JPII 11(3) (2022) 420-432

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

PROJECT-BASED SCAFFOLDING TPACK MODEL TO IMPROVE LEARNING DESIGN ABILITY AND TPACK OF PRE-SERVICE SCIENCE TEACHER

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DOI: 10.15294/jpii.v11i3.38566

Accepted: August 31st 2022. Approved: September 29th 2022. Published: September 30th 2022

ABSTRACT

Learning design abilities and TPACK are very much needed by prospective science teachers to prepare science learning in the 21st century. The specific objectives of this research were to analyze the improvement of the learning design ability and TPACK possessed by pre-service science teachers after taking lectures with the Project-Based Scaffolding TPACK (PBST) model and analyze the correlation between TPACK and learning design abilities. The research used was quantitative research with non-equivalent control group design. The samples selected were 4 classes of pre-service science teachers who were taking Science Learning Strategy and Design courses. The instrument used in this study consisted of a lesson plan assessment sheet and a TPACK evaluation test. Data analysis used was independent t test, N-Gain test, and bivariate correlation test using SPSS. The results showed that the experimental class obtained an increase in the high category on learning design ability and the medium category on TPACK. After being given PBST model treatment in the experimental class, there is a significant difference in the learning design ability and TPACK between the experimental and control classes. In addition, the results also show that there is a correlation between TPACK and learning design ability. The PBST model is expected to be a solution offer to prepare pre-service science teachers at higher education in line with the demands of 21st century learning based on technology integration.

Keywords: learning design ability; pre-service science teacher; project-based scaffolding TPACK; TPACK

INTRODUCTION

The development of Information and Communication Technology (ICT) in the 4.0 Industrial Revolution (4IR) spurred world developments involving educational scenario technology (Shafie et al., 2019). The form of change is that learning for 21st century students is very different from previous generations of students. Today's students are highly dependent on technology (Elam & Gibson, 2007; Lemley et al., 2014) because their lives are surrounded by technology, and they learn a lot with technology around them. The Partnership for 21st Century Skills (2008; 2009) states that important skills in entering 21st century life include critical thinking skills, problem solving, communication, collaboration, mathematical skills, creativity, and fluency in ICT. Rotherham & Willingham (2009) argue that a student's success depends on these 21st century skills. Schools are required to be able to prepare students to enter the 21st century. This of course demands that teachers can no longer rely solely on the lecture method in front of the class with a blackboard in learning (Shafie et al., 2019). Teachers must be able to have teaching skills that will help students face the global challenges of the 21st century.

Science is one of the subjects in the 21st century. Entering the 21st century, the application of technology and new ideas in the process and manufacture of new products is developing

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very rapidly. Of course, knowledge of this must be known by students in today's era. In this case, it is very important the role of science teachers to facilitate students to follow technological developments and get various kinds of learning resources that are increasingly varied to allow students to explore teaching materials (Wolters, 2010). Science teachers today must be aware of the demands of 4IR, so that the way of teaching in the classroom must change according to 21st century learning (Hussin, 2018; Shafie et al., 2019). This is where 21st century skills must take place in today's education. Students become relevant in the workplace, if science teachers train them with the 21st century skills demanded in 4IR. However, students will not be able to develop these skills if the teacher himself has less knowledge in training these skills to students (Shafie et al., 2019).

In line with the above demands, teachers are not only experts in content, but also must know teaching pedagogy as emphasized by Shulman (1986) within the framework of Pedagogical Content Knowledge (PCK). Meanwhile in the 21st century, it is important for science teachers to have good knowledge in integrating technology into teaching. Therefore, they need to have knowledge of technology, as proposed by Mishra & Koehler (2006) as a framework for Technological Pedagogical Content Knowledge (TPACK). Teaching in the 21st century is no longer the same because teaching priorities have shifted. To ensure that students can develop, practice, and apply 21st century skills, science teachers must have knowledge and competence in teaching and training 21st century skills to students.

TPACK is a theoretical framework in understanding teacher knowledge required for effective technology integration by introducing the relationship and complexity between the three basic components of knowledge (technology, pedagogy, and content) (Mishra & Koehler, 2006; Koehler & Mishra, 2008). TPACK describes the knowledge that is important for teachers in the millennial era to integrate technology in their teaching process (Zhang, 2011). It involves the interaction between technology, pedagogy, and content that are separate from each other, and this framework emphasizes the interaction between these three aspects and other forms of knowledge (Koehler et al., 2014).

