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Improving Technological Pedagogical Content Knowledge (TPACK) of Elementary School Teachers through Training with a Collaborative, Practical and Reflective Approach

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Abstract. The integration of technology into teaching and learning processes is highly relevant in today's educational landscape, as technology has become essential for facilitating student learning. However, in practice, technology has not been fully optimized to develop students' critical thinking skills. The TPACK framework, which guides teachers in integrating technology into the learning process, must be continuously refined through relevant strategies. This study aims to describe how elementary school teachers' TPACK can be improved through collaborative, practical, and reflective approaches. A mixed methods design with an embedded experimental approach was employed. The study involved 84 teacher participants, randomly assigned to experimental and control groups. Data were collected using a 21st-century TPACK questionnaire and interviews. The findings indicate that collaborative, practical, and reflective approaches significantly enhanced elementary school teachers' TPACK. Statistical tests revealed a significant difference between the experimental and control groups, with the experimental group achieving higher average TPACK scores. Training that incorporates teacher collaboration, real-world classroom practices, and self-reflection effectively enhanced Technological Pedagogical Knowledge (TPK), contributing to the overall improvement of TPACK.

Keywords: Training; Collaborative; Practice; Reflective; TPACK.

1. Introduction

Rapid technological advances in the 21st century have changed the way we teach and learn (Tanak, 2020). Technological developments are changing the paradigm of effective learning with technology (Ertmer & Ottenbreit-Leftwich, 2010). Initially the understanding of teaching with technology meant using technology as a medium of learning, for example using a computer to show PowerPoint slides or taking students to a computer lab to use the internet. As technology advances, there has been a shift. The focus of teaching with technology shifted to using technology to learn, collaborate, problem solve, lead and empower students (Agyei & Keengwe, 2014). This has given rise to a new paradigm on the meaning of effective learning. Good learning is one that facilitates students' learning process by utilizing relevant information and communication technology resources as meaningful pedagogical tools (Ertmer & Ottenbreit-Leftwich, 2010). This means that teachers must be able to facilitate students to use technology to learn, collaborate, think critically and solve problems, as well as think creatively and innovate (Valtonen et al., 2017).

Teachers play a major role in the process of integrating technology in learning (Sintawati & Abdurrahman, 2020). Competent teachers determine the success of the learning process (Rochintaniawati et al., 2018). Integrating technology in learning requires a competent teacher who can master the subject matter, understand pedagogy, and technological capabilities and mix them into more meaningful to improve teaching effectiveness (Koehler et al., 2011).

One of the frameworks in integrating technology in the learning process is TPACK (Technological Pedagogical Content Knowledge). TPACK is a relevant framework to measure teachers' ability to integrate content knowledge, pedagogy, and technology (Mishra & Koehler, 2006). TPACK as a framework for teachers to integrate technology in the learning process is important to develop. Integrating technology effectively in learning requires teachers to have technological and pedagogical knowledge and link methods, technology with content knowledge. In other words, understanding how to use technology is not enough to utilize technology effectively. Teachers must relate appropriate methods and technologies to the content of the subject, thus leading to the concept of TPACK (Aktaş & Özmen, 2022). TPACK is a theoretical framework that can provide direction for teachers to solve the problem of technology integration in classroom learning (Chai et al., 2011). This concept is a development of the concept of Pedagogical Content Knowledge (PCK) which was first initiated by Shulman (1986) TPACK can be used as a foundation in the professional teacher development process (Sorge et al., 2019).

TPACK combines three main types of knowledge: content, pedagogy, and technology (Koehler et al., 2013). Mastery of these three aspects enables teachers to create relevant and contextualized learning experiences for students, utilizing technology as a tool that supports deeper understanding. Contextualized learning and facilitating thinking skills by utilizing technology are the characteristics of 21st century learning (Cherner & Smith, 2017). TPACK is important in 21st century learning because technology has become an integral part of students' daily lives. Currently, students are the digital native generation, meaning that students in their daily lives are inseparable from technology. Teachers must be able to integrate technology into the curriculum in a way that enriches learning, not just as an addition or complement. This is where TPACK provides a framework that helps teachers to understand how technology can be used to teach content more effectively, as well as how technology can be integrated with different teaching strategies to achieve higher educational goals.

