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Assessing the performance of Turkish science pre-service teachers in a TPACK-practical course

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Abstract
This study assesses the performance of Turkish science pre-service teachers (PSTs) in a TPACK-Practical Course that consists of the training course and lesson-plan-micro-teaching stages. The subjects of the study were 46 PSTs (19 males and 27 females). In this study, after PSTs took a TPACK training course, they created a TPACK-based lesson plan and presented it to their classmates through micro-teaching. Data sources included lesson plans and video recordings of lesson presentations. Researchers developed and used a rubric of TPACK-based learning environments to evaluate the data sources. The rubric consisted of 12 items, and each item contained five performance levels. Researchers analyzed the data by using descriptive statistics and the Wilcoxon signed-rank test. There was a significant increase in the total score of TPACK among the PSTs after the course. There was also a significant increase in the items guiding, providing active participations of students, making assessment and evaluation, appropriateness of chosen teaching methods, and accuracy of the given information/concepts when teaching science subjects with technology. Possible reasons for this positive effect include using worksheets with technological tools such as simulation, the influence of the course lecturers as role models, the introduction of new technologies to the PSTs in the training course, and using class discussions to provide feedback.

Keywords Micro-teaching · Performance assessment · Pre-service science teachers · TPACK · Training course · Worksheet

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1 Introduction

Advances in Information and Communication Technologies (ICT) have greatly affected education (Thohir et al., 2020), especially in how pre-service teachers learn about new methods in learning (Collins & Halverson, 2018). Therefore, researchers are focusing on how to use technology effectively and efficiently in the teaching process to provide rich and understandable experiences for students (Aktaş & Özmen, 2020; Angeli & Valanides, 2009; Mishra & Kohler, 2006; Niess, 2005; Ocak & Baran, 2019; Tondeur et al., 2019a). Thus, using technology effectively in teaching has become one of the critical proficiencies for teachers in many countries (Muhaimin et al., 2019; Sheffield et al., 2015; Thohir et al., 2020). Using technology effectively in lessons requires teachers to have both technological and pedagogical knowledge and to associate technological methods with content knowledge. In other words, understanding how to use the technology alone is insufficient for the effective use of technology in teaching. Teachers must associate the appropriate method with the subject content, which leads to the concept of Technological, Pedagogical, and Content Knowledge (TPACK).

1.1 What is TPACK?

TPACK is a theoretical framework of knowledge and its application that teachers need to make effective use of digital technologies in teaching (Mishra & Kohler, 2006; Niess, 2005). Teachers who use this knowledge can make their teaching more comprehensible for students and assist students in learning (Jen et al., 2016). TPACK has become a professional qualification for teachers in today's learning environments (Joo et al., 2018). Due to its complexity, there is not a scholarly consensus on a single TPACK model, although numerous studies have focused on it (Aktaş & Özmen, 2020). One of the most prominent models, defined by Mishra and Kohler (2006), is called the integrative model, and it consists of seven knowledge components: Technology Knowledge (TK), Content Knowledge (CK), Pedagogical Knowledge (PK), the intersection of each pair of these knowledge types (TPK, TCK, PCK), and the intersection of all (TPACK). However, other scholars have determined that developments in sub-components of the integrative TPACK model do not automatically develop the TPACK component (Angeli & Valanides, 2009), that all seven components of the model do not always contribute to the TPACK component, that a different number of components may be more appropriate for the TPACK model (Archambault & Barnett, 2010; Jang & Tsai, 2012; Koh et al., 2010), and that it can be quite difficult to distinguish the seven components of the model from each other (Chai et al., 2010; Tseng et al., 2019). The transformative model of TPACK has gained popularity with the recognition of the importance of contexts, such as the classroom and classroom factors (Rosenberg & Koehler, 2015). However, there are few studies on the transformative model (Angeli & Valanides, 2005; Baran & Uygun, 2016; Jang & Chen, 2010; Kadıoğlu-Akbulut et al., 2020; Schmid et al., 2021; Yeh et al., 2015a). The transformative model is unique in its emphasis on the central TPACK component, rather than the seven individual components (Angeli & Valanides, 2009). This model emphasized that TPACK is the body of knowledge consisting of the interactions among context, content, pedagogy, learners, and technology knowledge (Angeli & Valanides, 2009). Figure 1 illustrates the transformative model of TPACK.

Angeli and Valanides (2009) defined these components as follows. *Content* knowledge is understanding the facts and structures of a content area. *Pedagogy* knowledge includes broad principles and strategies of teaching, classroom management, and organization that are specific to different subject areas. *Learners'* knowledge is students' characteristics and prior learning in a learning situation. *Context* knowledge relates to how the classroom operates, educational values, goals, as well as teachers' epistemic beliefs with philosophical foundations about teaching and learning. *ICT* knowledge is defined as knowing how to operate a computer or an interactive whiteboard and knowing how to use many tools/software, as well as how to troubleshoot problem situations. The transformative model is similar to the integrative model as both include content, pedagogy, and technology knowledge, but the transformative model adds the two additional components of learners and context knowledge. Also, in the transformative model, it is important to synthesize this knowledge rather than simply acquire each component individually. The transformative model emphasizes that teachers' TPACK skills will improve when they design content instruction with appropriate use of technology and gain presentation experience with it (Kadıoğlu-Akbulut et al., 2020; Schmidt et al., 2009; Yeh et al., 2015a). To assess the development of TPACK of in/pre-service teachers, researchers need to be able to measure it.

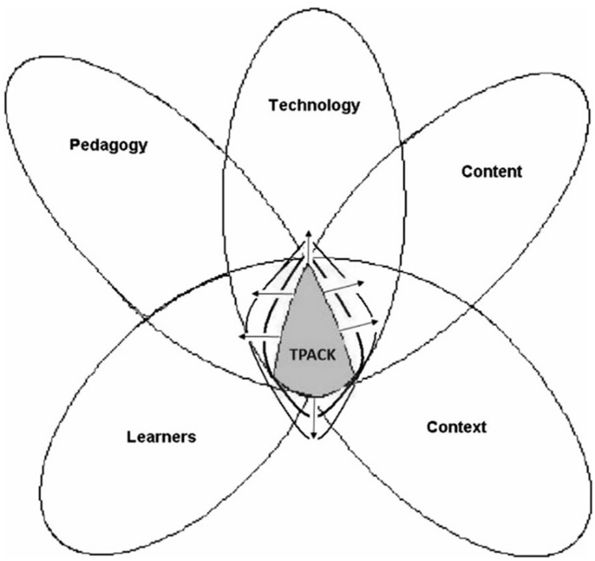

Fig. 1 The transformative model of TPACK (Angeli & Valanides, 2009)

1.2 How to measure TPACK?

Determining the TPACK of in/pre-service teachers requires different measurements because they will be teaching in different subject areas with different student groups (Koehler & Mishra, 2006). Researchers have used different types of measuring tools to measure the TPACK of in/pre-service teachers, such as standardized self-report rating scales (Archambault & Barnett, 2010; Chai et al., 2011; Graham et al., 2009; Irmak & Yılmaz-Tüzün, 2019; Kadıoğlu-Akbulut et al., 2020; Pamuk et al., 2015; Schmid et al., 2021; Schmidt et al., 2009), interviews (Aktaş & Özmen, 2020; Lee & Kim, 2014; Lu & Lei, 2012; Yeh et al., 2015b), daily reports (Jang, 2010; Özgün-Koca et al., 2011; Tokmak, 2013), observations of classroom teaching (Maeng et al., 2013; Muhaimin et al., 2019; Ocak & Baran, 2019), and examining lesson plans (Canbazoğlu-Bilici et al., 2016; Cheah et al., 2019; Lee & Kim, 2014; Lu & Lei, 2012; Sancar-Tokmak et al., 2014; Tokmak, 2013). In general, self-assessment surveys and performance-based assessments of the lesson plan and through classroom observation stand out as most effective (Chai et al., 2016; Tondeur et al., 2019a).

