frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 25 August 2022
DOI 10.3389/feduc.2022.897447

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Teacher Education, a section of the journal Frontiers in Education

RECEIVED 16 March 2022
ACCEPTED 09 August 2022
PUBLISHED 25 August 2022

CITATION
Diamah A, Rahmawati Y, Paristiowati M, Fitriani E, Irwanto I, Dobson S and Sevilla D (2022) Evaluating the effectiveness of technological pedagogical content knowledge-based training program in enhancing pre-service teachers' perceptions of technological pedagogical content knowledge. *Front. Educ.* 7:897447. doi: 10.3389/feduc.2022.897447

Evaluating the effectiveness of technological pedagogical content knowledge-based training program in enhancing pre-service teachers' perceptions of technological pedagogical content knowledge

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In this study, we sought to investigate the effect of a 2-week Technological Pedagogical Content Knowledge (TPACK)-based training program on how the pre-service teachers' TPACK was perceived. To achieve the goal, we used four TPACK activities; *Explore-Engage-Reflection-Transformation*. The study employed mixed methods with a TPACK questionnaire and open questions. Increased self-efficacy perceptions of TPACK was evaluated using a one-group pre-post-post research design. The sample was 30 pre-service teachers (5 male; 25 female) at a public university in Indonesia. Paired *t*-test was used to examine the significant difference between pretest and posttest scores and Cohen's *d* was calculated to check the strength of the effect size. As a result, the paired *t*-test showed that the posttest scores were significantly higher than the pretest scores for all TPACK dimensions with large effect sizes. In addition, qualitative data from students' reflections were analyzed. It found that pre-service teachers understand the role of technology integration in the TPACK framework for creating meaningful learning experiences. Participants reflected on the role as assessment for, and as learning. Professional learning from the New Zealand education system was introduced within a holistic framework to stimulate students to be creative future-directed teachers and agents of change. This indicates that the present training program increased the pre-service teachers' perceptions of TPACK at the end of the training. We

suggest that TPACK training programs that facilitate how pre-service teachers integrate technology, content, and pedagogy to create effective technology-enriched learning environments in their subjects should be included in teacher education programs.

KEYWORDS

TPACK, pre-service teacher, teacher education programs, information and communication technology, mixed methods

Introduction

The effective use of information and communication technology (ICT) to promote teaching and learning has become a major focus of researchers and educators in recent years. Information and communication technology can facilitate improved learning if teachers are digitally literate and understand how to integrate technology into teaching. The introduction and integration of ICT into the classroom also support students in acquiring the skills they need for future challenges, known as the 21st century skills. Valtonen et al. (2017) summarized the skills include collaboration, communication, ICT literacy, social and cultural competencies, creativity, critical thinking, and problem-solving. An approach that can help teachers integrate technology into their teaching is the technological, pedagogical, and content knowledge (TPACK) framework introduced by Mishra and Koehler (2006). The TPACK framework is designed to facilitate teachers' understanding of how to constructively integrate ICT to teach specific content with appropriate pedagogy (Mishra and Koehler, 2006; Koehler et al., 2013; Rienties et al., 2013; Lee and Kim, 2014; Valtonen et al., 2017; Tondeur et al., 2020; Wang et al., 2020; Lachner et al., 2021). In brief, the framework suggests that teaching is the integration of what teachers know, i.e., the content, pedagogy, and technology, and how the teachers can apply their knowledge in their classroom context.

The definition of TPACK varies in publications. According to the literature (e.g., Mishra and Koehler, 2006; Koehler et al., 2013), TPACK is generally viewed as a coherent set of knowledge and skills that teachers need for the application of ICT in their teaching. Theoretically, the TPACK framework consists of seven domains (Mishra and Koehler, 2006; Koehler et al., 2013); content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). This framework is an extension of Shulman's (1986) model for PCK. Content knowledge is knowledge including central facts, theories, concepts, and connecting ideas from certain subject matter to be taught (e.g., chemistry, mathematics). Pedagogical knowledge refers to knowledge of teaching and learning processes (e.g., pedagogical approaches, teaching methods, classroom management, and student assessment). Technological knowledge is seen as knowledge of digital technology and skills to operate and utilize technology efficiently (e.g., software, digital video, smart devices, and internet). Technological content knowledge is considered as knowledge of how technology and content influence and constrain each other. Technological pedagogical knowledge is knowledge about the benefits of using technology to support certain pedagogical practices (e.g., knowing that there are various technological tools for instructional practice). Pedagogical content knowledge refers to knowledge of appropriate pedagogy to teach certain content (e.g., knowing what teaching strategies are appropriate for the specific content). Technological Pedagogical Content Knowledge is seen as knowledge of utilizing appropriate technologies to deliver certain subject matter through effective learning approaches and pedagogical practices. In other words, TPACK demonstrates knowledge of effective pedagogical practices with appropriate technology applications to teach specific content (Koehler et al., 2013).