One of the strategies to improve teachers' TPACK can be done through training. This training is a program to improve teachers' knowledge and mastery of TPACK to improve teacher professionalism. Various TPACK development models have been researched including the TPACK-COIR (Comprehension, Observation, Instruction and Reflection), TPACK-COPR (Comprehension, Observation, Practice and Reflection) and TPACK-IDDIRR models with scaffolding in learning based on planning design (Zhang & Tang, 2021). From the various TPACK development models that have been carried out, there are several approaches that can be taken, namely the Collaborative, Practice and Reflective Practice approach. One of the results of TPACK development research has proven to be effective in improving teacher competence through discussion, reflection, and collaboration between fellow teachers. This approach allows teachers to exchange experiences, identify challenges in teaching and jointly seek innovative solutions. Thus, training that adopts this approach is expected to improve not only teachers' technical knowledge but also their ability to effectively apply TPACK in the classroom.

1.1. Problem Statement

TPACK as a framework for integrating technology in the learning process has not been widely implemented, it is only limited to the knowledge of a teacher. TPACK will be useful if it is implemented in the learning process. This study focuses on answering the following problem formulation. Is TPACK training with a collaborative, practical and reflective approach effective in improving the TPACK of elementary school teachers?

1.2. Previous Research

In recent years, the development of TPACK research has focused more on model development. Several designs have been researched related to the TPACK development process. Most of the designs developed are in the form of courses. One of the course models is integrating ICT with TPACK (Angeli & Valanides, 2009; Chai et al., 2011; Koh & Divaharan, 2011; Koh et al., 2013 ; Mouza et al., 2017). This form was found to be effective for TPACK development. This research also found that ICT courses that develop TPACK need to include aspects of trust building, subject-focused pedagogical modeling, and hands-on application processes (Koh & Divaharan, 2011).

Based on the results of the journal review of teachers' TPACK development, there are several principles that must be considered. First, TPACK development should consider teachers' knowledge and classroom experiences, and use them as a starting point to initiate efforts aimed at TPACK growth (Papanikolaou et al., 2014). Second, the development of TPACK by utilizing peer learning, collaboration with peers, observing each other will strengthen the results obtained (Chai et al., 2011). TPACK development should be based on interactions between teachers in order to build a process of mutual influence that creates a dynamic reciprocal relationship that provides a basis for facilitating teacher development (Trust et al., 2016). Third, the training process must pay attention to reflection activities as a process of strengthening the knowledge and experience gained (Nordin et al., 2013).

The combination of the three approaches of collaboration, practice and reflection is still not much. Especially direct practice in real classrooms. This study uses the concept of previous research results that training, especially for teachers, needs to be developed through collaboration with peers, direct practice in real classes so that the problems faced are in accordance with the context, and the reflection process so that training becomes meaningful for teachers.

1.3. Research Objectives

This study aims to determine the increase in TPACK of elementary school teachers after conducting a series of training with a collaborative, practical and reflective approach. These objectives were obtained through the stages of the brainstorming process, discussion forums, planning practices and teaching in the classroom. It ends with evaluation and reflection to strengthen the results that have been obtained. By understanding how the process of collaborative and reflective practice is expected to contribute to the development of more effective training programs in improving the quality of basic education in Indonesia, especially TPACK.

2. Theoretical Framework

2.1. Technological Pedagogical Content Knowledge (TPACK)

The concept of TPACK describes how teachers' understanding of technology, pedagogy and content are integrated. Based on Koehler and Misra's (2006) thinking, TPACK consists of three main types of knowledge: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). This knowledge is then enhanced by the interaction between the three components, resulting in additional knowledge such as Technological Pedagogical Knowledge (TPK), Pedagogical Content Knowledge (PCK), and Technological Content Knowledge (TCK), which support the comprehensive application of technology in learning (Mishra & Koehler, 2006). These knowledge domains overlap to form the TPACK concept as presented in Figure 3.

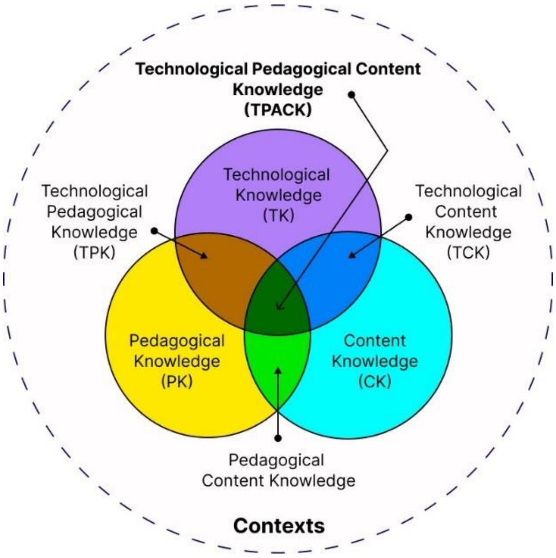

Figure 1. TPACK framework (Koehler et al., 2013).

