discordant, i.e., qualitative data were positive for teachers, but quantitative data did not show significant differences. Technological knowledge was in expansion, i.e., the qualitative data were favorable, and an increase in the levels stated in the quantitative instruments was observed. The paper attributed the discordance to the inadequate wording of the questionnaire items, while the expansion was explained by the limited access to technology in schools.

In the study by Sari et al. (2021), they used narrative inquiry to examine the stories of two English teachers regarding technology integration in classrooms who were chosen to integrate technology in the classroom regularly. Three patterns were identified. First, the two teachers reflected on classroom action; second, based on that reflection, they designed new classroom plans based on the TPACK constructs. And third, the connection between CK and TK resulted in teachers reflecting on TCK; they began to think about how the use of technology is directly related to students' needs in terms of understanding content. On the other hand, the participants agreed on the importance of incorporating technology into the classroom and that they were induced to step out of their comfort zone after participating in the research, using new resources in their instruction, and reflecting on the results obtained afterward. The results of the research by Harron et al. (2022) allowed them to establish that for the proper incorporation of materials developed with these digital tools, the level of teaching in which they are used and the connection that can be achieved with the real world must be considered. Additionally, it was evident that the teachers were more interested in the laser cutter than in 3D printing because it was more accessible to them.

Conclusions

Research on TPACK and specifically with in-service teachers in secondary education has been nurtured between 2017 and 2022, framed in studies to know the levels of perception of teachers concerning TPACK and in the implementation of professional development courses for proper technological integration in the classroom. Most of the publications aimed at establishing the levels of teacher perception have been developed using perceived self-efficacy questionnaires, with results of a quantitative nature since most of them use Likert-type scales to

measure the constructs that make up the TPACK framework. The results reported by this type of research were not homogeneous. There are TPACK constructs that, in some papers, established that teachers self-perceived themselves with high levels (Baturay et al., 2017; Ramakrishnan et al., 2020; Rodríguez-Muñiz et al., 2021), while in other studies, they were low (Akun & Mohamad, 2021; Li, 2022; López-Vargas et al., 2017; Paidi et al., 2021). This situation was more commonly present in TK and TPACK.

The studies conducted by direct perception of the use of TPACK in classroom practices were fewer, three in total (Aniq et al., 2022; Pamuk, 2022; Walan, 2020) and their results were reported qualitatively. In this research, it is established that the teachers who participated in the investigations expressed the importance of integrating technology in the classroom, given that it had improved their teaching methods. Other publications combined perceived self-efficacy questionnaires with data collection instruments such as analysis of classroom plans, interviews, and classroom observations, which led to the results of these investigations being presented quantitatively and qualitatively. In general, the results of these studies establish that the lowest levels of TPACK constructs are those with technology-based knowledge. Additionally, some investigations determined barriers for teachers to the adequate integration of technology in the classroom, and others found different results between those stated by teachers and what was observed during the teaching-learning process. The studies in which teacher professional development courses oriented by the TPACK framework were developed agree that at the end of the course, the participants improved their levels in all constructs, so it is recommended to develop more research related to this type of teacher training. Finally, it can be established that the TPACK framework is fertile ground for new studies, given the transversality of technological knowledge and the multiple applications and advances of technology that can be incorporated into the teaching and learning processes.

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Author Information

Javier Ricardo Guzmán González
https://orcid.org/0000-0002-4115-0457
Universidad Antonio Nariño
Ph.D. Candidate in Education.
Cl 22 sur 12D-81, Bogotá.
Colombia
Contact e-mail: *jguzman01@uan.edu.co*

Grace Judith Vesga Bravo
https://orcid.org/0000-0002-9990-360X
Universidad Antonio Nariño
Associate Professor
Cl 22 sur 12D-81, Bogotá.
Colombia