There are some problems with the measurement tools and data sources used by researchers. Too often, researchers use a single type of data to measure TPACK (Chang et al., 2015; Jen et al., 2016). However, related literature emphasizes that it is not appropriate to use a single type of data to measure teachers' TPACK levels because each data source is more suitable for different types of information such as knowledge, attitude, and application (Akyuz, 2018; Archambault & Barnett, 2010; Doering et al., 2009; Harris et al., 2011). For example, self-assessment scales such as Likert-type and open-ended questionnaires are insufficient to measure practical skills, although they do provide important information about TPACK awareness among individuals (Akyuz, 2018; Archambault & Barnett, 2010). In addition, the relationship between pre-service teachers' self-reported TPACK and direct assessment of their TPACK in practice is low (Copur-Genctürk & Thecker, 2020). Thus, researchers must go beyond self-reporting to measure teachers' TPACK development with performance-oriented measures like observations of classroom teaching (Krauskopf & Forssell, 2018; Schmid et al., 2021; Willermark, 2018). On the other hand, course observation alone is not sufficient to determine the TPACK levels of the teachers, since it cannot reveal the reasons for the observed teaching activities and actions (Harris et al., 2011). Therefore, collecting and analyzing data from different sources will further aid understanding of TPACK (Chang et al., 2015; Jen et al., 2016). For this reason, researchers can more accurately determine teachers' TPACK application levels by correlating the data obtained by observing their TPACK-based course practices and examining their lesson plans (Doering et al., 2009; Jen et al., 2016).

Studies of TPACK have focused on explaining the TPACK concepts and the relationships among them (Ay et al., 2015; Cherner & Smith, 2017; Chieng & Tan, 2021; Lin et al., 2013; Mishra & Koehler, 2006; Niess, 2005; Swallow & Olofson, 2017; Tondeur et al., 2017), in/pre-service teachers' TPACK perception and competence levels (Akyuz, 2018; Hechter, 2012; Jen et al., 2016; Lee & Tsai, 2010; Lin et al., 2013; Muhaimin et al., 2019; Redmond & Lock, 2019; Schmidt et al., 2009; Sheffield et al., 2015; Thohir et al., 2020; Tokmak, 2013; Yeh et al., 2015b, 2017), and the relationships between TPACK and other variables such as attitude, age, and gender, using various technological tools (Ergen, et al., 2019; Joo et al., 2018; Koh et al., 2010; Lee & Tsai, 2010; Lin et al., 2013; Scherer & Siddiq, 2015; Schmid et al., 2021; Wright & Akgunduz, 2018). Researchers have also focused on the development of teachers' TPACK and its application because their TPACK and application levels were not sufficient (Aktaş & Özmen, 2020; Canbazoğlu-Bilici et al., 2016; Chai et al., 2011; Chang et al., 2015; Cheah et al., 2019; Jen et al., 2016; Lehtinen et al., 2016; Ocak & Baran, 2019; Sancar-Tokmak et al., 2014; Tondeur et al., 2019b).

1.3 How is TPACK developed in pre-service science teachers?

Researchers have used six different methods to develop the TPACK of pre-service teachers (PSTs), due to the complex relations among the components of TPACK. The first method is to have PSTs prepare technology-based lesson plans to ensure their TPACK development (Baran & Uygun, 2016; Dalal et al., 2017; Sancar-Tokmak et al., 2014; Sheffield et al., 2015). This method has the advantage of providing PSTs with practical experience in preparing lesson plans, but it has the disadvantage that PSTs often do not have an opportunity to apply these lesson plans in the classroom (Voogt et al., 2013). The second method removes this disadvantage by having PSTs prepare lesson plans and make presentations of these plans to their classmates and faculty (Chai et al., 2010; Jen et al., 2016; Koh et al., 2017; Lehtinen et al., 2016; Tokmak, 2013). However, this method can have the disadvantage that PSTs do not gain enough experience using new technologies they encounter. The third method is to have PSTs present TPACK-based lessons after they have had some training in new educational technologies and basic TPACK concepts (Çalik, Özsevgec et al., 2014; Durdu & Dağ, 2017; Koh & Divaharan, 2011; Niess, 2005). This method helps the PSTs to accept and use the new technologies. The fourth method is to benefit from peer-coaching in collaborative studies, through which the PSTs could gain certain skills with the support of their classmates and could realize their own deficiencies (Jang, 2010; Jang & Chen, 2010; Sancar-Tokmak et al., 2013). The fifth method is to have PSTs make presentations of TPACK-based lessons to real students in actual classrooms (Cheah et al., 2019; Lu & Lei, 2012; Ocak & Baran, 2019). This method provides advantages for PSTs in integrating information technologies into their lessons. However, it has the disadvantage that they may not consider and use new technology (Aktaş & Özmen, 2020). The sixth method includes information education, micro-teaching, and school practices that incorporate many of the advantages of the previous models (Aktaş & Özmen, 2020; Lee & Kim, 2014; Tondeur et al., 2019b).

1.4 Rationale for the study

Although researchers have conducted many studies to ensure the TPACK development of PSTs, some problems could not be overcome in those studies. These problems included that PSTs structured the teaching process as teacher-centered, although they planned it to be student-centered in technology-based lessons (Angeli & Valanides, 2005; Ocak & Baran, 2019; Swallow & Olofson, 2017), and they made learners passive listeners when they used technology in their lessons (Yeh et al., 2015b), and they changed the variables themselves in the simulation and did not allow learners to change them (Graham et al., 2009). Also, PSTs used technological tools to transfer information rather than supporting learners in constructing knowledge (Chai et al., 2011; Ocak & Baran, 2019), although interactive tools such as simulations are among the most preferred tools in learning science (Jang, 2010; Jang & Chen, 2010; Lehtinen et al., 2016; Ocak & Baran, 2019). Although most science PSTs have sufficient theoretical TPACK, they do not transmit this knowledge adequately in the actual classroom environment (Aktaş & Özmen, 2020; Angeli & Valanides, 2005; Cheah et al., 2019; Graham et al., 2009; Jen et al., 2016; Ocak & Baran, 2019).

This study focused on encouraging PSTs' TPACK development because developments in ICT affected how pre-service teachers learn about changing teaching methods. In the present study, researchers used the TPACK-Practical Course (TPACK-C), which consists of two stages, a training course and lesson-plan-micro-teaching, to ensure the development of science PSTs' TPACK and application abilities. Three important features of TPACK-C should contribute to the development of the PSTs' ability to apply their TPACK. The first is that the lecturer presented sample lessons as models in the training course stage. The second is that the PSTs prepared lesson plans to support learners in constructing knowledge using technological tools with worksheets. Worksheets are pieces of paper with problems or sometimes a computer screen with problems (Podolak & Danforth, 2013; Ransom & Manning, 2013). Worksheets include brief learning guides, directions, tips on using information resources, and blanks (Macmillan, 2004). The teacher gives the learners initial guidance on the subject that they need to research individually. Learners achieve their learning goals by solving these problems or following directions (Podolak & Danforth, 2013). Learners use the blanks on the worksheets to take notes, outline their research strategies, and formulate concepts (Macmillan, 2004). Making use of worksheets while carrying out learning activities with ICT tools supports the learning process (Sang et al., 2011). The advantages of worksheets include being student-centered, providing more flexibility and interactivity, and allowing students to follow the teaching process (MacMillan, 2004). The third feature is that PSTs received ongoing feedback through class discussions at the end of their lesson presentations. Therefore, this study aims to assess the performance of science PSTs in the TPACK-C. For this purpose, the research questions are as follows.