As a result of the effective integration of ICT into learning, the TPACK framework has attracted the attention of scholars and educators over the last decade (Bingimlas, 2018). Due to its popularity, previous evidence reported that TPACK has been explored across a wide range of subject domains, including science (Aktaş and Özmen, 2020), language (Chai et al., 2013), geography and history (Ortega-Sánchez and Gómez-Trigueros, 2020), physical education (Semiz and Ince, 2012), and mathematics (Smith et al., 2016). Similarly, existing studies have succeeded in increasing the TPACK of pre-service teachers (e.g., Joo et al., 2018; Aktaş and Özmen, 2020; Wang et al., 2020; Lachner et al., 2021) and in-service teachers (e.g., Chai et al., 2013; Lehiste, 2015; Chai and Koh, 2017; Bingimlas, 2018; Kim and Lee, 2018) extensively in a variety of ways, such as internship course, instructional design model, TPACK-modules, programming languages, and outreach program (e.g., Lee and Kim, 2014; Chai and Koh, 2017; Kim and Lee, 2018; Chaipidech et al., 2021; Lachner et al., 2021). This suggests

that providing pre-service teachers with the opportunity to design technology-enriched materials is a promising approach to promote their TPACK (Tondeur et al., 2020). Teachers with TPACK are expected to be well-equipped to interpret the relationship between CK, PK, and TK in order to solve any challenges faced by students in the classroom.

There are many factors influencing the success of ICT integration into classrooms. Ertmer (2005) suggested two barriers to the integration of ICT in teaching; external barriers such as ICT resources and internal barriers, particularly teachers' perceived value of ICT and confidence in using ICT for classroom implementation. Since access to ICT resources are lesser of an issue in most schools, Ertmer et al. (2012) further investigated the internal factors and found that teachers' beliefs and attitudes toward ICT implementation are one of the most important independent variables. Similar to the findings of Ertmer (2005), teachers' perceived self-efficacy in using technology is also a contributing factor to teachers' intention to use technology in the classroom (Anderson et al., 2011; Joo et al., 2018). This reflects that teachers' TPACK correlated significantly with their perceived self-efficacy (Joo et al., 2018). In fact, Semiz and Ince (2012) also confirmed a positive relationship between pre-service teachers' TPACK and their self-efficacy in integrating ICT. In other words, pre-service teachers with high self-efficacy for integrating technology are likely to develop high TPACK skills.

Unfortunately, pre-service teachers' knowledge and skills of TPACK are low. For example, Smith et al. (2016) investigated relationships between middle-grade pre-service teachers' beliefs and their TPACK and reported that pre-service teachers performed the lowest levels of TPCK among the TPACK domains. In another study, Al-Abdullatif (2019) analyzed the TPACK confidence of Saudi pre-service teachers and found that participants displayed a very low level of confidence in most TPACK integration practices. Similarly, Chai et al. (2013) explored the profile of Singaporean Chinese language teachers' TPACK and pedagogical beliefs and found that teachers displayed low levels of technology-related knowledge (TK, TPK, TCK, and TPACK). Recently, Wang et al. (2020) investigated Chinese pre-service teachers' TPACK competencies and found that pre-service teachers attained relatively low scores on TK, TPK, and TPCK subscales. Saltan et al. (2017) also compared pre-service and in-service teachers' self-confidence on TPACK. They reported that pre-service teachers had the lowest score in TPACK and in-service teachers had the lowest score in the TK domain. This indicates that pre-service teachers' TPACK and their technology-related knowledge should be further improved.

