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Transforming TPACK of elementary school teachers: The role of training based on collaboration, practice, and reflection

Ai Hayati Rahayu [1]*, Ari Widodo [1] , Udin Syaefudin Saud [1] , Muslim [1]

[1] Universitas Pendidikan Indonesia, Bandung, Indonesia, 40154

Article info

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Abstract

Integrating technology into the learning process requires teachers to possess strong Technological Pedagogical Content Knowledge (TPACK). This study examines the impact of a training approach based on collaboration, practice, and reflection in enhancing elementary school teachers' TPACK and teaching abilities. The research employs a mixed-methods approach with an embedded experimental design. The training participants, totaling 84 individuals, were randomly divided into experimental and control groups, with the subjects participating in a training program designed to promote teacher collaboration, provide hands-on practice experiences, and integrate reflective learning. The instruments include a TPACK questionnaire, lesson plan (RPP) observation sheets, and classroom teaching practice observation sheets. Data analysis was conducted using difference tests and correlation tests. The findings reveal that this training approach significantly improved teachers' understanding and application of TPACK in classroom learning contexts. There was a significant difference in TPACK knowledge between participants in the experimental group and those in the control group. Additionally, this study emphasizes the importance of reflective practice in strengthening the integration of technology, pedagogy, and content knowledge. These findings provide valuable insights for designing professional development programs for educators to effectively enhance their technological and pedagogical competencies.

* Corresponding Author.
E-mail address: ahayati75@gmail.com (Ai Hayati Rahayu)
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1. Introduction

The transformation of education in the digital era requires teachers to not only master technology but also integrate technology with pedagogical strategies and subject matter effectively (J. M. Koehler et al., 2013). In this context, the concept of *Technological Pedagogical*

Content Knowledge (TPACK) is a key element teachers need, especially at the primary school level, to improve the quality of learning. TPACK allows teachers to integrate technology appropriately in the teaching process, thus creating a more innovative, relevant, and interactive learning experience for students (Valtonen et al., 2021).

Teachers' ability to transform TPACK into teaching practice does not happen automatically. Many teachers still experience difficulties in connecting TPACK theory with their teaching skills in the classroom. This obstacle is often caused by limited access to supportive training, lack of hands-on practice opportunities, and lack of systematic reflection on teaching experiences. Therefore, a training approach is needed to bridge TPACK theory with its application in learning (Njiku et al., 2021).

Teachers' TPACK growth goes hand in hand with the training process that facilitates teachers' collaboration and field practice. Teachers' involvement in daily activities supports TPACK growth or work in the classroom. In addition, optimizing peers to support each other in the actual school context and direct practice with real problems in the field has been shown to increase teachers' TPACK (Njiku et al., 2021).

Providing technical skills training and knowledge mastery is not enough to develop teachers' TPACK. However, teachers must also be directly involved in practicing what they have acquired during the training. Moreover, this will bring them closer to the problems in the field. This means that teachers need practical development in applying their TPACK to improve their technology-integrated learning process (Lehiste, 2015).

Training based on collaboration, practice, and reflection is one of the relevant approaches in this context. Through collaboration, teachers can share experiences and strengthen a common understanding of technology integration in learning. Hands-on practice allows teachers to try and apply TPACK concepts in real situations, while reflection provides space for teachers to evaluate and refine their learning processes. This approach helps improve TPACK competencies and promotes real transformation in teachers' teaching abilities.

This study aims to understand the relationship between TPACK and primary school teachers' teaching ability, focusing on the transformation that occurs through collaboration, practice, and reflection-based training. The results of this study are expected to make an important contribution to the development of teacher training programs that are more effective and relevant to the needs of education in the 21st century. The study aimed to answer the following research questions.

1. Is there a difference in TPACK between experimental and control groups after training with a collaborative, practical, and reflective approach?
2. Is there a relationship between TPACK and elementary school teachers' ability to design lesson plans and teaching practices?