1. What are the improvements at the level of science PSTs' TPACK application after the TPACK training course?
2. What are the improvements at the level of science PSTs' TPACK application after the lesson-plan-micro-teaching stage?

2 Methods

2.1 Participants

In Turkey, PSTs receive training for 4 years in the teacher education program they are placed in with a central examination named the Higher Education Institutions Examination. The Turkish science teacher education program was organized as a common curriculum by The Higher Education Council. PSTs take mostly science content courses in the first two years, and they take science teaching methods courses in the last 2 years. They also take two basic computer courses to gain using technology skills. Moreover, they attend school applications to gain experience about student teaching in a real classroom in their senior year. There were not enough courses to associate the knowledge of content, pedagogy, and technology, also this knowledge was beginning to be associated in the third grade of the program. For this reason, this course was designed, and it was preferred to work with PSTs attending the third grade.

The participants in this case study were 46 PSTs (19 males; 27 females) who attended a special teaching methods course taught in the second semester of their 3rd year as they pursued an undergraduate science education degree in Turkey. Researchers selected them according to the convenient sampling method of participants who were easily accessible to increase the reliability of the study data (Canbazoğlu-Bilici, 2019; Fraenkel et al., 2012). This study preferred the convenient sampling because it was investigating in depth the TPACK development of PSTs. Because the first researcher could reach the participants more easily in his institution, this situation increased the reliability of the study. Furthermore, prior to the study, research permission was obtained from the Institution. The participants were told about the aims of the research, their data confidentiality have guaranteed, and giving consent to the use of their data that was obtained. Participation in the study was on a voluntary basis.

The ages of the PSTs range between 19 and 26, and the average age is 21.35. These PSTs had taken basic physics, chemistry, and biology courses in the previous years within the scope of their science teacher education program. They had also taken pedagogy courses such as teaching methods, science curriculum, learning psychology, and material development. In addition, they had taken basic computer courses and had years of using experience in office programs such as Word, PowerPoint, and basic information technologies skills such as email, social media, and Google. Of the PSTs, 35% had 1 to 3 years of using ICT experience, 28% had 4 to 6, 28% had 7 to 9, and 9% had 10 or more.

2.2 Implementation of the TPACK-C

Content of the course TPACK-C consisted of two stages; the training course and the lesson-plan-micro-teaching. The training course stage included the introduction of the TPACK concept and its components, the introduction of new technologies, and the creation of sample lesson presentations. In this stage, researchers primarily worked to enhance PSTs' TK by introducing the new technologies that they could use in science lessons and explaining TPACK and its applications. They also aimed to raise awareness among PSTs about the integrity of TPACK concepts and to associate TPACK concepts by making sample presentations and leading class discussions after the presentations.

The lesson-plan-micro-teaching stage included the preparation of TPACK-based lesson plans by the PSTs, presentations of their lesson plans to their classmates with micro-teaching, and discussions for feedback. The purposes of this stage were to deepen PSTs' TPACK and to gain practical skills. Table 1 provides more information about the content of the TPACK-C.

The education faculty carried out this study over a total of 12 weeks in a special teaching methods course. The classroom had some technological features, such as an interactive whiteboard, Internet-connected computers, laptop computers for every 2 PSTs, and mobile desks for collaborative study. First, PSTs organized themselves in pairs. Then, the researchers divided the 46-person class into two groups and implemented the course separately for each group.

Researchers implemented the course in two stages: the training stage and the lesson-plan-micro-teaching stage. In the training stage, the course lecturer (first author) introduced TPACK concepts; field-specific instructional technologies, including an interactive whiteboard, a document camera, animations, and simulations such as PHET, which is interactive and research-based for science education (https://phet.colorado.edu/); and held class discussions on the effective use of these instructional technologies in lessons. The lecturer allowed PSTs to use new technologies to gain experience. Then, the lecturer presented three sample lessons.

In the lesson-plan-micro-teaching stage, the PSTs developed TPACK-based lesson plans working in collaboration with their group. They were free to select their own subject, technology, and teaching method because the TPACK needed to teach one subject is not the same as that needed to teach another subject. Then, they presented their lessons to their classmates twice with micro-teaching and their lesson presentations were videotaped. After the PSTs' first presentation, the class discussed it based on the self-evaluation of the PST, and the evaluations of their classmates and instructor. The discussions focused on the strengths and weaknesses of PSTs' lesson presentations and what needed to be done to improve the presentation. PSTs then re-presented their lessons after they made some adjustments based on the critiques that emerged in the class discussion. A photograph taken during the PSTs' lesson presentation is given in Image 1.

2.3 Data sources

This study used *lesson plans* and *video recordings* of lessons as data sources. Researchers analyzed these data through the *rubric of TPACK-based learning environments*.

Lesson plans PSTs prepared lesson plans to present at the micro-teaching stage and revised them based on the experience gained during the presentation. PSTs reported their lesson designs and experiences after completing both presentations.

Table 1 The content of the TPACK-C

Stage (duration)	Aim	Weeks	Content	Data sources
Training Course (6 weeks)	To raise awareness about TPACK concepts To gain the ability to use ICT tools	Week 1	Introduction of TPACK concepts and components	
		Week 2	Introduction and use of instructional technologies such as interactive whiteboard and document camera	
		Week 3	Introduction and use of instructional technologies, including animations and simulations such as PHET, an interactive and research-based science simulation (https://phet.colorado.edu/), and discussions of their effective use	
		Week 4	Presentation of first sample lessons about the subjects of the *atom and its structure*. Use of 5E teaching methods and PHET simulations, interactive whiteboard, PowerPoint, and computer by PSTs. PSTs use a laptop with a technology-based worksheet developed by researchers. Lesson plan provided as supplementary material	
		Week 5	Presentation of second sample lessons about the subjects of *electromagnetism and the transformation of motion energy into electric energy*. Use of guided inquiry teaching methods and PHET simulations, video, PowerPoint, and computer by PSTs. PSTs use a laptop with a technology-based worksheet developed by researchers. Lesson plan provided as supplementary material	
		Week 6	Presentation of third sample lessons about the subjects of *nuclear energy*. PSTs use argumentations teaching methods and Internet, interactive whiteboard, and computer by PSTs	
Lesson-Plan-Micro-Teaching (6 weeks)	To deepen TPACK To gain practical TPACK skills	Week 7–12	Preparation of TPACK-based lesson plans by PSTs Presentation of their lesson plans with micro-teaching Discussion for feedback	1st lesson plans and video recordings 2nd lesson plans and video recordings

Video recordings Researchers videotaped the lesson presentations to observe PSTs' practical TPACK skills, to follow the development of their TPACK skills, and to enable them to monitor and evaluate themselves. Researchers asked the PSTs to watch the video recordings of their first presentations carefully and correct the deficiencies and mistakes in the second lesson presentation.

The rubric of TPACK-based learning environment and its development stages In this study, the researchers used *the rubric of TPACK-based learning environment* that they developed to analyze the lesson plans and video recordings to investigate the development of PSTs' practical TPACK skills. The analytical rubric includes 12 performance criteria and each criterion has five performance levels. The researchers systematically developed the rubric as described below.