Considering the importance of students' experience of learning with technology, pre-service teachers should be prepared for ICT integration in classrooms. Specifically, pre-service teachers should be confident in their TPACK. With this in mind, the current study investigated the influence of TPACK-based training on the pre-service teachers' TPACK skills and levels of confidence. The training included four stages of activities: *Explore, Engage, Reflection, and Transformation*. To our knowledge, the use of TPACK-based training to promote pre-service teachers' perceptions of TPACK remains limited. In a quasi-experimental study, for instance, Lachner et al. (2021) developed subject-specific versions of a TPACK-module to support the acquisition of TPACK. They reported that pre-service teachers in the courses with the TPACK-modules acquired more TPACK than those in the control courses without the TPACK-modules. Lehiste (2015) also investigated in-service teachers' TPACK perceptions during the first year of educational technology professional development and found an increase in all the domains of the TPACK framework. Kim and Lee (2018) explored the effects of introducing programming as a technological tool for teachers' TPACK development and reported a statistically significant improvement in the knowledge related to technology. Chaipidech et al. (2021) recently reported that the TPACK-oriented teacher professional development intervention program was successful in improving in-service teachers' technological integration comprehension of digital technologies in Science, Technology, Engineering, and Mathematics (STEM) teaching. Rienties et al. (2013) implemented an 8–12 week online teacher training program for teacher educators in the Netherlands and found that teachers' TPACK skills improved gradually and most participants showed a positive attitude toward implementing an online professionalization program.

Given that workshop and training sessions on TPACK suggest a positive effect on the performance of pre-service and in-service teachers (e.g., Lehiste, 2015; Lachner et al., 2021), this study is intended to examine the effect of a much shorter 2-week TPACK-based training program on how pre-service teachers' TPACK is perceived. For this purpose, the research questions are:

(1) Is there a significant difference between pre-test and post-test scores of pre-service teachers in relation to their perceptions of TPACK?
(2) What are pre-service teachers' reflections after attending the TPACK-based training program?

According to the evidence in previous empirical studies of the benefits of TPACK training programs (e.g., Rienties et al., 2013; Lehiste, 2015; Kim and Lee, 2018; Chaipidech et al., 2021; Lachner et al., 2021), the primary hypothesis investigated was that pre-service teachers who are actively engaged in training on integrating knowledge of technology, pedagogy, and content together would statistically show more positive perceptions of TPACK than before. The second hypothesis is that pre-service teachers who attend TPACK

training will exhibit better views and opinions on technology-enhanced learning.

Materials and methods

Design

We employed mixed methods as methodology. The one-group pretest-posttest quasi-experimental design (Fraenkel and Wallen, 2006) was used in the present training program and students' reflections on open-ended questions were analyzed. The Pre-service Teacher Training (PTT) was a collaborative program between universities in New Zealand and Indonesia. This program was intended to develop Indonesian pre-service teachers' TPACK.

Participants

This workshop was held in the odd semester of the 2021/2022 academic year at a public university in Indonesia. Participants were 30 pre-service teachers who were selected using purposive sampling (see **Table 1**). Students were required to commit to the program until the end, with high motivation, good English proficiency, stable internet connection, and eagerness to learn new things. The mean age of the participants was 21.5 ranging from 20 to 36 years. The participants were 25 undergraduate students, four master's students, and one fresh graduate. At the beginning of the program, the participants were informed of the purpose of the study. In addition, written informed consent forms were distributed to the participants at the start of the study. They knew they could withdraw at any moment without reason. The subject matter experts involved in this training were senior lecturers, adjunct research fellows, and outreach coordinators from a university in Wellington, New Zealand.

Data collection

We used the Pre-service Teacher Technological Pedagogical Content Knowledge (PT-TPACK; Lux et al., 2011) to explore the TPACK of pre-service teachers. This scale consisted of 27 items in six TPACK domains; technology knowledge (TK; four items), CK (CK; three items), pedagogy knowledge (PK; four items), PCK (PCK; three items), TPK (TPK; five items), and TPACK (TPACK; eight items). The PT-TPACK Survey had a 5-point Likert scale format (1-strongly disagree to 5-strongly agree). The instrument was then translated into Indonesian and validated by three experts who hold Ph.D. After being tested on 210 pre-service teachers, all TPACK domains had Cronbach's alpha values between 0.617 and 0.922 (see **Table 2**). Aiming to explore the psychometric properties of PT-TPACK, Confirmatory Factor Analysis (CFA) was then performed using Lisrel 8.80 software. According to Hair et al. (2018), the model fitted well with the data if normed Chi-square (χ^2/df) $\leq$ 3; root mean square error of approximation (RMSEA) $\leq$ 0.08; root mean squared error (SRMR) $\leq$ 0.08; Tucker-Lewis index (TLI) $\geq$ 0.95; and parsimony normed fit index (PNFI) > 0.60. In the present study, the results of the CFA of PT-TPACK (i.e., χ^2/df = 2.01, RMSEA = 0.069, SRMR = 0.05, TLI = 0.98, PNFI = 0.84, goodness of fit index (GFI) = 0.83, adjusted goodness of fit index (AGFI) = 0.79, normed fit index (NFI) = 0.96, comparative fitness index (CFI) = 0.98, and relative fit index (RFI) = 0.96) indicated that the model had a good fit with the data. This shows that the PT-TPACK survey has high reliability to assess the efficacy of Indonesian pre-service teachers toward TPACK.