2. Literature Review

Technological Pedagogical Content Knowledge (TPACK)

Technological Pedagogical Content Knowledge is based on Shulman's concept as a foundation in the professional teacher development process (Sorge et al., 2019). The TPACK concept describes how teachers' understanding of technology, pedagogy, and content integrate. Based on Koehler and Misra's 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 thorough application of technology in learning (Mishra & Koehler, 2006). These knowledge components overlap to form the TPACK

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concept, as presented in **Figure 1,** which we see on the next page.

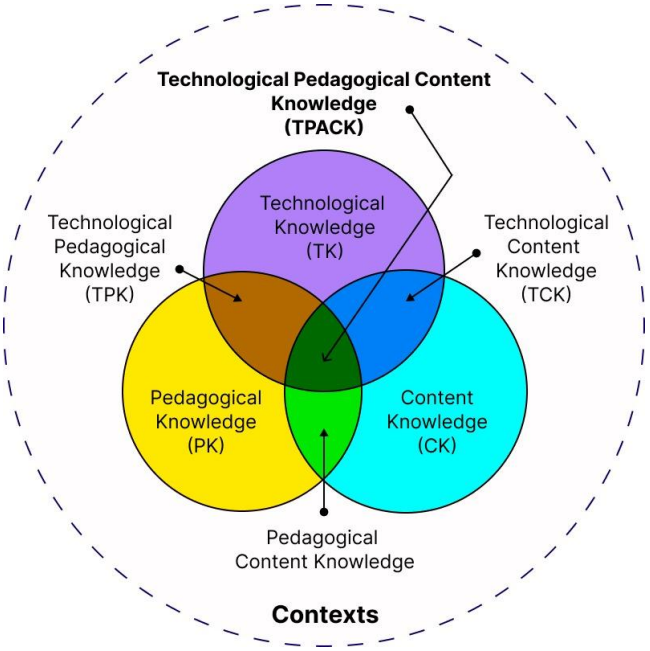

Figure 1 TPACK Framework according to (Koehler et al., 2013)

CK is knowledge about the material taught through facts, concepts, theories, and procedures. CK is also knowledge of the discipline in general and specific concepts that are usually ready organized in the curriculum (Janssen et al., 2019). PK is a teacher's in-depth knowledge of learning processes and practices or methods. Included in pedagogical knowledge is the notion of educational goals and values. It is also the knowledge of broad teaching principles and strategies, classroom management, and organization-specific to different material content (Aktaş & Özmen, 2022; Aktaş & Özmen, 2020). TK is the knowledge of how to operate computers, use software, use the internet and various applications, and solve problems in the classroom. TK is the continuation and development of knowledge about technology for information processing, communication, and problem-solving, and it focuses on the 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 education (Janssen et al., 2019).

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). TCK is knowledge about the relationship between subject and technology, including the appropriate technology to explore the content to be provided. TCK shows how ICT can represent content most effectively and understandably (Mishra & Koehler, 2006). TPK is the knowledge of how technology is utilized for teaching and learning and the advantages and constraints of technology concerning pedagogical design and strategies. It represents teachers' understanding of how ICT can enhance learning and how teaching methods should be aligned with ICT tools (Koehler et al., 2011).

TPACK Transformation in Teacher Performance

The transformation of TPACK (*Technological Pedagogical and Content Knowledge*) in teacher performance refers to the integration of three important elements: understanding of subject matter (*Content Knowledge*), teaching strategy skills (*Pedagogical Knowledge*), and mastery of technology (*Technological Knowledge*). With TPACK, teachers can shift from traditional methods to

curriculum-relevant technology-based approaches, such as digital platforms, educational software, and interactive media. This transformation helps teachers create more engaging and effective learning experiences and adapt learning methods based on student needs. It increases student engagement and encourages teacher creativity in structuring and delivering learning materials.