Researchers selected the rubric items by considering the theoretical framework of the TPACK integrative model and adapting some items used by Canbazoğlu-Bilici et al. (2016), Koh (2013), and Ministry of National Education in Turkey [MoNE] (2017). They created the rubric items by adapting four items (2, 3, 6, and 8) from Koh (2013), 5 items (4, 5, 7, 9, and 12) from Canbazoğlu-Bilici et al. (2016), and three items (1, 8 and 11) from the teaching profession Turkey adequacy (MoNE, 2017). They preferred Koh (2013) and Canbazoğlu-Bilici et al. (2016) because of their emphasis on both TPACK's integrative model and constructivist learning environment. Also, the criteria of the measuring instruments used in these studies were consistent with the Turkey teaching profession qualifications. This study used the integrative TPACK model, which views TPACK as a component of the knowledge that teachers use throughout the lesson, not as different information forms. Therefore, researchers added two items to the rubric that the instruments of Canbazoğlu-Bilici et al. (2016) and Koh (2013) did not use but that the Turkey teaching profession qualifications (MoNE, 2017) did include. The two added criteria were classroom management for managing the learning and teaching process and guiding criteria for guiding students in reaching information by communicating with students (MoNE, 2017). Finally, they added the criterion of drawing students' attention because it is important to motivate learning in constructivist authentic learning environments to attract and sustain students' attention (Aktaş & Bilgin, 2015). Researchers obtained the opinions of three experts in science education who hold a Ph.D. on the 12 items and found the content validity to be sufficient. Appendix Table 4 provides the rubric of 12 items in total.

Researchers decided that the scoring should have five sub-performance levels that considered both usability and sensitivity characteristics. The performance never received a score of 0 and the best performance score was 4. Each numerical value in the rubric reflects a performance level based on the specified criteria. To determine the PSTs' performance levels on each item, while PSTs were presenting their lesson design, the first researcher took observation notes and evaluated each PSTs' performance according to the five levels as defined.

For example, the third item of the rubric, *constructing knowledge of students* was the level at which the students were structuring information such as transferring information or synthesizing information when performing technology-based course activities. The first researcher observed PSTs' presentations throughout the course and took notes to determine performance levels. Two researchers then

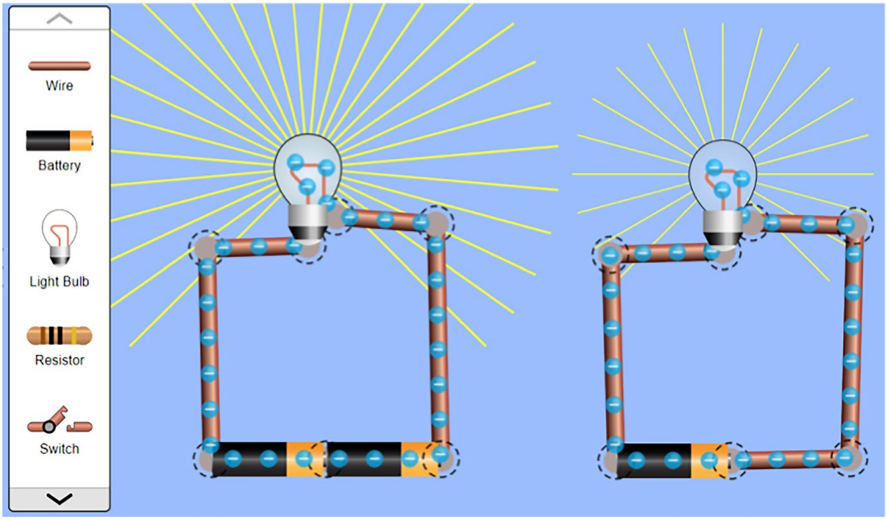

Fig. 2 The PHET simulation used by PST 13. https://phet.colorado.edu/tr/simulation/legacy/circuit-construction-kit-dc-virtual-lab (retrieved 2.08.2019)

Fig. 3 Part of the worksheet created by PST 13

Problem Statement: How do you change the brightness of the lamp?

Hypothesis: ....

First Variable (Number of Batteries)	Second Variable (Bulb Brightness)

Result: ....

met, divided the performances into categories, and created performance indicators. According to the observations, some of the PSTs made presentations using only PowerPoint. Some held topical discussions with classmates after using PowerPoint and video. Some used the simulations themselves. Some also allowed classmates to use simulations to access information and led them through worksheets to write down the information they had acquired. Figures 2 and 3 illustrate example simulations and worksheets. Thus, this item's indicators were: (1) PST (teacher) used PowerPoint or video to visualize the same information they were conveying, (2) PST had students (classmates) use PowerPoint or video to convey information different from that presented orally, (3) PST used simulations to construct information and product-focused expressions by students, and (4) PST had students use technologies to construct and explain information statements through personal information and experience. In evaluating the lesson presentations by the PSTs, researchers divided the performances on this item into levels as detailed in Table 2 and scored.

Researchers defined the performance levels for each item in the rubric as detailed in Appendix Table 5. They again consulted three experts to determine the scope validity of the developed rubric and revised the rubric based on their professional opinions.

2.4 Data analyses

This study collected a total of 40 lesson plans and 40 video recordings, consisting of the first and second presentations of each of the 20 groups. The lesson plans and their video recordings were analyzed through the rubric of the TPACK-based learning environment together. Researchers described the PSTs' performances using descriptive statistics such as arithmetic mean and standard deviation and compared the differences between the first and second presentation scores by determining the percentage of change and using the Wilcoxon signed-rank test.

Reliability of the assessment Two researchers assessed the data to increase the reliability of the assessment. The two researchers first met and scored the data of one group together. Then, they scored the data of the other groups separately. After completing the assessments, they calculated the Kendall's W coefficient as 0.962 to determine the agreement between the two researchers' scores. To determine the internal consistency between the items in the rubric, the researchers calculated the Cronbach's alpha coefficient as 0.942 by using the scores of both researchers. Finally, the researchers met again to compare their scores, and they reviewed and re-scored with a consensus the performances that they initially scored differently. This study also used lesson plans and video recordings for observation to ensure validity and triangulation of data.

3 Findings

3.1 PSTs' TPACK application levels after the TPACK training course

Table 3 presents descriptive statistics of arithmetic means, standard deviations, percentage changes, and significant differences in the scores between the first and second presentations by the PSTs.

Table 3 shows that PSTs in the first lesson presentation had the highest levels of performance in the items *accuracy of the given information/concepts* ($X=3.35$; $SD=0.67$), *considering students' levels* ($X=3.35$; $SD=1.09$), and *appropriateness of technologies used* ($X=3.35$; $SD=1.09$) while teaching science with technology. According to the average scores of the PSTs, they presented the concepts/information in the subject of science as a whole by associating them with the objectives and with each other. Also, the PSTs selected and used the appropriate technologies such as PowerPoint, simulation, video, or Internet resources to support the students' meaningful learning in accordance with the

Table 2 Performance levels on the third rubric item

Item	Constructing knowledge of learners	
Performance levels	Teacher used technology to transfer concepts rather than to make sense/meaning	0
	Teacher used technology to visualize, embody, or illustrate the same information presented by PowerPoint presentation or showing video	1
	Teacher made students use technology to support and to make sense of slightly different information from what the teacher presented by PowerPoint presentation or showing video and discussing	2
	Teacher made students synthesize information by using technology to construct verbal, visual, conceptual, or product-focused expressions	3
	Teacher made students use technology to express personal information and experience through written, verbal, visual, conceptual, and product-focused expressions	4

Table 3 Descriptive statistics of the scores obtained from the presentations of PSTs