Data were collected from students' self-reflections and observations throughout the process of implementing the model of *Explore-Engage-Reflection-Transformation* in the training. The students were closely observed during the workshop, and information was obtained on their engagement with educational issues, teaching and learning, curriculum, ICT, and assessment. Students were asked several questions designed to explore their conceptual understanding and feelings and implement the knowledge into their practices.

TABLE 1 Demographic characteristics of participants.

Variable	*N*	%
Gender		
Male	5	16.67
Female	25	83.33
Educational level		
Master of education	4	13.33
Bachelor of education	26	86.67
Age		
20–21	26	86.67
22–23	2	6.67
24–25	1	3.33
>25	1	3.33

TABLE 2 Reliability of pre-service teacher technological pedagogical content knowledge (PT-TPACK).

Dimension	*N*	α
Technology knowledge	4	0.617
Content knowledge	3	0.781
Pedagogy knowledge	4	0.875
Pedagogical content knowledge	3	0.819
Technological pedagogical knowledge	5	0.863
Technological pedagogical content knowledge	8	0.922
All dimensions	27	0.953

TABLE 3 Activities in pre-service teacher training (PTT).

Meeting	Topic	Goal
1	Digital technology integration in the New Zealand Classroom	Distinguishing between ICT and digital technology and the transition from using ICT to digital technology in learning in New Zealand. Pre-service teachers are encouraged to explore the use of digital technology in learning
2	Teaching in the digital age: Professional digital competence for teachers	Develop teacher competencies such as the ability to use technology, pedagogical knowledge, content knowledge, and professional knowledge in the digital era in terms of educational goals, namely: academic development, subjectification, and socialization
3	Assessment and evaluation	Understand various assessment paradigms, teacher competencies needed in conducting assessments, and issues related to assessment and evaluation
4	Student learning versus teacher-centered	Discuss the difference between teacher-centered and student-centered learning in Indonesia. Participants then linked this topic to the new Indonesian government policy, namely *Merdeka Belajar* (independent learning), where students are given the freedom to choose what they want to learn and how to learn it during the COVID-19 pandemic
5	Preparing teachers for diversity and difference	Recognize the education system in New Zealand including the level of participation and the results obtained. In addition, this session also discussed in more detail three important issues in the education system in New Zealand: (i) inequality in learning outcomes, (ii) the relevance of learning outcomes, and (iii) the impact of the designed education system
6	The education system in New Zealand	Provide an overview of teacher education programs in New Zealand and discuss approaches taken to address challenges and changes in the education system. In this session, pre-service teachers are also invited to discuss to evaluate what things have been implemented well and what still needs to be improved in the education system in both New Zealand and Indonesia
7	Learning design – curriculum	Provides curriculum principles and critical issues, as well as an overview of the curriculum, various forms of curriculum, curriculum philosophy, and comparison of educational curricula in New Zealand and Indonesia in order to stimulate pre-service teachers to reflect on their learning experiences

Procedure

Prior to the activity, all participants were instructed via email to bring a laptop or other electronic device to access the e-learning platform https://tpack-unj.com/ the training. At the beginning and at the end of the activity, students did pretest and posttest individually using Google Form. Then, students took part in a 7-meeting training program using the Zoom app. This program was carried out in four main stages; *Explore* (exploring the concepts and issues in related topics), *Engage* (implementing the concepts and ideas), *Reflection* (reflecting on implementation in relation to self and others), and *Transformation* (transforming self-understanding of personal and professional practices). At the end of the training program, all participants offered self-reflections and then wrote their opinions and views into the learning management system (LMS) that had been used. Reflection was intended to enhance the learning experience about what challenges they faced and how they were involved during the TPACK training process. Reflection was also designed to raise the level of self-awareness, develop skills, and reflect on their own work to improve their learning outcomes. The workshop was held for seven meetings (i.e., 2 h daily). At the first meeting, the training program was introduced to the participants and a pretest was conducted. For 2 weeks, TPACK was introduced to pre-service teachers (see **Table 3**). The instructors also facilitated class discussions on each topic. At the last meeting, the posttest was given to the participants after discussion and evaluation of the training program regarding contributions to participants.