CK is knowledge of the material to be taught in the form of facts, concepts, theories and procedures. CK is also knowledge of the discipline in general and specific concepts that are usually already organized in the curriculum (Janssen et al., 2019). Mastery of content knowledge makes teachers must master the important concepts of a topic of material to be delivered. Included in this knowledge is the possibility of conceptual errors owned by students related to the content. Content knowledge also provides reasons for teachers whether the concept is important for students to master, and why students should master the concept.

PK is a teacher's in-depth knowledge of learning processes and practices or methods. Included in pedagogical knowledge is the understanding of educational goals and values. It is also a broad knowledge of teaching principles and strategies, classroom management, and organization specific to different material content (Aktaş & Özmen, 2022). PK is concerned with teaching methods and their application to enhance student learning (Janssen et al., 2019).

TK is the knowledge of how to operate a computer, use software, use the internet, various applications as well as how to solve problems in the classroom situation at hand. TK is the continuation and development of knowledge about technology for information processing, communication and problem solving and focuses on productive applications of technology. Technological knowledge involves the ability and use of ICT tools in general and specialized ICT tools such as simulations and games in learning (Janssen et al., 2019). Technology is actually not only talking about digital-based tools, but with the development of the era, what is meant by technology here is included in Information and Communication Technology (ICT).

PCK is knowledge about pedagogy, teaching practices, and planning processes that apply to a particular material. Pedagogical Content Knowledge is a concept coined by Shulman (1986). Shulman's PCK theory emphasizes the importance of combining content knowledge (what to teach) and pedagogical knowledge (how to teach it). According to Shulman, an effective teacher not only needs to master the material or content of the field of study being taught, but also must understand how to best deliver the material to students, including appropriate teaching methods, strategies to overcome learning difficulties, and how to adapt teaching to the individual needs of students (Shulman, 1986).

TCK is the knowledge of the relationship between subject and technology including the appropriate technology to explore the content to be delivered. TCK shows how ICT can be used to represent content in the most effective and understandable way (Mishra & Koehler, 2006). TPK is the knowledge of how to utilize technology in the learning process, including the use, advantages and constraints of these technologies in the process with pedagogical designs and strategies. TPK represents teachers' understanding of how ICT can enhance the learning process and how teaching methods should be aligned with ICT tools (Koehler et al., 2011).

2.2. TPACK Training through Collaborative Practice and Reflective Approach

Research on TPACK training that uses a collaborative, practical and reflective approach shows significant results in improving teachers' ability to integrate technology into their teaching. TPACK can be enhanced through collaboration among teachers and the utilization of technology in lesson planning (Angeli & Valanides, 2009). The collaboration approach allows teachers to share knowledge and experiences, collaborate in designing and implementing lessons, and provide feedback to each other. The analysis shows that collaboration between teachers not only improves individual understanding of TPACK but also encourages innovation in the application of technology in the classroom. Teachers who collaborate in groups often find creative solutions to the challenges they face and can utilize their collective strengths to create more effective learning experiences.

The practice approach, on the other hand, focuses on the direct application of TPACK theory in a classroom context. Training programs based on hands-on classroom practice and shared reflection improve teachers' understanding of the use of technology in teaching (Koehler et al., 2013). Research shows that practice-based training, where teachers apply TPACK knowledge in real situations, helps them develop practical skills and gain deeper insights into how technology can be used effectively. Teachers involved in the practice sessions reported improvements in their ability to better design and implement technology-integrated learning activities. The experience also strengthened their understanding of how to adapt technology to content and pedagogical needs, as well as how to address technical issues that may arise.

Reflection is a key component of TPACK training, allowing teachers to critically evaluate and analyze their practice. Training that combines hands-on practice and individual and group reflection improves teachers' skills in adopting new technologies in the classroom (Jang & Chen, 2010). The use of a reflection approach among teachers through "lesson study" strengthens teachers' understanding in integrating content and technology in learning (Lee & Kim, 2014). Research shows that regular reflection after training sessions or classroom implementation helps teachers to understand what works and what needs improvement. This reflection often involves assessing the effectiveness of technology use, the teaching strategies implemented and the impact on student learning outcomes. Through reflection, teachers can make the necessary adjustments to improve their practice, thus continuing to grow in the application of TPACK.

3. Methods

3.1. Research Design

The research method used is mixed methods with embedded experimental design, which is a mixed research model that collects quantitative and qualitative data together or sequentially where one form of data plays a supporting role for another form of data. The use of mixed methods allows for qualitative and quantitative data collection. Figure 2. presents the research design with mixed method embedded experimental design.