	Items	Levels						Item		Change		Sig. Diff
	When teaching science subject with technology;	Pres	0	1	2	3	4					
			n (%)	n (%)	n (%)	n (%)	n (%)	X	SD	%	p	ES (r)
1	Drawing students' attention	First	7 (35)	3 (15)	3 (15)	2 (10)	5 (25)	1.75	1.65	−11.43		
		Second	8 (40)	4 (20)	1 (5)	3 (15)	4 (20)	1.55	1.64			
2	Providing active participation of students	First	–	4 (20)	14 (70)	2 (10)	–	1.9	0.55	21.05	0.011*	0.4
		Second	–	1 (5)	12 (60)	7 (35)	–	2.3	0.57			
3	Constructing knowledge of students	First	–	2 (10)	10 (50)	6 (30)	2 (10)	2.4	0.82	10.42		
		Second	–	1 (5)	8 (40)	8 (40)	3 (15)	2.65	0.81			
4	Appropriateness of chosen teaching methods	First	–	5 (25)	–	7 (35)	8 (40)	2.9	1.21	18.97	0.004**	0.46
		Second	–	1 (5)	3 (15)	2 (10)	14 (70)	3.45	0.94			
5	Appropriateness of technologies used	First	–	2 (10)	3 (15)	1 (5)	14 (70)	3.35	1.09	8.96		
		Second	–	–	2 (10)	3 (15)	15 (75)	3.65	0.67			
6	Appropriate use of selected technology for its purpose	First	–	–	6 (30)	13 (65)	1 (5)	2.75	0.55	1.82		
		Second	–	–	5 (25)	14 (70)	1 (5)	2.8	0.52			
7	Accuracy of the given information/concepts	First	–	–	2 (10)	9 (45)	9 (45)	3.35	0.67	13.43	0.007**	0.43
		Second	–	–	1 (5)	2 (10)	17 (85)	3.8	0.52			
8	Considering students' levels	First	–	2 (10)	3 (15)	1 (5)	14 (70)	3.35	1.09	4.48		
		Second	–	2 (10)	2 (10)	–	16 (80)	3.5	1.05			
9	Leading students to use higher–level thinking	First	–	1 (5)	11 (55)	6 (30)	2 (10)	2.45	0.76	10.2		
		Second	–	–	9 (45)	8 (40)	3 (15)	2.7	0.73			
10	Providing class management	First	–	9 (45)	11 (55)	–	–	1.55	0.51	9.68		
		Second	–	6 (30)	14 (70)	–	–	1.7	0.47			
11	Guiding	First	–	8 (40)	8 (40)	3 (15)	1 (5)	1.85	0.87	48.65	0.002**	0.5
		Second	–	1 (5)	6 (30)	10 (50)	3 (15)	2.75	0.79			

Table 3 (continued)

	Items	Levels						Item		Change		Sig. Diff
	When teaching science subject with technology;	Pres	0	1	2	3	4					
12	Making assessment and evaluation	First	–	1 (5)	15 (75)	1 (5)	3 (15)	2.3	0.8	13.04		
		Second	–	–	13 (65)	2 (10)	5 (25)	2.6	0.88			
	Total	First						29.9	5.21	12.04	0.000***	0.56
		Second						33.5	5.07			

Pres. Presentation, *X* arithmetic mean, *SD* standard deviation, *Sig*. *Diff.* significant difference**,** *ES* effect size

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

subject and teaching method. Moreover, PSTs selected and used these technologies by considering the learners' characteristics such as objectives, misconceptions, and learning difficulties and enabled individual learning.

Table 3 also shows that PSTs had a medium level of performance in the items *making assessment and evaluation* (X = 2.30; SD = 0.80), *providing active participation of students* (X = 1.90; SD = 0.55), *guiding* (X = 1.85; SD = 0.87), and *drawing the students' attention* (X = 1.75; SD = 1.65) while teaching science with technology. In the item *making assessment and evaluation*, PSTs made a traditional assessment (such as multiple-choice, true–false, filling-gap) that was appropriate for the objectives. The highest level in this item by rubric was to make a complementary assessment (such as interactive technological tools, structured grid, branched tree) with learners for critical objectives. In the item *providing active participation of students*, PSTs engaged their classmates in approximately half of the lessons by using simulation activities or using the Internet during the exploration phase of the lesson. In the exploration phase, for example, the classmates encountered a problem situation (in the worksheet given in Fig. 3) about the factors affecting the brightness of a lamp. The classmates initially hypothesized that the number of batteries would affect the lamp brightness and accordingly designed an experiment using the PHET simulation (Fig. 2). They filled in the blanks on the worksheets to record the results they reached. Those who established the correct hypothesis and reached the correct result moved on to other problem situations, and those who did not reach the correct result formed a new hypothesis and continued to use the simulations. The PSTs prepared the worksheets in accordance with the relevant simulation for the classmates to structure their knowledge. PSTs also used worksheets to ensure that classmates used technological tools and guided them to reach the information in the exploration phase. They could not use it in other phases of the lesson. The highest level in this item was to activate learners using technology in most of the lesson by using simulation during the exploration phase and interactive evaluations during the evaluation phase or conducting research on the Internet. In the item *guiding*, PSTs directed their classmates to understand the concepts by distributing worksheets and using the question-and-answer method. The highest level in this item was to guide learners in structuring information by giving tips and feedback to the learners in all parts of the classroom. In the item *draw students' attention*, PSTs started the lesson by using draw-attention activities that were appropriate for the objectives without involving the classmates in the activities. The highest level in this item was to start the lesson by using technological tools to involve the learners and draw their attention with activities appropriate for the objectives. In these four items, the PSTs performed at a moderate level and should have developed in relation to these items.

The least successful item for the PSTs was *providing classroom management* (X = 1.55; SD = 0.51) while teaching science with technology. PSTs tried to involve their classmates in the activities and provide classroom management with directions such as "we are doing this now"; however, they did not engage the classmates who did not attend the extracurricular activities. The PSTs were inadequate in providing classroom management while teaching science subjects with technology, and they needed to improve in this area.

3.2 Development of PSTs' TPACK application levels after the TPACK-C

When researchers compared the second presentations of the PSTs with the first presentations as a percentage change, the largest increase was in the *guiding* item (48.65%), which was also statistically significant ($Z = -3.140$; $p < 0.01$; $r = 0.50$). The average scores of the PSTs on this item increased from a medium level to a much higher level. While PSTs guided their classmates by distributing worksheets and directing them to concepts with question-and-answer methods in their first presentations, they guided their classmates to acquire information by giving tips and feedback in addition to using questions and answers in the second presentation.

For example, PST 13 used the 5E model and the PHET simulation illustrated in Fig. 2 to present "the factors affecting the brightness of the lamp" in the electrical unit for the 6th grade. PST 13 also used the worksheet given in Fig. 2 to activate their classmates and to provide them with the opportunity to take notes. While PST 13 stood in front of the class and guided the classmates with questions and answers in the first presentation, during the second presentation, they guided their classmates for a certain period and gave some hints about what, why, and how to do in the teaching–learning process, sometimes with gestures and facial expressions and sometimes by asking new questions. PST 13, when classmates were unable to answer, guided them by hinting with questions such as "What elements are in a simple circuit?", "If you change them, will the brightness change?", "What should be equal in both circuits for the correct result?" and sometimes with tips such as confirming the right hypothesis with head motions, mimes, and gestures.