Data analysis

It should be noted that during the study, none of the pre-service teachers requested that their data be excluded from the analysis. Inferential statistical analysis was used using IBM SPSS 25.0 to determine whether there was a significant difference between pretest and posttest scores of pre-service teachers. Since the parametric test assumptions were met ($p > 0.05$), a paired t-test was performed (Pallant, 2007). The significance level was set at 0.05. In addition, Cohen's d value was also examined to determine the effect size of the training program; $d = 0.2$ for small effect size, 0.5 for medium effect size, and 0.8 for large effect size (Cohen, 1988).

Data analysis was carried out in three stages: data reduction, data display, and concluding/verification. The data obtained from students' reflections and observations were reduced by categorizing the findings, after its coding, from appropriate data. The data were then presented in a matrix table based on the categorization of implications of the implementation of the model into pre-service teachers' TPACK and engagement. Triangulation of qualitative data was used to verify the data for inferring conclusions.

TABLE 4 Descriptive statistics.

Dimension		Mean	SD	Change
Technology knowledge	Pretest	4.325	0.446	+0.092
	Posttest	4.417	0.466	
Content knowledge	Pretest	4.456	0.459	−0.178
	Posttest	4.278	0.733	
Pedagogy knowledge	Pretest	4.600	0.434	+0.017
	Posttest	4.617	0.392	
Pedagogical content knowledge	Pretest	4.345	0.557	+0.244
	Posttest	4.589	0.417	
Technological pedagogical knowledge	Pretest	4.287	0.460	+0.466
	Posttest	4.753	0.314	
Technological pedagogical content knowledge	Pretest	4.176	0.526	+0.463
	Posttest	4.639	0.403	
All dimensions	Pretest	4.338	0.390	+0.240
	Posttest	4.578	0.346	

Results

Is there a significant difference between pre-test and post-test scores of pre-service teachers in relation to their perceptions of technological pedagogical content knowledge?

In this section, the effect of the TPACK training program on pre-service teachers' perceptions of TPACK is presented. Descriptive statistics were used to get the means, percentages, and standard deviations. The results of the study showed that pre-service teachers' perceptions of all dimensions of TPACK appeared to be greater than the average Likert scale score, which was 4.338 before the intervention and 4.578 out of 5.0 after the intervention. In other words, pre-service teachers generally considered their TPACK at a fairly high level. A higher average score indicates a higher perception of TPACK. In this study, the training program as a forum for assessing the activities of pre-service teachers related to the integration of knowledge of technology, pedagogy, and content increased the level of perception of pre-service teachers toward TPACK. This can be seen from the difference in pretest and posttest scores. In general, **Table 4** shows the change in the average posttest score for all TPACK dimensions of 5.51% compared to the pretest score.

In particular, the statistical differences in pretest and posttest scores are summarized in **Table 5**. Based on this table, the highest increase was observed in the TPK dimension with 0.466 points, while the decrease was seen in the CK domain with 0.178 points. To prove whether there was a statistically significant increase between the scores before and after the test, we ran a paired t-test analysis. The results showed that there was a statistically significant difference between the scores before and after the test ($t = -4.417$, $p < 0.05$) for the same sample. This confirmed that the mean score for the posttest was significantly higher compared to the pretest score after the intervention. These results indicate that the given intervention can promote positive perceptions of TPACK. In addition, the effect size was determined using Cohen's d formula, and the value of $d = 0.81$ was obtained. This shows that the effect of treatment on the level of efficacy of pre-service teachers on TPACK is large (Cohen, 1988). Therefore, these findings indicate that a 2-week training program in the current study is effective in increasing the level of pre-service teachers' confidence in TPACK.

What are the reflections of pre-service teachers after attending the technological pedagogical content knowledge-based training program?

After completing the training session, pre-service teachers conduct self-reflection to find out how far they understand the lectures given, how they apply them in the classroom when carrying out teaching practices, how they evaluate the training provided, and how deeply the changes they feel about themselves. The reflections of several students at each stage during the training are presented as follows.

Technology in technological pedagogical content knowledge framework for students' engagement

The training was carried out by conducting teaching practices, watching videos, conducting case studies on the implementation of education policies in other countries, and through discussions. The implication of this phase is that the TPACK training program has provided in-depth insights for pre-service teachers on the importance of integrating technology into teaching and learning in order to create a meaningful learning environment for students. As a result, participants claimed that they benefited from the training program and were able to differentiate between the use of ICT and digital technology in the classroom, as expressed by the following pre-service teachers:

> *"Before joining this training, I initially thought that ICT and digital technology were similar. As it turned out, the main difference I got after the training was how students were directed to be more active when using digital technology. For example, in the use of ICT, students only consume learning videos, while in the use of digital technology, students*

> *experience ICT-assisted learning and they are more creative"* (Self-reflection, PT-1).