Successful implementation of TPACK directly impacts teacher performance, especially in teaching effectiveness, learning innovation, and student satisfaction. Show the importance of TPACK as a framework in education, while local studies highlight its application in the Indonesian school context. With this transformation, TPACK is a technological tool and a foundation for building a better quality of education.

Teacher TPACK Training with a Collaborative-Practice-Reflective Approach

TPACK training with a collaborative, practical, and reflective approach is a training process based on three principles, namely, a process that facilitates collaboration, practice, and reflection. It is based on the results of a journal review of teacher TPACK development, which states that teacher training should be based on at least three principles.

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, developing TPACK by utilizing peer learning, collaborating with peers, and observing each other will strengthen the results (Chai et al., 2011). TPACK development should be based on interactions between teachers in order to build a process of mutual influence and create a dynamic reciprocal relationship that provides a basis for facilitating teacher development (Trust et al., 2016). Third, the training must focus on reflection activities to strengthen the knowledge and experience gained. Programs planned to improve teacher competence must be based on increasing self-motivation and based on needs according to the conditions of the era (Rahman, 2014). Self-reflection by teacher trainees significantly contributed to professional behavior and efforts to develop teacher professionalism by 35%. It means that the higher the teachers' awareness of self-reflection in their professional development, the better their professional development efforts will be. In other words, the process of teacher reflection has an impact on the development of teacher professionalism (Rahman, 2014)

3. Method

Research Design

This research uses *mixed methods* with *embedded experimental design*, a mixed research model that collects quantitative and qualitative data together or sequentially where one form of data supports another (Creswell, 2018). The subjects in this study were primary school teachers who were members of KKGs in Sumedang District. A sample of 84 people was taken and then randomized into 42 people in the experimental group and 42 in the control group at stage 1. The next stage was analyzed on the grounds of similarity in science content. The experimental group consisted of 18 people, and the control group of 15. The subjects came from public and private schools, with diverse educational backgrounds, work experience, and job status.

Research Instrument

The instruments used were TPACK questionnaires to determine the TPACK level, lesson plan assessment sheets, and teaching practice observations. The data obtained were then analyzed for the difference and correlation tests using statistical tests and assisted by the JASP application. Interview data further strengthened quantitative data.

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Table 1. TPACK questionnaire instrument grid

Aspect	Indicator	Statement number
TK	Knowledge of technology and ability to use technology effectively	1 - 7
	Ability to troubleshoot technology problems	8
	Keeping up with technological developments	9,10, 11
PK	Understand student characteristics	12,13
	Know learning strategies in order to organize effective and meaningful learning activities	14
	Developing student potential (critical thinking and problem solving, creative thinking, collaboration, communication, and reflection)	15-19
	Manage the class so that it is effective and interesting	20, 21
	Organize assessment and evaluation of learning processes and outcomes	22
CK	Understand the concept. law, and theory of the material to be taught and its application	23 -26
	Know the development of the material (content) of the lessons being taught	27- 29
PCK	Developing learning materials that are taught to support students' potential (critical thinking, creative thinking, collaboration, communication) and reflective thinking.	30-36
	Carry out learning activities that are appropriate to the material being taught	37, 38
TPK	Using appropriate technology to support learning activities	39 - 41
	Using appropriate technology that supports student independence and potential communication and collaboration processes	42 – 44
TCK	Using appropriate technology for the representation of the subject matter being taught	45 - 48
	Using appropriate technology to develop the material to be taught	49 - 50
TPACK	Carrying out technology-based learning activities following the learning material taught effectively.	51- 59
	Develop and share information about effective technology-based learning activities and technology ethics in education	60 - 63

The questionnaire uses a Likert scale. The RPP assessment sheet includes indicators for achieving learning objectives, organizing relevant material, learning methods, learning media and resources, implementing learning activities, classroom management, and assessment. The observation rubric has the same indicators as the RPP analysis sheet with the addition of classroom management. Next, the analysis results are categorized based on **Table 2** (Anwar et al., 2016).