In the second presentations, the second-largest increases were in the items *providing active participation of students* (21.05%), which was statistically significant ($Z = -2.530$; $p < 0.05$; $r = 0.40$), and *appropriateness of chosen teaching methods* (18.97%), which was also statistically significant ($Z = -2.887$; $p < 0.01$; $r = 0.46$). In the item *providing active participation of students*, PSTs started to activate their classmates by using technology in most of the lessons through interactive evaluations or using the Internet during the evaluation and explore phases of the lesson. In the item *appropriateness of chosen teaching methods*, PSTs began to use appropriate activities for the stages of the teaching method and used appropriate teaching methods for the objectives.

For example, PST 8 had used the JIGSAW method and the simulation illustrated in Fig. 4 when presenting the "digestive system organs and their functions" subject for the 7th grade. While PST 8 used the simulation in the exploration stage and evaluated classmates' knowledge with multiple-choice questions in the assessment stage in the first presentation, PST 8 used the interactive matching simulation illustrated in Fig. 5 during the assessment stage in the second presentation. Thus, classmates became more active and the time that learners were active with technology during the lesson increased. In addition, the problems experienced in the teaching methods' stages of creating home and expert groups when using the jigsaw method in the first presentation did not re-occur in the second presentation.

The item *accuracy of given information/concepts* (13.43%) showed improvement, which was statistically significant ($Z = -2.714$; $p < 0.01$; $r = 0.43$), as did the item *making assessment and evaluation* (13.04%), which was not statistically significant.

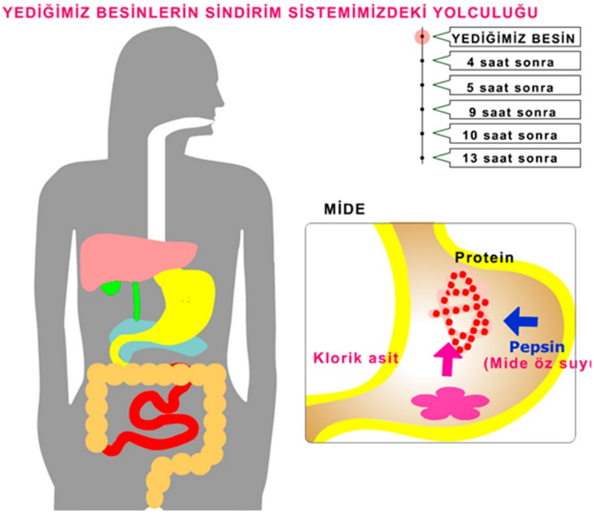

Fig. 4 The simulation PST 8 used to construct knowledge by classmates. https://www.fenokulu.net/portal/Sayfa.php?Git=KonuKategorileri&Sayfa=KonuDeneyListesi&baslikid=31&DeneyNo=1285 (retrieved 2.08.2019)

Fig. 5 The simulation PST 8 used to evaluate knowledge gained by classmates. https://www.fenokulu.net/portal/Sayfa.php?Git=KonuKategorileri&Sayfa=KonuDeneyListesi&baslikid=31&DeneyNo=1207 (retrieved 2.08.2019)

Image 1 A photograph taken during the PSTs' lesson presentation

In the *accuracy of given information/concepts* item, PSTs focused more closely on the relevant lesson objectives in their second presentations, while in their first presentations, they sometimes presented concepts and information about objectives for the upper grade or next-lesson objectives, thus exceeding the scope of the one-hour lesson. The number of PSTs who presented the subject as a whole and fluently by associating the concepts/information in the science subject content with the objectives increased in the second presentation. In the item *making assessment and evaluation*, PSTs made traditional assessments of the objectives in their first presentations, but more of them made contemporary assessments for the critical objectives in the second presentations. This development improved both the fluency and integrity of the lesson and the critical objectives.

The least improvement was in the items *constructing knowledge of students* (10.42%), *leading students to use higher-level thinking skills* (10.20%), *providing classroom management* (9.68%), and *appropriateness of technologies used* (8.96%). The improvement in these items was not significant although their average scores increased. In the item *providing classroom management*, in which the PSTs performed poorly in the first presentations, they showed a moderate performance level by striving for the class to act together in the second presentations.

On the other hand, the PSTs exhibited a lower performance (−11.43%) in the second presentation than in the first presentation regarding the item *draw students' attention* to a science subject by using technology. For this item, the standard deviation was quite large ($SD = 1.65$), and this result reveals that there were PSTs who had started the lesson with technology, as well as PSTs who had started the lesson without these activities. The PSTs tended not to start using technology and tended to start the course directly.

Considering the total score for the TPACK application level of the PSTs in Table 3, the PSTs had an average score of 335 ($SD = 5.07$) in the second presentation, while in the first presentation the average score was 29.9 ($SD = 5.21$). Comparing the total score averages reveals a statistically significant increase of 11.87% in the second presentation ($Z = -3.523$; $p < 0.001$; $r = 0.56$). These increases had a moderate effect value ($0.3 < r < 0.8$). Therefore, the training course and lesson-design-micro-teaching stages were effective in increasing the TPACK application performance of PSTs.

4 Discussion

In this study, which assesses the performance of science PSTs in a TPACK-Practical Course, researchers examined PSTs' TPACK levels in the lesson-design-micro-teaching stage after they participated in the training course. Researchers used a rubric of the TPACK-based learning environment that they developed to assess the PSTs' TPACK levels. The findings revealed that PSTs' TPACK application levels increased in overall score and especially in the items *guiding, providing active participations of students, making assessment and evaluation, appropriateness of chosen teaching methods,* and *accuracy of the given information/concepts* while teaching science subjects with technology. These findings are consistent with the findings of previous studies (Akyuz, 2018; Guzey & Roehrig, 2009; Jang & Chen, 2010; Maeng et al., 2013; Yeh et al., 2015b). There are several possible reasons for this increase.

The first reason is the use of technological tools with worksheets. In this study, the researcher (lecturer) used the simulations with worksheets while presenting the sample lessons. He also encouraged the PSTs to use worksheets containing problem situations, blanks, and directions for learners (Fig. 3). The learners use the worksheets to take notes while using technological tools and fill them in to acquire information. PSTs' classmates encountered a problem situation in the worksheet. They proposed a hypothesis to solve the problem and wrote it on the worksheet. Then, they set up an experiment using the PHET simulation or other technological tools to test the hypothesis. They filled in the blanks on the worksheets with the results of their experiments. PSTs used worksheets to activate their classmates using technological tools and to guide them in acquiring the information. This approach yields student-centered learning because the selected simulations allow the learners to experiment, and classmates acquired the information themselves with the instructions in the worksheets. That is, the worksheets created a student-centered learning process by creating tasks in students' minds and activating them. Thus, using worksheets contributes to the solution of the problem of making teaching student-centered in technology-based lessons (Angeli & Valanides, 2005; Ocak & Baran, 2019; Swallow & Olofson, 2017). Too often, teachers make learners passive listeners (Yeh et al., 2015b) and change the variables themselves in the simulation rather than allowing learners to change them (Graham et al., 2009).