> *"We have to improve our ability to use digital technology (including ICT) in teaching and learning. As pre-service teachers, we must have professional competence in teaching in the digital era such as the integration of technology, pedagogy, and CK related to educational goals"* (Self-reflection, PT-12).

> *"Teaching in the digital age offers an alternative for me to make the classroom more fun and make it easier for students to understand the subject"* (Self-reflection, PT-29).

Pre-service teachers are stimulated to think about how to integrate information and communication technology in teaching and learning, not only in using technology but also in creating meaningful learning experiences.

Being creative teachers in digital era

The pre-service teacher reflected on how the theories can be applied in the classroom, how well they execute the competencies learned, and how profoundly the impact is given to students. They think of different ways to implement in their classroom because they realized that teachers should find creative ways of integrating technology by considering students, resources, and topics. The responses of pre-service teachers are presented as follows:

> *"For further learning, I should focus on ICT, and gradually prepare to apply digital technology in the classroom. I think I should be more creative and innovative for my own learning in school. As a future teacher, I have to learn digital technology first, it is very good to use it, show it to students, and then teach them"* (Self-reflection, PT-15).

During the training, two pre-service teachers think of innovative ways in using digital technology to overcome various difficulties and make students more interested in studying chemistry, as shown by the following views of pre-service teachers.

> *"I believe that digital technology can be integrated into the context of teaching chemistry to overcome various difficulties. For example, the abstract nature of chemistry that causes students to perceive chemistry as a difficult subject can be reduced by the integration of digital technologies such as augmented reality"* (Self-reflection, PT-9).

> *"In utilizing digital technology in chemistry education, I can use augmented reality which can make it easier for students to learn chemistry and make students more interested in chemistry"* (Self-reflection, PT-24).

They reflected on the topic of ICT in the training to be integrated into their future teaching practices.

Assessment for and as learning

Pre-service teachers learn assessment from different perspectives. Their experiences as university students have influenced their view that assessment is only for grading, making judgments of performance, and teaching to the test. They found that the feedback to students on their learning is not only simply related to learning conducted in the classroom setting but also to their future lives. The assessment used to focus on measuring students' skills and abilities in a summative sense without providing opportunities for students to learn from the assessment itself. The last mentioned is assessment as learning where the importance of students undertaking self-assessment is underlined. Given that each student is unique with a different approach to learning, each student should be offered and supported in the opportunity to engage in deep learning which can only be achieved by providing opportunities to experience different types of assessment. Such an understanding relates to the statements of two pre-service teachers below:

> *"I realize feedback is very important to be given during the assessment process thus students know which things need to improve and be better in the future. Last but not least, teachers can do the evaluation based on the result then decide what is a good plan to enhance the success of teaching and the learning process in the class"* (Self-reflection, PT-5).

> *"I realize that assessment and evaluation are two important things that must be done to measure learning outcomes. However, in the future, it is expected that in conducting the assessment it needs to be balanced with other aspects than the final test, such as students' attitudes, skills, and involvement during the learning process itself. So, the assessment and evaluation results can be trusted and in accordance with the circumstances. The assessment and evaluation process can also be done in a fun way such as through interactive quizzes, giving rewards and reinforcement, as well as other positive forms of feedback that can increase student's learning motivation"* (Self-reflection, PT-10).

One of the pre-service teachers understood the power of assessment for students' agency:

> *"Teachers sometimes forget to conduct assessments during the learning process and involve students in self-assessments because they focus on completing the demands of the material*

> *in the curriculum. In addition, shifting the paradigm that the quality of the process is more important than the final score is a difficult thing to do. Currently, in Indonesia, the score in numbers is still the main parameter of student success in learning. On the other hand, teachers still have difficulty presenting student learning outcomes qualitatively. The values that develop during the learning process must be considered because the purpose of education is to build students' academic abilities (knowledge) and attitudes, skills, so they become independent learners, and are able to participate actively in society"* (Self-reflection, PT-12).

She realized the power of scoring in the assessment system and completing the content in curricula. As noted it is important to enhance the future agency of students.

Learning from New Zealand

Pre-service teachers were exposed to and learned from the different perspectives presented during the 2-week period of the program. Descriptions from subject experts on New Zealand painted rich, holistic pictures of the education ecosystem. It stimulated pre-service teachers to make comparisons with the Indonesian education system. They highlighted the importance of collaboration between stakeholders to create contextual and cooperative learning as stated below:

> *"Every teacher who teaches requires professional development and the skills to provide learning for all the needs of students. Also, in practice education requires cooperation with all stakeholders such as policymakers, teachers, parents, and the community in creating an environment that accommodates contextual and cooperative learning"* (Self-reflection, PT-5).

