# Technological-pedagogical knowledge and teacher training: A systematic analysis

## El conocimiento tecnológico-pedagógico y la formación docente: un análisis sistemático

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**Abstract**

The purpose of this review is to analyze the contribution of technological-pedagogical content knowledge (TPACK) to comprehensive teacher training. To this end, the study was conducted using a qualitative approach, using the systematic review method based on the PRISMA model. Searches were conducted in academic databases such as Scopus and Web of Science, covering the period between 2020 and 2025. After applying inclusion and exclusion criteria, 18 relevant studies were selected and analyzed to assess the technological and pedagogical competencies necessary to integrate technology in the classroom, as well as the opportunities, challenges, and impacts associated with implementing the TPACK model. In conclusion, the TPACK model proved to be fundamental for teachers to develop digital skills and integrate technology into their educational practices, provided they have ongoing training, adequate planning, and institutional support. Although it offers great opportunities, it also faces challenges such as a lack of technological resources, insufficient training, and the diversity of educational contexts, especially in rural areas. Therefore, overcoming these obstacles requires a practical approach tailored to each situation. This will allow the model to have a positive and sustainable impact on educational quality when implemented appropriately.

**Keywords**: digital competencies, teacher training, TPACK model.

## Resumen

La presente revisión tiene como propósito analizar la contribución del conocimiento tecnológico-pedagógico del contenido (TPACK) en la formación integral de los docentes. Para ello, el estudio se llevó a cabo desde un enfoque cualitativo, utilizando el método de revisión sistemática basado en el modelo PRISMA. Se realizaron búsquedas en bases de datos académicas como Scopus y Web of Science, abarcando el periodo entre 2020 y 2025. Tras aplicar criterios de inclusión y exclusión, se seleccionaron 18 estudios relevantes que fueron analizados para evaluar las competencias tecnológicas y pedagógicas necesarias para integrar la tecnología en el aula, así como las oportunidades, desafíos e impactos asociados con la implementación del modelo TPACK. En conclusión, el modelo TPACK demostró ser fundamental para que los docentes desarrollen habilidades digitales e integren la tecnología en sus prácticas educativas, siempre que cuenten con formación continua, una planificación adecuada y respaldo institucional. Aunque ofrece grandes oportunidades, también enfrenta desafíos como la falta de recursos tecnológicos, una capacitación insuficiente y la diversidad de contextos educativos, especialmente en áreas rurales. Por lo tanto, superar estos obstáculos requiere un enfoque práctico y adaptado a cada situación. Esto permitirá que el modelo tenga un impacto positivo y sostenible en la calidad educativa cuando se implemente de manera adecuada.

**Palabras clave**: competencias digitales, formación docente, modelo TPACK.

## Introduction

The Technological Pedagogical Content Knowledge (TPACK) model has become an essential tool for educators to effectively integrate technology into their teaching practices (Balladares & Valverde, 2022). Developed by Mishra and Koehler in 2006, this framework combines three fundamental pillars: pedagogical knowledge, technological knowledge, and content knowledge, enabling teachers to design meaningful learning experiences tailored to their specific contexts. However, its implementation faces significant challenges, particularly in Latin America, where teachers' digital skills are limited due to inadequate training programs and poor technological infrastructure (Constante & Mora, 2024).

In the region, inequalities in connectivity exacerbate the issue. The 2023 Global Education Monitoring Report (GEM) by UNESCO, which evaluates the use of technology in education globally, highlights that access to meaningful connectivity remains unequal. According to the report, worldwide, only 40% of primary institutions, 50% of lower secondary schools, and 65% of upper secondary schools have internet access. Although 85% of countries have implemented policies to improve connectivity in educational institutions, disparities persist and severely affect the most vulnerable areas.