The second reason is the introduction of new technological tools such as interactive whiteboard and simulations that followed sample lesson presentations. Many PSTs are not familiar with technological tools such as interactive whiteboards and simulations (Hechter, 2012). In this study, the PSTs increased their TK and had the opportunity to apply this knowledge in the training course. After the PSTs were introduced to new technologies, they realized that these technologies make their job easier and they could use these technologies at different stages of engagement, exploration, and assessment. They also experienced these technologies and improved their technical skills. PSTs learned that they could more easily explain some science concepts that were difficult to explain with traditional methods by using technology-based tools such as animations and simulations

(Jang & Chen, 2010). Observing the lecturer's sample lessons helped them determine the various technological tools and teaching methods that they could use in their teaching. This experience led them to learn how to use these technologies in lessons and be more successful in integrating them into their plans. Previous research has demonstrated that the use of ICT tools in classrooms increased when PSTs learned their use and became aware of their convenience to the classroom environment (Irmak & Yılmaz-Tüzün, 2019; Jen et al., 2016; Koh & Frick, 2009; Tokmak, 2013). Providing training to PSTs about new technologies increases their TPACK levels (Dalal et al., 2017; Koh & Divaharan, 2011; Lehtinen et al., 2016; Tondeur et al., 2019a, 2019b). Previous studies revealed that TPACK application skills of in/pre-service teachers increased when they practiced with ICT tools in the classroom (Chai et al., 2010; Dalal et al., 2017; Irmak & Yılmaz-Tüzün, 2019; Jen et al., 2016; Koh & Divaharan, 2011). Researchers have also stated that technology-based education and the role model of the instructor have increased the PSTs' TPACK development levels (Aktaş & Özmen, 2020; Chang et al., 2015; Cheah et al., 2019; Guzey & Roehring, 2009; Lee & Kim, 2014; Tondeur et al., 2019a, 2019b). In this study, unlike previous studies, the PSTs were informed about new technologies, gained experience, and observed sample lesson presentations on different science topics containing various technological tools including the use of PHET simulations, the Internet, laptops, and interactive whiteboards, and teaching methods such as 5E, guided inquiry, and argumentation. The diversity in teaching methods and technological tools has increased the PSTs' TPACK levels by enabling classmates to acquire information in science subjects, choose technologies for critical objectives, and follow the correct steps in methods. Selecting and using appropriate technologies for subject and context facilitated learners' inquiry activities and activated them (Maeng et al., 2013).

The third reason is the use of classroom discussions. PSTs made their lesson presentations twice with micro-teaching, and they participated in classroom discussions of their performance after the first presentation. In these discussions, researchers and their classmates made suggestions to the PSTs on all rubric criteria. Thus, PSTs had the opportunity to correct themselves in the second presentation. One reason for the PSTs to choose the appropriate technologies may have been that these discussions affected their cognitive structure. Agyei and Keengwe (2014) found that reviewing lesson plans positively influenced PSTs' TPACK development, as it allowed them to review what they would do in their guidance and active engagement practices and generate new ideas. As classroom environments are becoming more student-centered, remaking lesson presentations allows PSTs to reorganize their use of technology to engage learners more actively and have them participate more actively in the lesson. Feedback made the PSTs aware of their misconceptions and where they were missing information (Chang et al., 2015; Sancar-Tokmak et al., 2014). These results support the findings of previous studies that the TPACK development of in/preservice teachers improved when they made lesson presentations and received pedagogical or technological support (Cheah et al., 2019; Sancar-Tokmak et al., 2014; Tokmak, 2013). Baran et al. (2019) stated that PSTs' TPACK development was most influenced by strategies such as seeing role models, recognizing the contribution of technology to education, and discussing the difficulties they encountered in making technology-based lesson presentations in the classroom.

On the other hand, there was a decline in the item *drawing students' attention*. One of the possible reasons for this result is that PSTs need to make more efforts to use technology in accordance with teaching methods and activities. Another is that a 12-week course does not provide enough time because the development of TPACK is a time-consuming process. Özgün-Koca et al. (2011) found that short-term studies were not enough to develop greater TPACK in pre-service teachers. Tseng et al. (2019) found that English pre-service teachers were having difficulty in planning activities to attract students' attention while preparing lesson plans, and they especially had difficulty in preparing activities to keep students' attention in the later sections of the lesson. Dalal et al. (2017) found that pre-service teachers had the most difficulty in preparing lesson plans that activated students by using technology in the classroom to attract students' attention. These findings demonstrate that there is an inherent difficulty in attracting and retaining student attention.

4.1 Limitations of the study

The findings of this study are subject to some limitations. First, because the participants were PSTs chosen according to the convenient sampling method, the generalizability of the findings may be lower than for participants chosen through random sampling. Second, PSTs did not make presentations in a real classroom but in a classroom about teaching methods at the university. There are inevitably differences between presenting to a real classroom and presenting to classmates. For this reason, it would be useful to evaluate the PSTs' practices in real classrooms. Third, the lesson-plan-micro-teaching practices were carried out by groups of two. This practice may have led to more positive results because the PSTs supported each other. However, this support is also helpful in increasing TPACK application skills because classmates learn new things from each other. Fourth, the researcher emphasized in the training course that PSTs should conduct lesson presentations with worksheets. The literature is clear that worksheets are an important factor in activating learners and creating student-centered learning environments. Moreover, the realization of real classroom experiences for the PSTs in the continuation of TPACK-C will have different results in terms of TPACK application levels. Besides, the statistics used while developing the rubric can be considered as a limitation.

5 Conclusion

In this study, the TPACK-C had positive effects on PSTs' TPACK application skills. Encouraging PSTs to use technological tools with worksheets helped create student-centered classrooms where learners are active participants and help to structure knowledge. In addition, classroom discussions helped PSTs to improve their TPACK application skills. As a result, the use of a technology-supported training course with a lesson-plan-micro-teaching method helps to increase the PSTs' TPACK application skills. Also, it would be beneficial to more trial and developed further the rubric with more participants and to cover different pre-service teachers in different content fields in future study.

Appendix

Table 4 Definitions and indicators of TPACK performance criteria

No	TPACK performance criteria	Definitions	Indicators
When teaching science subjects with technology;			
1	Drawing students' attention	Using effective presentation methods to draw the students' attention to the subject using technological tools	√Draw-attention activities harmonized with the objectives √Draw-attention activities ensured students' participation using technology √Draw-attention activities used multiple sensory technologies
2	Providing active participation of students	How busy the students are with technology activities in learning subject concepts	√Discussions presented concepts through video or PowerPoint √Students discovered concepts using the web or simulations √Teacher used technological tools to assess whether students learned the concepts √Teacher used technological tools to reflect students' personal experiences about learning concepts
3	Constructing knowledge of students	At what level are the students structuring information such as transferring information or synthesizing information when performing technology-based course activities	√PowerPoint or video visualized the same information statements presented by teacher √Students used PowerPoint or video to make sense of information statements different than those presented by teacher √Students used simulations to construct information and product-focused expressions √Students used technologies to construct and explain information statements through personal information and experience

Table 4 (continued)

No	TPACK performance criteria	Definitions	Indicators
4	Appropriateness of chosen teaching methods	Whether the teaching method chosen to teach subject concepts using technology is appropriate to the subject and technological tools and whether the method is used correctly	✓The method was appropriate for the concepts of the subject taught with technology ✓The method was appropriate for the steps and the outcomes ✓The method ensured the participation of students ✓The method supported students' understanding
5	Appropriateness of the technologies used	Whether the technological tools chosen to teach the subject concepts increase the meaning of the subject concepts	✓Teacher used technologies such as PowerPoint, video, simulations to teach science subjects ✓Teacher used appropriate technologies for the issue and teaching method activities ✓Teacher used appropriate technologies to support students' understanding
6	Appropriate use of selected technology for its purpose	The purpose of using the technological tools chosen to teach the subject concepts	✓Technologies represented problems ✓Technologies presented real-life events and examples ✓Students used technologies to explore real-life events and problems ✓Students used technologies to find solutions to real-world events and problems
7	Accuracy of the given information/concepts	How accurate and up to date the curriculum, concepts, and content of the technological tools chosen are to teach the subject concepts	Teacher gave scientific definitions of concepts correctly ✓Teacher related the concepts were to the objectives ✓Teacher presented the concepts in the science issue as a whole and fluently related them with objectives and each other