> *"By recognizing a good education system in New Zealand then we may adopt some good things which can be implemented here in Indonesia. Core standards for hiring teachers, full support from the government, schools, and parents, and good infrastructures will enable students to receive a better education. New Zealand also prepares the students to face future education so they can compete globally and equip with good technology. Learning in a diverse context is also one thing that needs to take into account since Indonesia also has different backgrounds according to age, socio-economic status, and ethnicities"* (Self-reflection, PT-11).

They realized Indonesia has different contexts and that they can conduct teaching in new ways that prepare students in classrooms to face future challenges. They expect that Indonesia can continue to develop improved education for subsequent generations.

Teachers as agents of change

The final aspect of the training program involved pre-service teachers writing final reflections concerning changes in their self-understanding as regards personal and professional practice in the future. Some of these reflections on the TPACK training program are presented below:

> *"Preparation of knowledge as prospective teachers who will continue and become agents of change in the field of education in Indonesia. I hope this program will continue for the next generation, and add resource persons from Indonesia who have teaching experience in the country so that they can explain a deeper understanding of progress in Indonesia in the field of education"* (Self-reflection, PT-3).

> *"I have become more interested in majoring in the education field and more confident that Indonesian education needs agents of change like who will bring important changes in the Indonesian education system"* (Self-reflection, PT-2).

> *Through this training, I discovered my future goals. I became more motivated to learn how to be a good teacher and able to*

TABLE 5 The results of the paired-samples *t*-test.

Dimension	Paired differences		*t*	*df*	*p*	Cohen's *d*
	Mean	SD				
Technology knowledge	−0.092	0.476	−1.056	29	0.300	0.19
Content knowledge	0.178	0.782	1.246	29	0.223	0.23
Pedagogy knowledge	−0.017	0.334	−0.273	29	0.787	0.47
Pedagogical content knowledge	−0.244	0.612	−2.182	29	0.037	0.40
Technological pedagogical knowledge	−0.467	0.428	−5.975	29	0.000	1.09
Technological pedagogical content knowledge	−0.463	0.484	−5.247	29	0.000	0.96
All dimensions	−0.239	0.297	−4.417	29	0.000	0.81

> *adapt to change. The knowledge that I have gained from this workshop can be useful in my future personal and professional development* (Self-reflection, PT-14).

This program raised the awareness of pre-service teachers about the importance of understanding the role of teachers. They realized that a teacher has a great moral responsibility to society and to all human beings. Becoming a teacher means educating people to become holistic individuals in society. Good holistic individuals and great leaders are shaped through education. They would like to move toward becoming teachers who have a passion to empower students to actively participate and contribute to society within their various roles and engage students as lifelong learners who develop their knowledge throughout their lives.

Ethical approval

The participation of pre-service teachers in this workshop was on a voluntary basis. At the start of the study, written informed consent forms were distributed to the participants. They knew that they could resign at any time without coercion. The researchers also informed them that their pretest and posttest scores would not affect their final scores. In addition, participant names were removed from all data collection forms to ensure confidentiality (Fraenkel and Wallen, 2006).

Discussion

This study has successfully investigated how the effect of a 2-week TPACK-based training program on pre-service teachers' TPACK was perceived. The results of descriptive statistics indicated that there was an observable growth in the post-training survey for all dimensions. In the post-training survey, pre-service teacher self-assessments were highest for the TPK domain and TPACK, indicating pre-service teachers' confidence in their ability to integrate new technologies into suitable teaching methods for different content. A possible reason for this finding is that training programs provide pre-service teachers with opportunities to learn about new digital technologies and their applications in the classroom to catalyze student learning. This finding is in line with the work of Ortega-Sánchez and Gómez-Trigueros (2020) which noted the benefits of digital technology in the acquisition of pedagogical, disciplinary, and TK. Conversely, it was observed that there was a non-significant decrease in the CK domain in the current study. This may be explained that teaching practice was not carried out during the training. As suggested by Ryu and Lee (2017), practical teaching experience is effective for nurturing pre-service teachers' TPACK skills. One of which is CK because it provides a dynamic relationship between each knowledge subdomain in TPACK.

