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Technological Pedagogical and Content Knowledge (TPACK) on Mathematics Learning: A Systematic Review

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Abstract

This study aimed to determine the extent of research using TPACK on Mathematics Learning. This Systematic Review used the PRISMA method and, with the help of the Publish or Perish and VOS Viewer software applications, obtained 142 articles from journals sourced from Scopus. The article journal is related to using the TPACK method in mathematics learning. It was found from the results of the literature review that the study of TPACK keywords could be categorized into (1) TPACK on the use of teaching/learning devices/tools and the development of learning innovations; (2) TPACK in learning planning; and (3) TPACK in evaluating teacher competency. The author believes that applying TPACK in mathematics learning requires careful planning and clear output/outcomes, so using tools can also provide optimal benefits. However, it must still be coupled with qualified teaching teachers' competence.

Keywords: Systematic Review, TPACK, Mathematics Learning

INTRODUCTION

Innovative creative learning is needed for students (Rafi & Sabrina, 2019; Hayani & Sutama, 2022; Rahayu *et al*., 2023; Yanti & Mawarwati, 2023). One of these learning models is based on the concept of Technological Pedagogical Content Knowledge (TPACK). This concept was inspired by Shulman's theory in 1986, namely Pedagogical Content Knowledge (PCK) (Diana & Mampouw, 2019; Hayani & Sutama, 2022; Suyamto *et al*., 2020). TPACK is a teacher framework for teaching effectively using technology (Amrina *et al*., 2022; Yurinda & Widyasari, 2022). TPACK is an inseparable part of the four main teacher competencies: pedagogical, personality, social, and professional (Murtiyasa & Atikah, 2021).

Pedagogical and Technological Content Knowledge (TPACK) is important knowledge that teachers must master. TPACK consists of seven dimensions: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and the integration of these into in Pedagogical and Technological Content Knowledge (TPACK) (Aini, 2024). Applying TPACK is very important in preparing, planning, and evaluating learning competencies that are being have been carried out (Kafyulilo, 2019; Indrawati, 2021; Najibah & Salsabila, 2022). There have not been many literature studies on TPACK specifically for mathematics learning. Mathematics learning requires an effective learning system (Nyikahadzoyi, 2015; Stoilescu, 2015). Therefore researchers conducted a Systematic Review to determine the extent of research using TPACK on Mathematics Learning as the basis for further study.

METHOD

This type of research is a Study Literature Review (SLR) which uses the PRISMA (Select, Report, Items for Systematic Review and Meta-analysis) method (Muhammad *et al*., 2022; Hudha *et al*., 2023; Manikam & Maat, 2023; Banjar *et al*., 2023; Bastidas-Orrego *et al*., 2023; Madueme & Chirove, 2024 ; Galletta *et al*., 2024). The PRISMA method is used because the stages in the systematic review are structured and planned. The database used to carry out a Systematic Review is Scopus. The database was chosen because Scopus is one of the main databases used for international studies in academic literature (Nugrahanti *et al*., 2023; Sarkar *et al*., 2024).

The implementation of collecting journals/articles as material for this research literature study utilizes the Publish or Perish (PoP) software application. The number of articles obtained was then filtered using the PRISMA method with inclusion and exclusion criteria. The filtered literature was then subjected to an in-depth study. The next stage is to use the VOSviewer software application. Use this application to see the keyword relationships of all the articles collected.

The literature review was conducted on 20 September 2024. The literature selection process is an important stage with several steps in the activities carried out (Blundell *et al*., 2022; Jameson *et al*., 2022 ; Brianza *et al*., 2024 ; Fabian *et al*., 2024). The initial search related to TPACK obtained 200 articles, and the second search focused on getting the latest trends and research results on TPACK in mathematics learning, which obtained 142 articles. The steps are presented in Figure 1.

The article screening process began by examining relevant literature for inclusion and exclusion criteria. These criteria are presented in Table 1. After determining these criteria, the articles to be reviewed were selected.