Furthermore, the report emphasizes that while the right to education is increasingly linked to the right to meaningful connectivity, efforts to integrate essential digital competencies into curricula and assessment regulations have been insufficient. In Latin America, more than 70% of individuals lack basic digital skills, a concerning figure compared to nations within the Organisation for Economic Co-operation and Development (OECD). This situation reflects a deficiency in teacher training, as most educators lack the adequate digital skills necessary to effectively implement technology in the teaching-learning process (OECD, 2020).

In this regard, addressing this issue is crucial, as advancements in teachers' digital capabilities can not only improve the quality of education but also promote inclusion and equity by ensuring that all students have access to an education that meets the demands of the digital age. Previous studies have demonstrated that the successful implementation of the TPACK model fosters a more participatory and student-centered teaching method, which enhances motivation, engagement, and academic performance (Balladares, 2020; Cachoa, Amaya, & Álvarez, 2024). However, educators will not be able to fully benefit from these advantages without solid training in technological competencies that enable them to adjust their pedagogical approaches to adapt to a constantly evolving digital environment.

In this context, the current research is part of a systematic review following the PRISMA method, ensuring that the process of selecting relevant studies on TPACK in teacher training is rigorous and transparent. The aim of this review is to identify the technological, pedagogical, and content skills that teachers need to effectively implement technology in the classroom, considering both barriers and opportunities, as well as the impact of TPACK reported in the scientific literature. The search will be conducted in databases such as Scopus, Web of Science, Google Scholar, and Redalyc, using key terms related to TPACK, teachers' digital competencies, technological implementation in the classroom, and teacher training in the 21st century. Strict criteria will be applied

to include or exclude studies, ensuring that those selected are relevant and of high quality, following the guidelines of the PRISMA method.

## Methodology

The presented study adopted a qualitative approach, implementing a systematic, descriptive, and deductive review. The systematic review was conducted in accordance with the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), ensuring that the process is comprehensive, clear, and replicable, thereby strengthening the validity and quality of the information collected. The research was developed in the following phases:

### 1. Identification Phase

An exhaustive search for primary research was conducted in recognized academic databases such as Scopus, Web of Science, Google Scholar, and Redalyc. The search focused on the key terms “Technological Pedagogical Content Knowledge (TPACK), teachers' digital competencies, technological implementation in the classroom, teacher training in the 21st century.” To enhance the results, Boolean operators (AND, OR) were utilized to refine the findings and obtain more precise information. The search procedure applied in each database is detailed below.

**Table 1**

*Search strategy for the research*

| Databases | Keywords with Boolean Operators |
|---|---|
| **Scopus** | "technological pedagogical content knowledge" AND "teacher digital competencies" AND "TPACK" |
| **Web of Science** | "TPACK" AND "teacher training" AND "educational technology" |
| **Google Scholar** | "teachers' technological and pedagogical skills" AND "technology integration in the classroom" |
| **Redalyc** | "21st century teacher training" AND "TPACK" AND "technology implementation in education" |
| **Scopus** | "technological pedagogical content knowledge" AND "teacher digital competencies" AND "TPACK" |

It is worth noting that the time frame for the search encompasses articles published between 2020 and 2025, in order to gather an updated and relevant sample for the research.

### 2. Selection Phase

To ensure that the selected studies were of high quality and relevance, inclusion and exclusion criteria were established based on the PRISMA guidelines.

**Inclusion Criteria:**

- Research published between 2020 and 2025.
- Studies in Spanish and English.
- Research analyzing the TPACK model in teacher training.
- Works on technological, pedagogical, and content competencies in teacher education.
- Qualitative, quantitative, or mixed studies investigating technology application in the classroom.

**Exclusion Criteria:**

- Duplicate articles or those in languages other than Spanish or English.
- Research that does not consider the TPACK model or technology in teaching.
- Studies without full text access.
- Opinion articles or those lacking a defined methodology.

- Articles outside the accepted publication deadline.