The *t*-test results suggested that there was a statistically significant increase in TPACK scores before and after a 2-week intensive training among pre-service teachers. It may be concluded that the TPACK development training program has proven successful in positively enhancing perceptions of TPACK among pre-service teachers. This result is in parallel with the findings of the previous studies (e.g., Kim and Lee, 2018; Aktaş and Özmen, 2020; Chaipidech et al., 2021; Lachner et al., 2021). One of the reasons for this increase is that whole-class and small-group discussions conducted after the expert presentation provided valuable feedback for pre-service teachers which in turn contributed positively to their perceptions of TPACK (Aktaş and Özmen, 2020). During the discussion, pre-service teachers exchange opinions, arguments, ideas, and thoughts with their peers. As stated by Aktaş and Özmen (2020), discussions affect the cognitive structure of pre-service teachers while offering them an opportunity to consider suggestions from other teammates, thereby strengthening their TPACK development. Appropriate collaboration with peers and learning how to use technology can also be reasons why pre-service teachers' TPACK perceptions tend to be positive (Tondeur et al., 2020). In this study, the TPACK-based training program has also introduced website and technology tools that pre-service teachers had not previously encountered for teaching and learning purposes (Aktaş and Özmen, 2020). Thus, these reasons may play a key role in the development of pre-service teacher TPACK perceptions. Therefore, it is suggested that TPACK workshops should be integrated into teacher training programs. We hope that the increased technology-related knowledge of pre-service teachers in the current study increases their awareness of using ICT in their future classrooms (Hammond et al., 2011). This is especially important given that there is a need for teachers to change their teaching methods from traditional learning to technology-enhanced learning (Semiz and Ince, 2012; Lehiste, 2015; Bingimlas, 2018).

The training has provided pre-service teachers with experiences in reflecting on their future roles as teachers. They understand that integrating technology is required from them to contextualize the CK in curricula with its application in students' lives. According to Chai and Koh (2017), the first step to developing lesson design in the TPACK framework is developing PCK which is centered around finding authentic applications and students' engagement to be relevant to current curricula. They realized that focusing on students learning through integrating technology with CK is a fundamental issue in the TPACK framework. As the characteristics of TPACK, the pre-service teachers need to consider this CK and how it can be integrated with the ICT to guide student learning (Yang and Tsai, 2010; Janssen et al., 2019). They understand the strategies of analyzing subject knowledge characteristics, focusing on the learning objectives and students' engagement,

and integrating ICT has helped them in designing the lessons. In assessment, they found the value of assessment both for and as learning. Assessment is not only about grading and judgments but also about empowering students to learn and undertake self-assessment. In so doing, their teaching practices become truly transformative. The pre-service teachers learned from the New Zealand education system through listening to and collaborating with program topic experts who shared their knowledge and understanding of New Zealand educational practices and students' learning and agency.

Conclusion and recommendations

The findings of this study suggest that the TPACK-based training program has a promising impact on the perceptions of TPACK among pre-service teachers. The results showed that there was a statistically significant increase from pretest to posttest after the training program in terms of how TPACK was perceived with large effect sizes. After attending a 2-week TPACK training, pre-service teachers showed a fairly high perception of TPACK. Given the findings of this study, it is important for teacher education institutes to integrate technology into courses in order to increase the development of TPACK skills among pre-service teachers. Specifically, there should be more courses that require pre-service teachers to develop their technology-related skills. In addition, the integration of technology into the pre-service teacher curriculum should be an integral part of the educational process, such as planning, implementing, and evaluating learning using technology. In order to achieve educational goals appropriate for the 21st century, it is fundamental to use the TPACK framework in pre-service teacher preparation programs. The current findings directly contribute to the growth of research on TPACK training programs for pre-service teachers. It is important for pre-service teacher programs to integrate technology within content and pedagogy framework which focuses on students' learning. They learn that assessment for and as learning plays an important role in improving students' learning and reflecting on their teaching. They understand both the difference and similarities between the Indonesian and New Zealand education systems. In their learning, they reflected on what it means to be creative future teachers and agents of change. The training has helped the pre-service teachers to develop their agency in their future roles as teachers.

The study has several limitations that should be considered. First, the small sample size of the participants reduces the generalizability of the findings in the current study. Further, data from online self-reported surveys depended upon participants' ability to provide truthful information (Sue and Ritter, 2007). We suggest future studies employ case studies of different kinds of pre-service teachers, both nationally and internationally to better understand their engagement. To widen our understanding, it is desirable to embark upon studying implementation in the classroom. Lastly, the training program was introduced for only 2 weeks. Thus, conducting long-term TPACK training and involving a comparison group may add new findings to the field.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Universitas Negeri Jakarta. The participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Funding

This study was supported by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia under Grant No. 032/E5/PG.02.00.PT/2022.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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