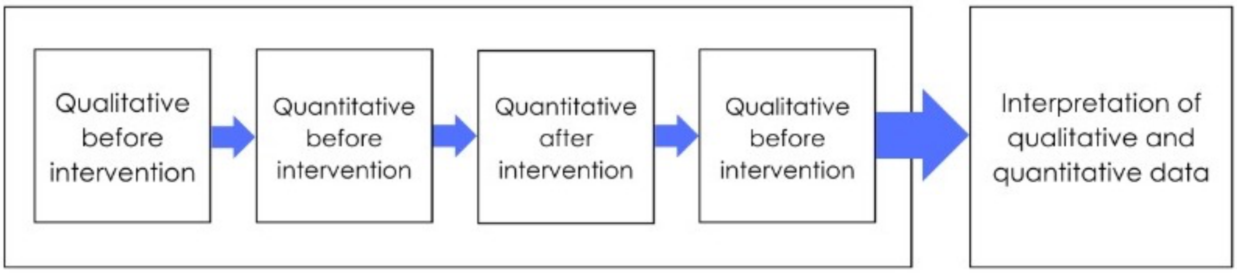

Figure 2. Research design

The sample consisted of 84 elementary school teachers who taught in grades 4, 5 and 6. The sample was randomized into two groups: experimental and control. Before the training, both groups were given TPACK questionnaires and interviews were conducted. The experimental group was treated in the form of training with a collaborative, practical and reflective approach. The training stages followed the following flow: brainstorming, strengthening content knowledge, pedagogical knowledge and technological knowledge (through the process of discussion and exposure), collaboration and practice of designing lesson plans, reflection on the results and process of lesson plan design, teaching practice, finally evaluation and reflection on the teaching process. While the control group followed the training as usual, namely exposure related to content knowledge, pedagogical knowledge and technological knowledge to strengthen understanding of concepts, pedagogy and technology. This was followed by the practice of designing lesson plans and teaching but independently without collaboration and reflection. After the training was completed, participants were given back the TPACK questionnaire and a final interview.

3.2. Participants

The sample consisted of 84 elementary school teachers in Sumedang Regency. The sample characteristics are presented in Table 1.

Table 1. Sample characteristics of TPACK training participants

Data Type	Number of Group Participants	
	Experiment	Control
Educational background		
S1	39	42
S2	3	0
Status		
PNS	39	13
Honorer	3	29
Age		
21 - 30	8	16
31 - 40	23	16
41 - 50	6	5
51 - 60	5	5
Teaching Experience		
1-5	8	20
6-10	3	8
11- 15	18	5
16 - 20	12	7
20 years and above	1	2
Gender		
Male	20	31
Female	22	11

3.3. Data Collection

The data collection techniques were interviews and TPACK self-assessment questionnaires. The instruments used were the 21st century TPACK questionnaire and interview guidelines developed based on the results of previous studies (Valtonen et al., 2017; Nurina et al., 2019;Yulisman et al., 2019). The lattice of the TPACK questionnaire instrument is presented in Table 2.

Table 2. TPACK Questionnaire Instrument Grid

Component	Indicator	Code
Tecnological Knowledge Knowledge and skills related to various available technologies and their characteristics that can facilitate students' potential.	Knowledge of technology and ability to use technology effectively	TK1
	Ability to solve technology problems	TK2
	Keeping up with technology	TK3
Pedagogical Knowledge	Understand student characteristics	PK1

Knowledge of learning processes and readiness to support and guide learning and learning situations in the 21st century	Knowing learning strategies in order to organize effective and meaningful learning activities	PK2
	Develop student potential (critical thinking and problem solving, creative thinking, collaboration, communication and reflection)	PK3
	Manage the class so that it is effective and interesting	PK4
	Organize assessment and evaluation of learning processes and outcomes	PK5
Content Knowledge Knowledge of lesson content	Understand the concepts, laws, and theories of the material to be taught and its application.	CK1
	Knowing the development of the subject matter (content) taught	CK2
PCK Knowledge of how to use teaching strategies to address student difficulties and misconceptions and foster meaningful understanding	Develop subject matter to support students' potential (critical thinking, creative thinking, collaboration, communication) and reflective thinking.	PCK1
	Carry out learning activities that are in accordance with the material taught	PCK2
TPK Knowledge of the nature of teaching and learning with technology and the advantages and disadvantages of using such technology.	Use appropriate technology to support learning activities	TPK1
	Using appropriate technology that supports independence and the process of communication and collaboration of student potentials	TPK2
TCK Knowledge of appropriate use of technology in teaching content	Use appropriate technology for the representation of the subject matter taught	TCK1
	Using appropriate technology to develop the material to be taught	TCK2
TPACK Knowledge of how to use appropriate technology to teach content to students with specific characteristics and facilitate their potential development (such as critical thinking, creativity,	Implement technology-based learning activities in accordance with the learning materials taught effectively	TPACK1
	Develop and share information on effective technology-based learning activities and technology ethics in education.	TPACK2

_communication and collaboration).	