**3. Eligibility Phase**

In this phase, a thorough review of the abstracts and topics addressed in the identified studies was conducted, analyzing their alignment with the research objectives. After removing duplicates and performing an initial relevance assessment, a total of 171 studies were reviewed. Of these, 105 were discarded for not meeting the inclusion criteria. Finally, 18 relevant studies were selected for an in-depth analysis regarding the following aspects:

- Assessment of whether the studies employed appropriate approaches to investigate technological and pedagogical competencies among teachers.
- Verification of whether the studies implemented suitable qualitative, quantitative, or mixed methods to explore the relationship between TPACK and teacher training.
- Collection of the most relevant findings related to the opportunities and challenges in implementing TPACK in the classroom.

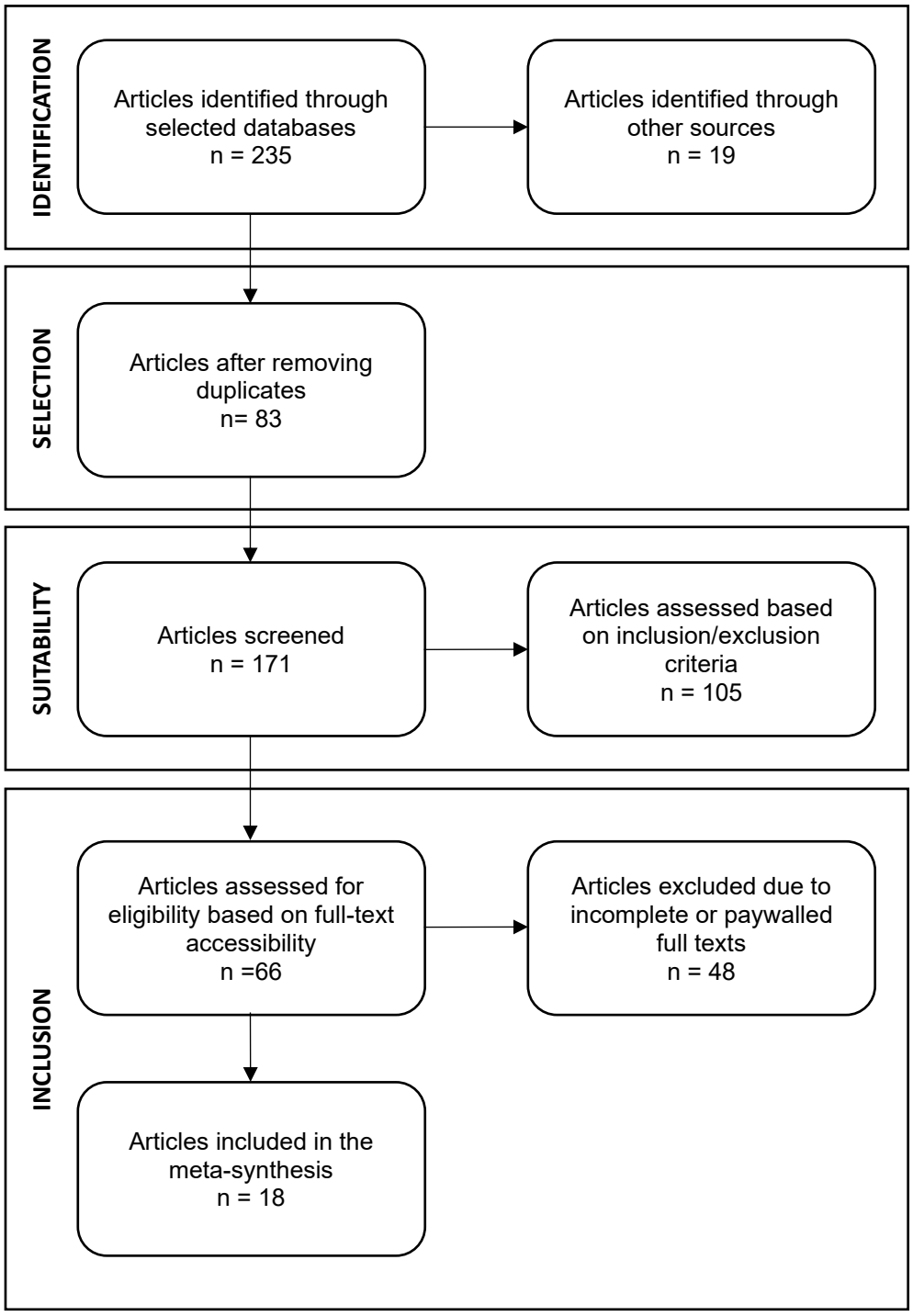
**4. Inclusion and Synthesis Phase**

The 18 selected studies were thoroughly analyzed, recording key information on author/year, journal/repository, and applied methods, as well as the main findings. This analysis facilitated:

- Identification of essential factors related to the technological, pedagogical, and content skills required for successfully integrating technology in the classroom.
- Exploration of the opportunities and challenges mentioned in the literature for pre-service teachers when applying the TPACK model.
- Evaluation of how the TPACK model influences teachers' digital competencies and their ability to enhance the quality of education through technology implementation.

A chart summarizing the procedures outlined in the previous phases is presented below:

**Figure 1**
*PRISMA Flow Diagram*



## Results and discussion

First, regarding the identification of essential factors related to the technological, pedagogical, and content skills necessary for successfully integrating technology in the classroom, the results of the review have allowed for the identification of the following:

**Table 2**

*Objective 1 of the study*

| N° | Author/ Year | Title | Journal/ Repository | Methods | Main Findings |
|---|---|---|---|---|---|
| **1** | (Cafferata, 2024) | Technological pedagogical disciplinary knowledge in Mathematics teacher training: An experience related to Quadratic Functions content | RDI University Repository, National University of Comahue | Qualitative, descriptive research with a case study in a group of first-year Mathematics teacher students. | Demonstrated how future teachers integrate technological, pedagogical, and disciplinary knowledge, emphasizing the opportunities provided by ICT to improve the representation of mathematical content. |