Table 2. TPACK categorization

Mark	Category	Information
0 – 33	Pra TPACK	Teachers have not found a link between pedagogy, content, and technology, so there is no clear cut between the three.
34 – 66	*Growing* TPACK	Starting to be able to integrate pedagogy, content, and technology so that a wedge begins to form between the three
67 -100	*Maturing* TPACK	Increasingly capable and mature in integrating pedagogy, content, and technology flexibly and rationally

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4. Results and Discussion

A teacher's TPACK is complex and dynamic. Its development is obtained from theoretical sources and enhanced through practice and experience. Teachers' TPACK develops not only through training with conceptual understanding. This means that training in TPACK is not enough; it is necessary to form a learning community to implement the concept. Alternatively, in other words, it needs practice in applying the knowledge in real practice(Niess, 2011).

In this training, practice sessions on designing lesson plans and implementing these plans in the classroom are applied. In addition to document review, observations were also made during learning practices. Of the 84 elementary school teachers participating in the training, not all teach science content in their implementation. So, what is taken next is the teacher who designs lesson plans with science content. The following data analyzes the TPACK ability, planning design, and teaching practice.

Table 3. Elementary school teachers' TPACK based on questionnaire data

Data Type		Pre		The post	
		Experiment	Control	Experiment	Control
Number of participants		42	42	42	42
Average		68	69	79	72
Normality Test (Shapiro-Wilk Test) (α=0,05)	P	0,279	0,081	0,067	0,173
	Interpretation	Normal	Normal	Normal	Normal
Homogeneity Test (Brown-Forsythe Test) (α=0,05)	P	0,830		0,267	
	Interpretation	Homogeneous		Homogeneous	
T-test (mean difference)	Sig	0,472		<0.001	
	Interpretation	There is no significant difference		Significantly different	

Based on **Table 3**, Teachers' TPACK before and after the training significantly differs between the experimental and control groups. This conclusion is drawn by looking at the t-test results where the significance value is <0.001. This means there is an average difference between the experimental and control groups. 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 enough to improve the TPACK of elementary school teachers. Furthermore, a t-test analysis was conducted for the ability to design lesson plans.

Table 4. Analysis data of elementary school teachers' lesson plans based on the TPACK instrument for experimental and control groups.

Data Type		Pre		The post	
		Experiment	Control	Experiment	Control
Number of Participants		18	15	18	15
Average		59	60	73	60
Normality Test (Shapiro-Wilk Test) (α=0,05)	P	0,841	0,769	0,970	0,056
	Interpretation	Normal	Normal	Normal	Normal
Homogeneity Test (Brown-Forsythe Test) (α=0,05)	P	0,803		0,815	
	Interpretation	Homogeneous		Homogeneous	
T-test (mean difference)	Sig	0,673		<0.001	
	Interpretation	There is no significant difference		Significantly different	

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Based on **Table 4**, it can be concluded that the ability to design lesson plans for the experimental and control groups has a significant difference where the average lesson plan score of the experimental group is higher than that of the control group. It means that training plays a role in improving teachers' ability to design lesson plans that are integrated with technology and facilitate 21st-century skills. If categorized based on their TPACK abilities according to Anwar et al. (2016) and Rochintaniawati et al. (2018), then the ability to design TPACK-based learning in the control group is still *growing*, namely at level 2, while the experimental group began to enter level 3, namely *maturing*. In the growing category, trainees can integrate content, pedagogy, and technology, while in the maturing category, trainees can integrate content, pedagogy, and technology in designing their lesson plans.

TPACK training can be used to develop the use of technology in the learning process. However, training limited to providing information without any practice to improve skills does not seem to have a long impact on teacher performance. Therefore, continuous training and real practice are needed to apply technical skills in using technology, designing lessons, and implementing the lesson plan. Training that includes activities to design lesson plans can effectively develop teachers' TPACK (Aktaş & Özmen, 2020).