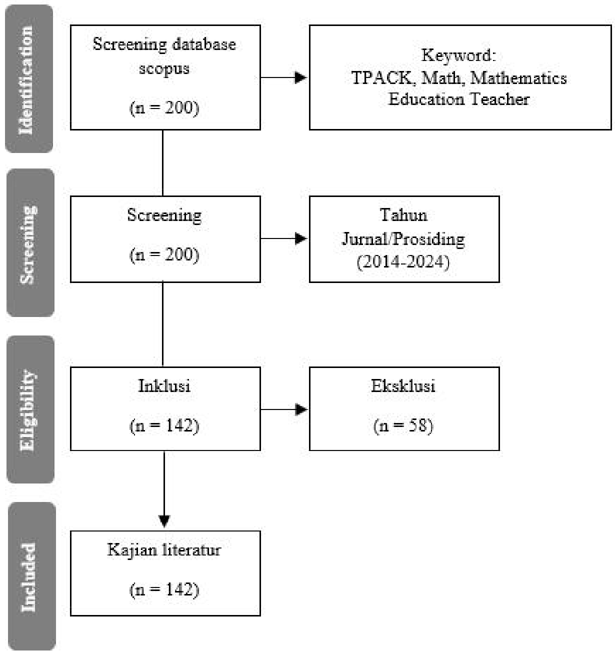

Figure 1. PRISMA Stages

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	1. Literature review comes from journal articles/proceedings 2. Scopus-sourced 3. Journal/proceedings already published 4. Originating from 2014-2024 5. Topics: TPACK, mathematics learning, teacher, mathematics education
Exclusion Criteria	1. Literature review in the form of books, final coursework, theses, papers, reports 2. Inaccessible article and incomplete abstract 3. Research topics other than focusing on TPACK, mathematics learning, teachers, mathematics education

(Hudha *et al*., 2023)

RESULTS AND DISCUSSION

Based on the articles/journals obtained from the literature review source of the Publish or Perish software application, TPACK learning is grouped into several categories, namely:

a. TPACK on the use of teaching/learning *tools* and the development of learning innovations;

b. TPACK in lesson planning and

c. TPACK on teacher competency evaluation

TPACK on the Use of Teaching/Learning *Tools* and the Development of Learning Innovations

Goodson-Espy (2014) and Muir (2016) use Interactive White Boards (IWB) with the TPACK learning model in mathematics learning. The results of his research prove that students and teachers can develop an understanding of critical mathematical ideas. Teachers can also engage with useful mathematical tasks and discuss existing lessons.

Courey (2015) conducted research using Dynabook for three years. The results showed that lecturers noted improvements in proportional problem-solving skills and in answering questions in pedagogical content knowledge and mathematical thinking.

Lane (2015) researched the use of iPad devices in learning. In ten classrooms in Western Australia, from kindergarten to year ten, quantitative and qualitative research was conducted over two years. The study resulted in short vignettes (digital curriculum) called "i-Stories". This sketch includes a list of TIPs Mobile Pedagogies in Mathematics Checklist (Tips-Mobile-Maths), which is an effective pedagogical learning technique using iPads in mathematics education. Evans (2015) investigated the use of iPads in learning. The Candy Factory app—a learning game specifically for the iPad that focuses on pre-algebra concepts, especially fraction knowledge—was used in this study conducted in southwest Virginia. This resulted in a coding system to discover patterns and themes that best suited the alignment of learning and implementation of students' learning styles, assessments, and learning methods.

Cabus (2017) explored the impact of grade-level differentiation by innovatively utilizing an interactive whiteboard (SMARTboard) on math proficiency. The results showed a significant increase in math proficiency by 0.25 points after using the SMART board tool.