3.4. Data Analysis

The data were analyzed using t-test, comparing teachers' TPACK before and after the training. The analysis process was assisted by the JASP application. The survey results were then categorized according to three criteria, namely Pre TPACK, growing and maturing (Anwar et al., 2016; Rochintaniawati et al., 2018). More details are presented in Table 3.

Table 3. TPACK categorization

Value	Category	Description
0 - 33	Pre TPACK	Unable to find the link between pedagogy, content and technology so that there is no intersection between the three.
34 - 66	Growing TPACK	Beginning to integrate pedagogy, content and technology so that the intersection between the three begins to form
67 -100	Maturing TPACK	More capable and mature in integrating pedagogy, content and technology flexibly and rationally

3.5. Validation and Reliability

The TPACK instrument is a questionnaire with 63 statements, developed from several previous research results. The instrument was subjected to expert validation and empirical validation. All statements were tested for validity and were in the valid category so that all statements were used in the study. The reliability of the instrument using Cronbach Alpha obtained a value of 0.976. This means that the instrument has a high level of reliability. Table 4 presents the complete results of the instrument reliability test.

Table 4. Reliability Test Results

	Cronbach's α
Point estimate	0,976
95%CI lower bound	0,962
95% CI upper bound	0,986

4. Findings

4.1. Effectiveness of Collaborative Practical and Reflective Training on Teachers' TPACK

Before conducting training using a collaborative, practical, and reflective approach, teachers as training participants were interviewed. Qualitative data from interviews about teachers' TPACK revealed variations in both understanding and practice in the field. In general, younger teachers tend to have better technological knowledge compared to senior teachers. Meanwhile, teachers with longer experience demonstrate stronger pedagogical knowledge. In practice, some teachers feel confident in utilizing technology, such as social media platforms like WhatsApp groups, presentation media such as PPT or interactive applications like Quizizz. On the other hand, many teachers still face challenges in integrating technology with teaching methods and content. Limited resources and low technological proficiency are the main factors preventing teachers from effectively leveraging technology in their teaching.

Findings from interviews in other practices show that teachers are still unable to integrate content, pedagogy, and technology effectively. For instance, while WhatsApp groups are widely used by teachers, the practice lacks interaction. WhatsApp is primarily used to deliver information about activities students need to perform, without any guidance or monitoring to ensure students actually engage in the expected learning activities.

Content delivery through presentation slides remains limited to providing information and is not yet aligned with the methods or models being employed. For example, when teachers use a problem-based learning model, where the initial stage involves problem identification, the content in the presentations does not present the expected problems but merely provides conceptual material. As a result, students are unable to identify the intended problems.

The measurement of teachers' TPACK was carried out using the 21st century TPACK questionnaire instrument. The results analyzed using JASP are presented in Table 5 below.

Tabel 5. TPACK Elementary School Teachers Based on Questionnaire Data

Data Type		Pra		Post	
		Experiment	control	experiment	control
Number of participant		42	42	42	42
Average		68	69	79	72
Normality test (Shafiro-Wilk test) (a=0,05)	P	0,279	0,081	0,067	0,173
	Interpretation	Normal	Normal	Normal	Normal
Homogeneity test (Brown-Forsythe test) (a=0,05)	P	0,830		0,267	
	Interpretation	Homogeneous		Homogeneous	
T test (avearage difference)	Sig	0,472		<0.001	
	Interpretation	There is no significant difference		significantly different	

Based on Table 5. Teachers' TPACK before and after the training is significantly different between the experimental and control groups. This conclusion is drawn by looking at the results of the t test where the significance value is <0.001. This means that there is an average difference between the experimental group and the control group. When looking at the average, the experimental group is higher than the control group, so it can be concluded that the training organized is effective for improving the TPACK of elementary school teachers.

4.2. Teachers' TPACK by Component

The analysis continued to compare each TPACK domain between the experimental and control groups. The difference test analysis between the experimental and control groups is presented in Table 6.