| **2** | (Balladares & Valverde, 2022) | The TPACK technopedagogical model and its impact on teacher training: a literature review | Caribbean Journal of Educational Research | Systematic literature review. | Showed that the TPACK model is essential for developing teaching competencies and applying digital technologies, along with their pedagogical integration, but challenges such as lack of resources and ongoing training exist. |
| **3** | (Morales, 2020) | TPACK for effectively integrating ICT in education: a theoretical model for teacher training | Scientific Journal Education and Society, National Autonomous University of Nicaragua | Qualitative research based on the analysis of the TPACK model and its application in teacher training. | Concluded that the successful integration of ICT depends on teacher training in pedagogical, disciplinary, and technological knowledge, as well as the attitudes of both teachers and students, and instructional planning. |
| **4** | (Cenich et al., 2020) | Technological pedagogical content knowledge in mathematics teaching in the upper cycle of secondary school | Educational Profiles | Quantitative approach with structured questionnaires. | Concluded that the TPACK model helps to better understand mathematical content by effectively combining digital tools. However, continuous training is necessary. |

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| **5** | (León, 2024) | The TPACK model: a strategy to enhance teachers' digital competencies | LATAM: Latin American Journal of Educational Technology | Document and descriptive review of indexed scientific articles and theses, based on a quantitative approach. | Asserted that the TPACK model serves as an effective strategy to strengthen teachers' digital skills, particularly by integrating technological, pedagogical, and content knowledge in their educational practices. |
| **6** | (Ulloa, 2024) | Teaching ICT through Technological Pedagogical Content Knowledge and Action Research | Master's Thesis, Luis Vargas Torres Technical University, Ecuador | Action Research methodology (AR) with techniques including Participatory Observation, Focus Groups, and analysis of student work. | The study allowed for partial integration of content, pedagogy, and technology, improving the learning of future teachers. Reflective and systematic self-assessment of teaching practice was key to professional development. |

The analysis of the research presented in Table 2 revealed several important similarities and differences regarding the key factors related to the technological, pedagogical, and content competencies necessary for proper technology integration in classes, according to the TPACK model.