Table 4 (continued)

No	TPACK performance criteria	Definitions	Indicators
8	Considering students' levels	Whether students' preconceptions, misconceptions, and learning difficulties are taken into consideration in the selection of technological tools used to teach science concepts and whether they give opportunities for individual learning	✓Teacher included all lesson objectives but not more ✓Teacher considered students' pre-knowledge, misconceptions, and learning difficulties ✓Teacher chose technologies to provide opportunities for individual learning
9	Leading students to use higher-level thinking skills	The level of thinking skills that the students use while performing the selected technological activities to teach the subject concepts	✓Teacher used skills such as question-and-answer, discussion, research, and problem-solving to perform the selected technological activities to teach the subject
10	Providing classroom management	The activities of the teacher to keep the students engaged in course activities or to prevent them from being engaged in extra-curricular activities while teaching subject concepts using technology	✓Teacher used verbal warnings such as "Are you listening? Let us listen." with students who were not engaged in lesson activities ✓Teacher used simultaneous activities with all students ✓Teacher used facial expression and body movement or asking questions to draw the attention of students who were not engaged in lesson activities ✓Teacher gave new duties to engage the students who were not engaged in lesson activities
11	Guiding	The teacher's guidance helps students to understand the desired concepts while teaching subject concepts using technology	✓Teacher used worksheets, tips, and feedback when students used technology ✓Teacher directed the students to the activities ✓Teacher walked around the classroom to direct students ✓Teacher performed these activities during the lesson

Table 4 (continued)

No	TPACK performance criteria	Definitions	Indicators
12	Making assessment and evaluation	The technology-based measurement and evaluation activities used to determine whether students understand the desired concepts after the subject concepts are taught	✓Teacher met critical objectives in assessment activities ✓Teacher preferred process-based assessment techniques rather than product-based ✓Teacher ensured students' participation in the assessment process ✓Teacher used technology-based assessment activities

Table 5 Rubric for teacher performance and performance levels in a TPACK-based learning environment

Performance	Definition of Performance Levels				
	0	1	2	3	4
When teaching science subjects with technology;					
Drawing students' attention	Teacher performed no attention activities	Teacher performed attention activities with objects that were partially appropriate	Teacher performed appropriate attention activities with objects	Teacher performed appropriate attention activities with objects with the students	Teacher performed appropriate attention activities with objects with the students using technology
Providing active participation of students	Students explored the subject passively; teacher merely read the PowerPoint presentation or showed a video	Students used technology (PowerPoint presentation or video consisted of debates) to learn the subject	Students participated using technology and activities to learn approximately half of the lesson (using web resources or simulations to discover)	Students participated using technology to learn most of the lesson (in many stages, such as discovering, assessing, searching on the web)	Students participated using technology to learn nearly the whole of the lessons and conducted discussions to reflect their personal experiences (hypothesize and testing)
Constructing knowledge of students	Teacher used technology to transfer concepts rather than to make sense/meaning	Teacher used technology to visualize, embody, or illustrate the same information presented by PowerPoint presentation or showing video	Teacher made students used technology to support and to make sense of slightly different information from what the teacher presented by PowerPoint presentation or showing video and discussing	Teacher made students synthesized information by using technology to construct verbal, visual, conceptual, or product-focused expressions	Teacher made students used technology to express personal information and experience through written, verbal, visual, conceptual, and product-focused expressions
Appropriateness of chosen teaching methods	Teacher taught science subjects with technology without using a certain method	Teacher used inappropriate method with objectives	Teacher used a certain method even if partially appropriate steps with objectives were lacking	Teacher used a certain method even if appropriate steps with objectives were lacking	Teacher used appropriate activities with a certain method that is appropriate to the objectives, activating students and supporting their understanding

Table 5 (continued)

Performance	Definition of Performance Levels				
	0	1	2	3	4
Appropriateness of the technologies used	Teacher used technologies that were not suitable for the subjects	Teacher used limited technology for the subject (like PowerPoint presentation, video) that was not particularly appropriate	Teacher used limited technology (like PowerPoint presentation or video) that was particularly appropriate for the issue and teaching method	Teacher used several and different (PowerPoint presentation + simulation) technologies that were appropriate for the issue and particularly appropriate for the teaching method (even if some method steps were inappropriate)	Teacher used several and different technologies (PowerPoint presentation, simulation, web) that were appropriate for the issue and teaching method and supported students' understanding
Appropriate use of selected technology for its purpose	Students did not use technology to resolve learning deficit or teacher was not aware of their knowledge related to the subject	Students used technology without representations of real-life events and problems	Students used technology to represent their real-life events and examples related to the issue	Students used technology to research real-life events and problems	Students used technology to find solutions to real-world events and problems related to the issue
Accuracy of the given information/concepts	Some of the objects and information were not true	The information and concepts were true	The information and concepts were related to the objectives	The information and concepts were related to the objectives and each other	The information and concepts were presented as a whole and fluently related to the objectives and each other
Considering students' levels	Teacher did not consider objectives and students' pre-information, misconceptions, and learning difficulties	Teacher considered objectives but did not consider students' pre-knowledge, misconceptions, learning difficulties	Teacher considered both objectives and students' pre-knowledge, misconceptions, learning difficulties	Teacher chose technologies by considering objectives and students' pre-knowledge, misconceptions, and learning difficulties	Teacher chose technologies to provide opportunities for individual learning

Table 5 (continued)

Performance	Definition of Performance Levels				
	0	1	2	3	4
Leading students to use higher-level thinking skills	Teacher simply answered students' questions	Teacher allowed students both to answer questions and to express themselves	Teacher made lessons based on exchanging information through discussions	Teacher encouraged students to query their thoughts with questions related to critical objectives	Teacher led students to use higher-level thinking skills with example events and problem situations
Providing classroom management	Teacher made lessons without considering what students made activity in lesson	Teacher provided class management by verbally warning students who were not dealing with lesson activities with prompts like "Are you listening? Let us listen."	Teacher provided class management with guidance such as "Now we are doing this" but did not intervene with students who were not dealing with lesson activities, using phone, or not attending lessons	Teacher provided class management through facial expression, body movements, or asking questions to students who were not dealing with lesson activities	Teacher provided class management by assigning new duties and engaging students who were not dealing with lesson activities
Guiding	Teacher made lessons without considering students and stayed in front of the board	Teacher led students to engage the concepts with questions and moved in front of the board	Teacher led students to engage the concepts by distributing worksheets and by asking questions	Teacher led students to engage the concepts by giving clue and feedback to students who do not patch their works	Teacher led all students to engage the concepts by giving clues and feedback and by walking around the class
Making assessment and evaluation	Teacher did not make an evaluation	Teacher made an evaluation that covered some section of the objectives or other objectives	Teacher made traditional assessment and evaluation activities that were appropriate to the objectives	Teacher made alternative assessment and evaluation activities that were appropriate to the critical objectives	Teacher and students made alternative assessment and evaluation activities that were appropriate to the critical objectives

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All the procedures performed in the study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Prior to the study, ethical approval was obtained from the Institution. The participants were told about the aims of the research, and giving consent to the use of their data that was obtained. Participation in the elective course and the study was on a voluntary basis.

Consent for publication Aktaş, İdris. & Özmen, Haluk hereby declare that we participated in the study and in the development of the manuscript titled Assessing the Performance of Science Pre-Service Teachers in a TPACK-Practical Course. We have read the final version and give our consent for the article to be published in Education and Information Technologies.

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