Teachers' mastery of TPACK can be seen in their lesson plans. Teachers should have a lesson plan with systematic steps to be applied during learning activities. Teachers' TPACK competencies can be developed through training proficiency in using technology, designing or designing learning activity instructions, and implementing and applying ethics in using technology (Yurdakul et al., 2012).

The lesson plan contains systematic steps the teacher prepares in the form of learning scenarios, which will later be used as a reference for implementing learning activities. There are many differences in the presentation of lesson plans in the field, so the importance of lesson plans becomes only an administrative burden. The contents contain components of the objectives, steps, or stages of learning and assessment. The lesson plan does not fully describe what the teacher will do. For example, the assessment is only written for cognitive, affective, and psychomotor assessments. How to assess it, the researcher did not find.

TPACK-based lesson plans referred to in this study are learning designs teachers will use when learning activities occur. The application of TPACK is indispensable in lesson plans because it will make learning designs that are loaded following the times, namely integrating technology, pedagogy, and content in learning activities (Wardani et al., 2022).

Table 5. Observation result of elementary school teachers' teaching practice based on TPACK instrument

Data type		**The post**	
		Experiment	**Control**
Number of Participants		18	15
Average		67	59
Normality test (Shapiro-Wilk test), (α=0,05)	P	0,229	0,602
	Interpretation	Normal	Normal
Homogeneity Test (Brown-Forsythe Test) (α=0,05)	P	0,09	
	Interpretation	Homogenous	Homogenous
T-test (mean difference) (α=0,05	Sig	0,02	
	Interpretation	Significantly different	

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Table 5 informs that the training effectively improves teachers' teaching practice skills by integrating technology and facilitating students' 21st-century skills. In this case, the TPACK framework can be used as a guide by teachers to integrate technology to improve the quality of learning. This, in turn, will impact the development of teacher professionalism in facing the challenges of 21st-century learning, namely organizing learning with technology (Aulia et al., 2023). If categorized, the teaching ability of the experimental group has begun to enter the early *maturing* category, while the control group is still in the *growing* category.

The integration of technology in learning has a significant effect on the teaching and learning process (Delgado et al., 2015). Using technology in the learning process can improve the efficiency and effectiveness of the learning process (Wuryaningtyas & Setyaningsih, 2020). Integrating technology in learning makes learning more innovative and helps teachers organize a more productive learning process.

Teachers' TPACK affects their teaching process. Therefore, TPACK, as a dynamic framework for integrating technology, is used in designing and implementing learning designs in the classroom. Overall, teachers in the experimental group followed the stages of the process that were designed in the lesson plan. The collaborative planning process allows teachers to review the lesson plan design frequently. In addition, discussions and *feedback* from both peers and facilitators proved to help teachers design and implement them in the field. The *feedback* provided is useful for improving the design. Unlike in the control group, the training results, which only obtained information, did not immediately impact the action in the field.

In the control group, some teachers skipped steps in their lesson plans. In addition, 53% of teachers in the control group had not tried to utilize technology even though the school's facilities and infrastructure were available. One of the reasons given during the interview was inadequate time to prepare the technology equipment. Other teachers expressed that they were not confident in teaching with technology due to their lack of technology skills. Teachers do not have positive views and attitudes towards technology. Positive attitudes and views toward technology's importance will help teachers adopt and integrate it into their learning activities (Charles, 2012).

Previous research proves that technological competence attitudes toward technology integration correlate positively (Yulisman et al., 2019). In particular, teacher attitude is a moderator variable in the relationship between technological competence and teacher TPACK. Even teachers' positive attitude towards technology directly affects teachers' TPACK (Karaca et al., 2013). Observation of teaching practice includes aspects of the lesson plan and classroom management. The following is a resume of the analysis of the teacher's teaching ability. Teachers who are enthusiastic and confident in their use of technology are more likely to integrate it in meaningful ways, enhancing their instructional practices and improving student engagement and learning outcomes. In addition to attitudes and technological competence, observations of teaching practices provide valuable insights into how effectively these factors are implemented. Observations typically focus on various aspects of the lesson plan, including how well the teacher integrates technology into lesson delivery and how they manage classroom dynamics when utilizing such tools.