In general, most studies agree that comprehensive teacher training is crucial, combining knowledge in technology, pedagogy, and discipline to achieve effective teaching in the digital realm. Authors such as Cafferata (2024), Morales (2020), León (2024), and Balladares & Valverde (2022) highlight that the TPACK model is essential for enhancing teachers' capabilities, enabling them not only to manage digital tools but also to use them appropriately within the educational context. Moreover, this comprehensive approach seeks to transform conventional teaching into meaningful learning experiences, which can only be achieved when educators can effectively combine these three types of knowledge.

Furthermore, Morales (2020), León (2024), and Ulloa (2024) argue that the success of integrating ICT in the classroom largely depends on instructional planning, the chosen pedagogical approach, and the attitudes of both teachers and students. Ulloa (2024) emphasizes the importance of reflective and methodical self-assessment as a key tool for teachers' professional growth, aligning with Morales (2020) on the need for ongoing training that fosters active learning tailored to the context.

Finally, Ulloa (2024) indicates that the connection between content, pedagogy, and technology was achieved only partially in their research, highlighting the need for a reflective and systematic approach to achieve effective teacher professional development. This aspect is less clear in studies such as those by Cafferata (2024) and Morales (2020), who present a more optimistic perspective on the impact of the TPACK model without addressing the limitations as extensively.

On the other hand, regarding the exploration of opportunities and challenges mentioned in the literature for pre-service teachers when applying the TPACK model, the following studies were considered:

**Table 3**
*Objective 2 of the study*

| N° | Author/ Year | Title | Journal/ Repository | Methods | Main Findings |
|---|---|---|---|---|---|
| **1** | (Balladares J. A., 2020) | Remote Education in Times of Academic Contingency | Andean Journal | Documentary analysis and literature review. | Highlighted that the pandemic accelerated the use of the TPACK model, emphasizing its potential for remote education. However, it also identified barriers such as a lack of advanced digital competencies. |
| **2** | (Cadena, 2022) | TPACK Model in the Teaching-Learning Process of Students at Barreiro Educational Unit | Repository of Technical University of Babahoyo | Qualitative case study through interviews and observations. | Demonstrated that the TPACK model facilitates active learning but also identified limitations due to poor technological infrastructure and lack of training. |
| **3** | (Fernández et al., 2022) | Perception of Preschool Educators Regarding Their TPACK Knowledge When Integrating ICT During COVID-19 | Technological Information | Descriptive study with surveys of 86 preschool educators. | Educators recognize the importance of the TPACK model but face limitations in technical and pedagogical training. |
| **4** | (Sumba et al., 2020) | Higher Education in Ecuador During COVID-19 within the TPACK Framework | San Gregorio Journal | TPACK survey (TK and TPK). Comparative analysis and results of assessments to measure TPACK knowledge. | Showed that teachers struggle with insufficient training to combine teaching with technology while also highlighting opportunities in the growing demand for training in digital tool management and tele-education to enhance teachers' skills. |
| **5** | (Cayachoa et al., 2020) | The TPACK Model as a Strategy to Integrate ICT in the Classroom through Teacher Training | Espacios Journal | Mixed, descriptive study with a comparative design. A teacher training program was conducted with eight primary education teachers. | Evidence indicated that active training in ICT, rather than theoretical, enabled effective implementation of ICT in classes. Challenges included lack of time and resources, while opportunities focused on increasing digital competence and educational quality through proper ICT usage. |