Integrating technology into writing instruction is integral to improving students' abilities. This is following the results of research conducted by Abubakir & Alshaboul (2023). He conducted descriptive research using questionnaires to compare the results of using technology in the classroom. Her other research results show that teachers participating in professional development outperform their peers in TPACK. This is also in accordance with research conducted by Hidayat (2024), which found that technological knowledge (25%), technological pedagogy content knowledge (69%), and technological content knowledge (39%) had a significant effect on discovery learning. On the other hand, technology knowledge (25%), technology pedagogy content knowledge (69%), and technology content knowledge (39%) have a significant effect on multiple representation learning.

TPACK in Lesson Planning

In his research, Patahuddin (2016) examined critical learning events to determine how the TPACK construct influences teachers' understanding and development of pedagogical practices using digital technology. To develop and assess teacher TPACK, critical learning events and the use of web-based resources require careful planning.

An experiment in developing collaborative learning between cooperative science teachers and researchers was carried out by Chatmaneerungcharoen (2019) . The goal is to combine coaching strategies with teaching practices that align with professional development in technology pedagogy content knowledge (TPACK). The study shows that STEM cooperative science teachers' understanding and learning practices can be enhanced with the STEM Education Professional Development Model (STEMed-PD) developed within the framework of coaching and mentoring, instructional learning, post-action reflection, and professional development communities. For future lesson planning, lesson plans created during STEMed-PD demonstrate progress in teacher understanding and practice.

Quasi-experiment was used as a research methodology (Habiyaremye, 2024) . The experimental and control groups were used as control groups. The experimental group received MKT development interventions through lesson planning and TPACK. In contrast, the control group prepared teaching materials using conventional lesson plan templates. This study investigates how effective Mathematical Knowledge for Teaching (MKT) through lesson planning and technological pedagogical content knowledge (TPACK) is among mathematics tutors in teacher training colleges in Rwanda. This research emphasizes how important it is for education stakeholders and continuing professional development providers to incorporate TPACK into lesson planning during teacher training to encourage more effective lesson planning approaches.

TPACK on Teacher Competency Evaluation

According to Sampaio & Coutinho (2015) and Sampaio (2016), professional development of mathematics teachers through ongoing programs and training across the country must involve experiences involving inquiry, ideation, planning, practice, and reflection. This technology is not just a tool; it's more about how teachers and students use it. Teachers must use technology according to specific goals, content, and pedagogy so that it benefits student learning and is suitable for content-based activities.

Getenet (2016) investigated how elementary school science and mathematics teachers acquire the skills necessary to integrate ICT into their teaching. The Technology and Pedagogical Knowledge (TPACK) professional learning workshop, which covers areas such as learning design, classroom teaching, and reflection activities in teams, was attended by the teachers. Learning evaluation sheets, questionnaires, observation lists, and notebooks were used to collect data. The results show that teachers gained the ability to utilize available ICT in their teaching by using intervention activities.

Li (2023) developed the technology pedagogy and content knowledge scale (TPACK) or SMTTS for secondary mathematics teachers. It is designed to meet specific mathematics educational needs and contexts and is subject-oriented. The development of SMTTS assists the field by providing appropriate and reliable tools to aid the design of targeted professional development programs and assist policy decisions regarding the integration of technology in mathematics education. This study has theoretical and practical consequences. In teacher TPACK, SMTTS can also help find curriculum that needs improvement.

According to Njiku (2024) research, the TPACK Framework has become a favorite in research on assessing and developing teachers' abilities to teach with technology. To validate the instrument and assess the TPACK levels of 30 participants, this study used six videotaped sessions. The observation rubric was designed to assess mathematics teachers' TPACK, but teachers must contextualize it based on content and technology. Additionally, the findings of this study suggest that more engaged, collaborative professional development activities may be more effective in building teachers' TPACK. It is important to ensure that teachers have access to relevant technology when organizing professional development. conducted a survey on the implementation of TPACK on PST. The results showed that the trainees/pre-service teachers (PSTs) had not used technology in micro-teaching sessions and first lessons to teach students.