Table 6. TPACK Domain T Test Results between Experimental and Control Groups

Domain	Group	Average	Std	T	Df	p	Description
TK	Experiment	77	7,5	0,797	82	0,428	No difference
	Control	76	9,1				
PK	Experiment	84	8,5	4,072	82	<0.001	Significantly different
	Control	75	10,8				
	Experiment	76	8,5				

CK	Control	73	11,6	1,419	82	0,160	No difference
PCK	Experiment	78	9,9	2,891	82	0,005	No difference
	Control	71	10,8				
TPK	Experiment	79	8,7	3,627	82	<0.001	Significantly different
	Control	71	11,7				
TCK	Experiment	74	9,4	0,6	82	0,020	No difference
	Control	66	14,6				
TPACK	experiment	79	9,4	4,533	82	<0,001	Significantly different
	control	72	13,6				

Table 6. presents the results of further analysis of TPACK domains. The analysis was conducted by comparing the scores of each domain after training between the experimental group and the control group. From the data in Table 6, it can be concluded that the domains that differ significantly between the control and experimental groups are PK, TPK and TPACK itself. While other domains have no significant differences. The TPACK survey results were further categorized based on Table 3 and presented in Table 7 in the next page.

Table 7. Categories of Elementary School Teachers' TPACK by Component Before and After Training

Component	Experimental Group Category		Control Group Category	
	Pre	The post	Pre	The post
TK	Growing	Maturing	Growing	Maturing
PK	Maturing	Maturing	Maturing	Maturing
CK	Growing	Growing	Growing	Growing
PCK	Growing	Maturing	Growing	Growing
TPK	Growing	Maturing	Growing	Growing
TCK	Growing	Maturing	Growing	Growing

Based on Table 7. it can be concluded that training with a collaborative practice and reflective approach can improve TPACK, especially in its PCK, TPK and TCK components in the experimental group, while the control group that was not given the intervention did not experience significant changes. Based on the results of the statistical analysis test, the components that were significantly different between the experimental and control classes were PK, TPK and TPACK. Meanwhile, when compared between before and after training, the components that have increased are PCK, TPK and TCK. The results of training in both experimental and control groups can improve teachers' technological knowledge. While in the content component there is no significant change.

5. Discussion

5.1. Effectiveness of Collaborative Practical and Reflective Training on Teachers' TPACK

The research findings show that training with a collaborative, practical and reflective approach effectively improves teachers' TPACK. This is evidenced by statistical tests where there is a significant difference between the TPACK of experimental class teachers who were given training with a collaborative practice and reflective approach and the TPACK of control class teachers. Teachers' TPACK was measured using a questionnaire instrument.

The TPACK questionnaire instrument shows teachers' self-assessment of their TPACK skills. Teachers' self-assessment of technology, learning and lesson content can serve as a foundation for TPACK

(Valtonen et al., 2017). A positive teacher self-assessment of the benefits and importance of using technology in learning can influence teachers' understanding of TPACK (Valtonen et al., 2019). Likewise, good teacher knowledge of how to effectively integrate technology in the learning process increases teacher self- assessment of the importance of using technology in learning.

The training process intervention with the collaboration, practice and reflection approach is proven to develop teachers' positive appraisal of the use of technology, resulting in the improvement of their TPACK. Teachers who realize their ability to integrate technology effectively in learning will increase their confidence and belief in their TPACK. A high level of confidence resulting in positive teacher attitudes is a determinant in the development of technology integration (Charles, 2012). Other research suggests that teachers' beliefs and values have a stronger influence on the technology integration process than their own knowledge (Abbitt, 2011). Teachers' belief in technology becomes a mediator variable or a connecting variable (Yulisman et al., 2020).

The results of this training are in line with previous studies that used a collaborative approach in the TPACK training process. There is evidence that there is an increase in TPACK pre-post meaningful learning course with ICT with an effect size of 0.6 (Chai et al., 2011). Training with a collaborative approach and microteaching practice has been shown to be effective for improving prospective teachers' TPACK (Mouza et al., 2014; Papanikolaou et al., 2014; Papanikolaou et al., 2017;Dalal et al., 2021). Collaborative TPACK training involving elementary school teacher participants through design activities has been shown to be effective in improving TPACK (Njiku et al., 2021).