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| **6** | (Ortega, 2020) | Technological Pedagogical Content Knowledge (TPACK): An Analysis of the Relationship and Integration Between Technological and Pedagogical Content Knowledge | Tecné, Episteme, and Didaxis: TED | Theoretical review and conceptual analysis based on Mishra and Koehler's (2006) proposal and the integration of the technological component into the educational curriculum. | Showed that opportunities include improved pedagogical approaches using technologies in the classroom, while challenges revolve around the lack of continuous training and appropriate use of technologies. |

The evaluation of the studies presented in Table 3 allowed for the detection of both similarities and differences in the opportunities and obstacles faced by pre-service teachers when implementing the TPACK model. In this regard, studies conducted by Balladares (2020), Sumba et al. (2020), Cayachoa et al. (2020), and Ortega (2020) agree that the TPACK model offers a useful theoretical-practical framework for integrating ICT in education, promoting improvements in educational quality through student-centered active learning.

Specifically, Ortega (2020) mentions that the TPACK model facilitates a more coherent pedagogical approach focused on incorporating technology into the curriculum, which supports Cayachoa et al. (2020) regarding the need for active teacher training as a key aspect for effective integration. Similarly, Sumba et al. (2020) and Fernández et al. (2022) highlight the growth of distance education as an opportunity for continuous teacher development in applying digital tools.

Despite the clear advantages of the TPACK model, most studies indicate significant barriers to its successful implementation. Cadena (2022), Fernández et al. (2022), and Cayachoa et al. (2020) underscore that the lack of technological infrastructure, restricted access to devices, and poor connectivity are relevant challenges, especially in rural or resource-limited areas. In this sense, technological limitations become an obstacle that impedes the full integration of the TPACK model.

Moreover, Ortega (2020) and Cayachoa et al. (2020) emphasize that teacher training based solely on theory is insufficient; training should focus on active methodologies that promote the practical application of ICT. This perspective is also supported by Sumba et al. (2020), who note a lack of technological competencies among teachers, negatively affecting the effective implementation of the model.

Finally, to conclude the presentation of results on the evaluation of the impact of the TPACK model on teachers' digital competence and their ability to improve educational quality through technology use, the analysis of the following studies is presented:

**Table 4**
*Objective 3 of the study*

| N° | Author/ Year | Title | Journal/ Repository | Methods | Main Findings |
|---|---|---|---|---|---|
| **1** | (Constante & Mora, 2024) | Integration of the TPACK Model and Digital Resources in Teaching Ancestral Knowledge | LATAM: Latin American Journal of Social Sciences and Humanities | Case study with direct observation and interviews with teachers. | Concluded that the TPACK model enhances the teaching of ancestral knowledge through the effective use of digital resources, but requires cultural and contextual adaptation. |

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| **2** | (Paidicán & Arredondo, 2024) | Technological Pedagogical Content Knowledge (TPACK) in Rural Contexts: A Literature Review | Journal of Studies and Experiences in Education | Systematic literature review. | Demonstrated that the TPACK model presents significant opportunities in rural areas but faces barriers such as restricted access to technology and insufficient teacher training. |
| **3** | (Padilla & Ayala, 2022) | Digital Competencies in Higher Education Teachers in Ibero-America: A Systematic Review | RIDE: Ibero-American Journal for Research and Educational Development | Systematic review of previous studies. | Evidenced significant gaps in the use of the TPACK model, with basic technological competencies but limited pedagogical integration, as well as inequalities in access to technology and lack of continuous training. |
| **4** | (Vivanco, 2020) | Technological, Pedagogical, and Disciplinary Knowledge of the Virtual Tutor: A Case Study of a Distance Education Program | Andean Journal of Education | Quantitative descriptive study with online questionnaires applied to teachers. | Revealed that tutors positively value technological, pedagogical, and disciplinary competencies separately, but their ability to integrate all three types of knowledge decreases when approached collectively. |
| **5** | (Zambrano, 2023) | Evolution of Teachers' Digital Competencies in the Technological Era: An Approach for Effective Integration in the Classroom and Its Impact on Learning | Identidad Bolivariana, 7(2), 22-30 | Mixed research (quantitative and qualitative). Analysis of data on technology use in the classroom and its impact on teachers and students. | Identified the importance of continuous and tailored training for each teacher, highlighting the need for curricular adaptations to effectively integrate technology and improve educational quality, promoting a more dynamic and enriched teaching approach. |
| **6** | (Bedoya, 2021) | Solving Trigonometric Problems Mediated by GeoGebra within the Framework of Technological Pedagogical Content Knowledge (TPACK) | Master's Thesis in Teaching Exact and Natural Sciences | Design of a technological proposal in GeoGebra based on the TPACK model. Learning guides and pre- and post-tests were applied. | Results showed a significant improvement in students' competencies for solving trigonometric problems, with the percentage of students achieving high grades increasing from 15% to 65%, indicating a clear impact on mathematical and technological skills through the mediation of GeoGebra. |