Systematicsy Literature Review (SLR) Results

The results of the connectedness (network) and density (density) carried out using keywords from each article/journal used as source material for the literature review found that of the 142 source articles used, only four keywords showed a connection with each other, namely: (1) technological pedagogical content knowledge; (2) teacher training college; (3) lesson plan intervention; and (4) mathematical knowledge for teaching. The visualization is shown in Figure 2 and Figure 3.

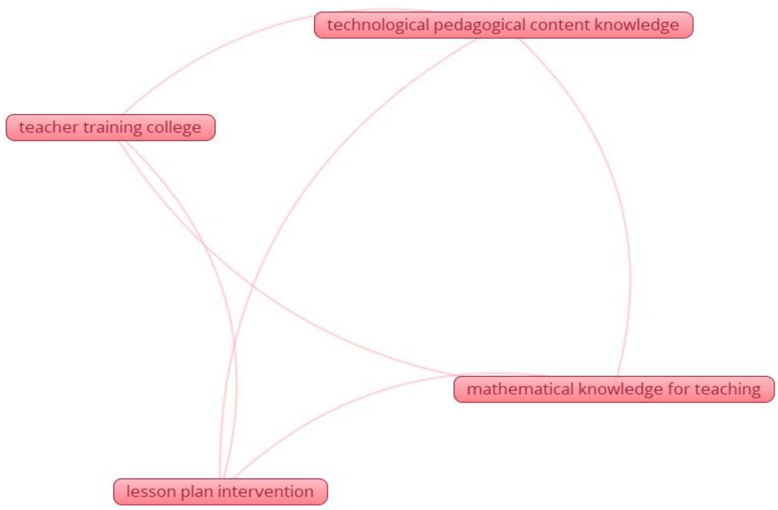

Figure 2. Network Visualization of the Keywords of the Articles/Journals Used

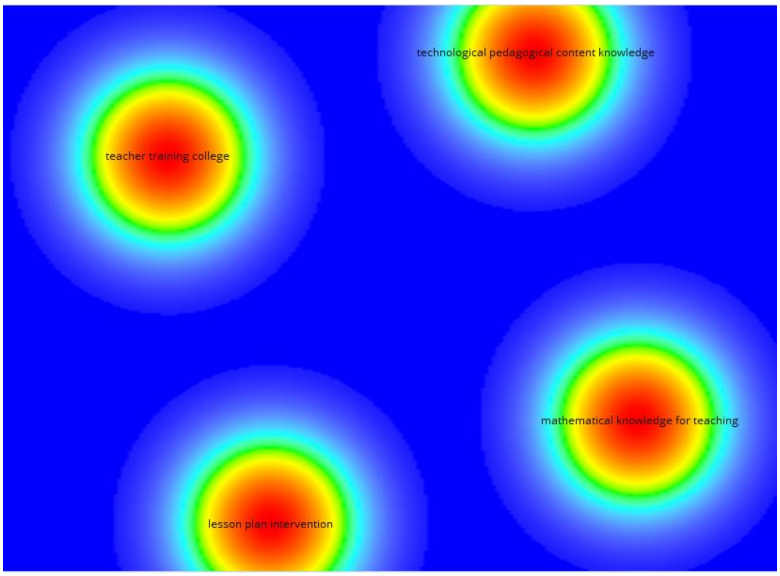

Figure 3. Visualization of *Density* Against the Keywords of the Articles/Journals Used

CONCLUSION

This literature review research using the PRISMA method and the help of Publish or Perish and VOS Viewer software applications obtained 142 articles/journals from Scopus (Blundell *et al.*, 2022; Sarkar *et al.*, 2024) . The articles/journals are related to using the TPACK method in learning mathematics. The results of the literature review showed that TPACK keyword studies can be categorized into (1) TPACK in the use of teaching/learning devices and the development of learning innovations, (2) TPACK in lesson planning, and (3) TPACK in evaluating teacher competence. The author argues that applying TPACK in mathematics learning requires careful planning and clear outputs/outcomes so that tools can also benefit optimally. However, it must still be juxtaposed with the competence of qualified teaching teachers.

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