The hypothesis states that a significant relationship exists between TPACK knowledge and the ability to design lessons and teaching practices. A correlation test was conducted. The analyzed data is presented in **Table 6**.

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Table 6. Correlation test analysis results of teachers' TPACK with ability to design and practice learning

Variables		TPACK	RPP
TPACK	**Average**	**73**	
	Correlation coefficient		
	p-value		
	Interpretation		
RPP	Average	71	
	Correlation coefficient	0,837	
	p-value	<0,001	
	Interpretation	There is a correlation.	
Practices	Average	67	
	Correlation coefficient	0,758	0,917
	p-value	<0,001	<0,001
	Interpretation	There is a correlation	There is a correlation

Table 7. Multiple regression test results

Model	R	R^2	Adjusted	RMSE
Ho	0,000	0,000	0,000	7,356
H_1	0,837	0,700	0,661	4,286

Table 7 shows that TPACK ability is explained or influenced by 70% of the factors of ability to design lesson plans and teaching ability together. To support the quantitative test results, the following descriptive analysis was conducted. It also implies that teachers' TPACk skills will increase as they are used in designing lesson plans and teaching practices in the classroom by integrating technology, particularly as they adapt their teaching strategies to include various technological tools. As teachers gain more experience in using technology effectively, they become better equipped to design and implement lessons that not only leverage the potential of technology but also align with pedagogical principles and the content being taught.

Table 8. Comparison of TPACK ability, designing planning, and teaching practice

Sample	Competency Level		
	TPACK	Designing the plan	Teaching
1	Growing	Growing	Growing
2	Growing	Growing	Growing
3	Growing	Growing	Growing
4	Growing	Growing	Growing
5	Growing	Growing	Growing
6	maturing	maturing	maturing
7	maturing	growing	growing
8	maturing	maturing	maturing
9	maturing	maturing	maturing
10	maturing	growing	maturing
11	maturing	growing	growing
12	Growing	Growing	Growing
13	Growing	Growing	Growing
14	Growing	Growing	Growing
15	maturing	maturing	maturing
16	maturing	maturing	growing
17	maturing	maturing	maturing
18	maturing	maturing	maturing

Of the 18 samples analyzed, four teachers have a TPACK ability level different from the ability to design and teach with technology. Samples 7, 10, 11, and 16 have TPACK at a mature level but have been unable to implement it in designing plans and teaching practices in the classroom. This is influenced by several factors, including the availability of facilities and policies in schools that are less supportive. This means that transforming TPACK into daily teacher performance is also influenced by external factors. The reflection results obtained the following information during and after the training process ended.

Sample 7 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 11 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." The results of the reflection found that the lack of proficient use of technology is one of the factors forthe teacher's lack of confidence in the added value of using technology. Teachers still hesitate to use digital technology in learning for fear of harming students.

5. Conclusion and Implications

The results concluded that there was a significant difference between the TPACK of the control group and the experimental group. The average TPACK score of the experimental group was higher than that of the control group. So, it can be concluded that the training effectively improves the TPACK of elementary school teachers. To see the transformation of TPACK, we can see teachers' performance in the field, both in designing lesson plans and teaching practices in the classroom by integrating technology. The results concluded that the ability to design and practice teaching elementary school teachers was also significantly different between the experimental and control groups.

The correlation test analysis results concluded a strong positive correlation between teachers' TPACK and the ability to design and practice teaching in the field. 70% of TPACK ability is explained by the ability to design and practice in the field. This training is important for teachers to be able to integrate technology into the learning process in the classroom. The results of this study are also important information for future researchers related to the use of training models to improve the TPACK of elementary school teachers.

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