The review of the research reveals that the TPACK model plays an important role in enhancing teachers' digital competence and improving educational quality, provided it is adapted to the cultural, contextual, and technological characteristics of each situation.

On one hand, studies such as those by Constante & Mora (2024) and Bedoya (2021) highlight how the use of specific digital tools, such as GeoGebra or technologies for teaching traditional knowledge, enhances learning by effectively combining pedagogy, technology, and content. The studies show notable advances in student performance and the resolution of complex topics, such as trigonometry, where technology integration allows for a more active and contextualized learning experience.

However, there are challenges that limit the effectiveness of the TPACK model. In this regard, Paidicán & Arredondo (2024) and Padilla & Ayala (2022) emphasize that limited access to technology, inadequate infrastructure, and insufficient teacher training hinder the application of the TPACK model in rural settings and in higher education across Ibero-America. Additionally, barriers are also reflected by Vivanco (2020), which notes that combining technological, pedagogical, and disciplinary knowledge remains a challenge, especially in virtual environments where the complexity of integrated teaching is often overlooked.

Finally, Zambrano (2023) highlights that continuous and personalized training is essential for the TPACK model to be effective. He suggests that teacher training should be tailored to the specific needs of the educational environment to promote more enriching teaching practices.

## Conclusions

Upon completing the research, it is established that the TPACK model is a valuable tool for enhancing teachers' skills and facilitating the integration of technology into the classroom. This is possible as long as there is continuous training, adequate educational planning, and necessary support from institutions. Although many studies highlight the transformative power of the model, challenges that depend on the educational context are also recognized, justifying the need for a practical and adaptable approach to local circumstances.

Additionally, it has been observed that the TPACK model promotes meaningful learning through the integration of ICT, especially in remote or hybrid teaching situations that arose due to the pandemic. However, structural barriers such as a lack of technological resources, limited ongoing training, and insufficient teacher skills still exist. To overcome these obstacles, it is essential to have practical training, the right infrastructure, and a comprehensive approach that maximizes the advantages of the model.

Finally, the TPACK model has had a positive impact on fostering teachers' digital competencies and improving educational quality, provided that technological tools are adapted to the educational context and relevant continuous training is promoted. The integration of technology encourages dynamic and tailored learning, although challenges remain in rural areas and places with limited resources. This emphasizes the importance of sustained efforts to ensure effective implementation and significant impact on the teaching-learning process.

In conclusion, TPACK is a fundamental model that helps teachers develop their digital competencies and integrate technology into their classes, as long as it is accompanied by continuous training, adequate planning, and institutional support. Despite the great opportunities it offers, it faces challenges such as the scarcity of technological resources, inadequate training, and diversity in educational contexts, especially in rural areas. Consequently, addressing these issues requires a practical and personalized approach for each situation. In this way, the model will have a positive impact on educational quality if applied in a comprehensive and sustainable manner.

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