Teachers' TPACK growth goes hand in hand with the training process that facilitates teachers' collaboration and field practice. TPACK growth is supported by teachers' involvement in regular professional activities. In addition, optimizing peers to support each other in real school contexts and hands-on practice with real problems in the field has been shown to improve teachers' TPACK. (Njiku et al., 2021). Lesson design activities also seem to be one of the effective ways to develop teachers' TPACK (Kay, 2007). The growth of TPACK should actively involve teachers in meaningful activities within their school context. Providing technical skills training and mastering knowledge is not enough to develop teachers' TPACK, but teachers also need to be directly involved in practicing what they have acquired during training. This process will bring them closer to the problems in the field. This means that teachers need professional development in the application of their TPACK to improve their technology- integrated learning process (Lehiste, 2015).

The collaborative process in this stage of training began with a brainstorming process. It was assumed that the teachers who participated in the training already had teaching experience. On average, the teachers who participated in the training had a long teaching experience of between 5-10 years. At least they mastered teaching knowledge and skills, lesson content and classroom management experience. The brainstorming stage at the beginning of the training is meaningful to find out the initial knowledge of the teachers so that the instructions given in the training will be in accordance with the needs of the teachers themselves. This is important because to begin a teacher development process, the needs and knowledge of trainee teachers must be considered as a starting point (Papanikolaou et al., 2014).

At this stage, teachers share ideas on the practice of using technology in the classroom. Share experiences and problems they face while using the technology. Discussing the problems faced and experienced by teachers in integrating technology and finding alternative solutions to problems according to the characteristics of learning, school conditions, and their respective environments. The brainstorming stage can also be a process of teacher reflection on the learning process in the classroom so far.

The next stage is the collaboration between trainees and instructors. The instructor provides an overview of how to integrate technology in learning. Instructors provide hands-on modeling in learning design. Modeling can position trainees as students and teachers. When positioning as teachers, trainees learn to decide what kind of technology integration process is fun to use in learning (Lu & Lei, 2012).

Integrating technology in learning is a complex process. Early initiators Koehler and Misra (2005) suggested that to improve TPACK teachers should be given practice by directly designing technology with learning instructions. Digital technology may still be new to some teachers, so they struggle with how to make it work when they are learning. It is not only a tool but also can empower students, help students' thinking process both critical thinking and creative thinking, improve students' collaboration and communication skills. Without excluding the three building blocks of TPACK knowledge, namely pedagogical knowledge, content and technological knowledge itself, modeling provides a complete picture for teachers how the technology is integrated in their learning. When collaborating with instructors with live modeling teachers will learn from observing the behavior of others when teaching with technology. At the same time teachers also position themselves as students. Because during the implementation of the modeling, the teacher is included as a student. After the modeling is complete, the teacher is then asked to criticize. Teachers are also asked to discuss the process and estimate what changes can be made to make learning effective. In this position, it is expected that the teacher can decide which method is more effective to be applied to his/her learning later. The final impact of this process is the improvement of teachers' TPACK (Lu & Lei, 2012).

The collaboration process with instructors is also done by sharing technological knowledge to enrich and improve their technological knowledge. This is also expected to increase teachers' confidence in the use of technology. The initial survey results from the training participants, on average, have used digital technology, especially video and PowerPoint. The technology used is obtained from other people's results such as YouTube channels. Increased technological knowledge is expected to increase teachers' confidence in their technological knowledge which in turn can help them to develop confidence in other knowledge domains (Uçar et al., 2014). Technological knowledge is one of the foundations for technology integration, and research has shown that improving teachers' technological skills increases the likelihood of them using these technologies in the classroom. So in addition to pedagogical knowledge, technological knowledge and teacher confidence are one of the most important factors for teachers to integrate technology into learning (Wright & Akgunduz, 2018).

TPACK does not emphasize the importance of technology integration alone but also reveals the relationship between its three main building blocks of technology, pedagogy and content. All of this knowledge varies depending on the conditions of the learning environment, which is the context in which the technology is applied (Çam & Erdamar Koç, 2021). Research results revealed that in order for a teacher's TPACK to develop, providing TPACK training is not enough and needs to form a real learning environment (Niess, 2011). Therefore, facilitating teachers to practice hands-on learning in the classroom is a strategic method. In previous TPACK development research, this practice was conducted but limited to microteaching classes, not in a real environment. This is quite an experience especially for trainee teachers, but for a teacher practicing directly in their classroom with real problems will help develop their TPACK.

The final stage is evaluation and reflection. The reflection stage is a process of introspection by trainees to assess their own learning experiences. This reflection allows participants to identify strengths, weaknesses, as well as future improvement strategies in integrating technology into teaching (Bashan & Holsblat, 2017). By conducting evaluation and reflection, teachers can continue to improve their TPACK competencies, so that learning using technology becomes more effective and relevant according to the times. Some post-training reflection statements from the interview results reinforce the following.

Sample G stated in his reflection, "Multimedia-based learning is more fun, but the drawback is that teachers are required to be more creative in finding and making visual media more attractive, and the need for school support in providing infrastructure". While sample J mentioned that, "The learning that has been done still lacks the use of digital media, even though the use of digital media can attract students, besides that teachers also need to apply strict rules before using digital technology to avoid negative impacts". From the results of the reflection, it was found that the lack of proficient use of technology is one of the factors is the teacher's lack of confidence in the added value of using technology. Teachers are still hesitant to use digital technology in learning for fear of having a negative impact on students. Overall, the trainees have started to utilize technology, but the effectiveness of its use in the field must continue to be improved. Based on the research results, technology utilization is still mostly for content presentation such as PPt and video. Where content is presented informatively. While the utilization of technology for learning processes such as communication, collaboration and student interaction is still lacking. In this case, teachers still need experience and continuous training (Alayyar et al., 2012).

5.2. Teachers' TPACK by Component

TK, PK and CK are the main components of TPACK. From the intersection of the three components, PCK, TPK, TCK are formed and the intersection of the three gives birth to TPACK. The results showed that the average teacher's mastery of TPACK was at level 2 (developing). This means that teachers begin to know how to integrate content, pedagogy and technology so that the intersection between the three is formed. Based on its components, TPACK is built from three main components, namely CK, PK and TK (Based on TPACK components, the highest average aspect is pedagogical knowledge and the lowest is technological knowledge and content technology knowledge (TCK).

There is evidence that teachers' overall TPACK development is influenced by specific TPACK knowledge domains. Several studies reveal that pedagogical knowledge (PK) and technological pedagogical knowledge (TPK) have the greatest impact on TPACK development. There is a strong positive correlation between pre-service teachers' TPK, TCK, and TPACK(Chai et al., 2011).

High technological ability does not necessarily have a significant direct effect on TPACK ability. Technological knowledge will affect TPACK if it is through its TPK and TCK abilities. This result is slightly different from the results of research conducted by Yulisman et al., (2019)where the CK, PK and PCK components have direct and indirect effects on teachers' TPACK. However, this research is in accordance with the results of Tanak, (2020) which states that pedagogical ability has more impact on the development of TPACK, while high TK does not have enough impact on TPACK.

What is quite interesting from the results of the TPACK development research for elementary school teachers is that their pedagogical knowledge is relatively higher than the other domains. Whereas in prospective teachers they are higher in technological knowledge than other components. The component that must be improved is content knowledge. Understanding the correct concepts will make it easier for teachers to represent them through appropriate technology.

6. Conclusion

Training with a collaborative, practical and reflective approach is proven effective in improving the TPACK skills of elementary school teachers. This is evidenced by the results of statistical tests between the experimental and control groups with a p value <0.001 there is a significant difference. By comparing the mean scores, the experimental group has a high average compared to the control group. Based on the statistical test results of the components, PK, TPK and TPACK are significantly different between the experimental group and the control group. While the other components are not significantly different. This means that in this study the components that influence the improvement of teachers' TPACK are the PK and TPK components. When comparing before and after the training, it was found that the training could improve the PCK, TPK and TCK components in the experimental group while the control group did not experience significant changes. In addition, the training can also improve teachers' technological knowledge in both the experimental and control groups. This means that the training provides enough knowledge about technology but does not necessarily improve the ability to integrate technology. The training did not focus on improving teachers' material content, so there was no significant change in both groups. This shows that the mediator components, namely PCK and TCK, do not significantly affect the improvement of teachers' TPACK. The training by implementing a process of collaboration between fellow teachers, real classroom practice and a process of self-reflection, was effective in improving the TPK component of teachers so that it had an impact on improving teachers' TPACK. The improvement of teachers' TPACK has an impact on improving the quality of the learning process with technology.

Limitations

The use of survey instruments using self-assessment in this study has limitations, namely the conditions in the field teachers sometimes overestimate or even underestimate their abilities, thus providing inappropriate assessments. This research needs to be improved, especially in providing an explanation of TPACK and its components, because there is still confusion in classifying which components include PCK, TCK, or TPK and which are not. Thus, the boundaries of understanding between components in TPACK still need to be further strengthened. The research also did not focus too much on the material content component even though it is an important component so that the results are more optimal.

Recommendation

Teacher professional research needs to be continuously developed to improve the quality of teachers as the frontline of education. TPACK knowledge also needs to be approached with technology-related skills such as design skills and computational skills and linked to more specific contexts such as school environment and policies.

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Conflict of Interest

The authors declare that there is no conflict of interest

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