TPACK framework articulates complex forms of knowledge and recognizes that teachers need to create lessons that promote technology-based learning (Mishra & Koehler, 2006; Angeli & Valanides, 2009). Specific efforts directed at promoting certain 21st century skills may require further research especially considering the current state of technology integration generally supports traditional learning (Pringle et al., 2015; Scherer et al., 2017; Valtonen et al., 2019).

TPACK is an important part of 21st century science learning and learning achievement, this can be achieved by students in various domains and cannot be separated from the learning process carried out (Juhji & Nuangchalerm, 2020). The TPACK framework to answer the challenges of 21st century learning also applies to the field of science education. In response to this mandate, science educators have renewed their efforts to promote the integration of learning technologies and inquiry-based practices into their teaching to increase students' understanding of science and also to better prepare them for the 21st century workforce (Pringle et al., 2015).

There have been many studies related to TPACK. The most frequently researched topic is the knowledge aspect of technology. This is natural because technology is at the core of the discovery of TPACK ideas to answer the challenges of 21st century learning that requires information technology in learning (Shafie et al., 2019). Research related to technology that has been carried out includes barriers to the integration of information and communication technology in learning (de Freitas & Spangenberg, 2019), the influence of confidence about technology on the TPACK ability of pre-service teachers (Abbitt, 2011; Semiz & Ince, 2012; Oskay, 2017; Hodges, 2018), the effect of technology courses on the development of TPACK abilities of pre-service teachers (Hsu et al., 2013; Lee & Kim, 2017), the development of technology-based tasks to develop TPACK (Polly & Orrill, 2012), motivation of pre-service teachers to develop TPACK with the model technology-integrated education (Holland & Piper, 2016), Integration of Science and Technology using the TPACK framework (Pringle et al., 2015), a computational thinking approach for teacher candidates in an effort to reorganize technology education (Mouza et al., 2017), descriptions of teachers' conceptions of technology in science inquiry learning (Mishra et al., 2019); mapping of technology in the development of TPACK (Angeli & Valanides, 2013), the effect of TPACK on technology ethics (Scherer et al., 2017; Kozikoğlu & Babacan, 2019), measuring the dimensions of technology in TPACK (Scherer et al., 2017). However, as in the previous explanation, TPACK does not only focus on increasing technological knowledge, so that TPACK research that only focuses on technological knowledge is still partial.

There have also been many studies that discuss the ability of TPACK teachers and pre-service teachers. Most of the research focuses on measuring TPACK ability (Horzum, 2013; Giannakos et al., 2014; Mouza et al., 2014; Cetin-Berber & Erdem, 2015; Urban et al., 2018; Vivian & Falkner; 2019) and measuring teachers' perceptions of TPACK. (Koh et al., 2013; Lin et al., 2013; Luik et al., 2018; Redmond & Lock, 2019). From these measurements, most of them result that the TPACK ability of pre-service teachers is still not good, especially for Asian countries.

Research on the application of teachers' TPACK abilities was carried out by Abera (2014) by applying the TPACK framework to English teachers in Ethiopia and Tajudi and Kadir (2014) on the practice of teaching mathematics using TPACK. The development of the TPACK model has been carried out by Chai et al. (2011, 2013) for elementary school teachers. The results show that the positive influence of the basic knowledge factor model Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK) is not directly related to the second layer knowledge factor model that has integrated Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Pedagogical Content Knowledge (PCK). This indicates that the strengthening of the ability of TPACK separately is not positively correlated with the ability of TPACK as a whole. Whereas the TPACK framework argues that programs that emphasize the development of knowledge and skills in these three areas separately are doomed to failure (Koehler et al., 2014). In addition, other factors that influence teachers' TPACK abilities have also been investigated, namely self-confidence (Abbitt, 2011; Semiz & Ince, 2012; Oskay, 2017; Hodges, 2018), motivation (Hollan & Piper, 2014; 2016), and behavior (Scherer et al., 2018; Kozikoğlu & Rabacan, 2019).

Research has also been carried out related to the ability of TPACK on teachers and pre-service science teachers, although the number is still very small. Kafyulilo et al. (2015) conducted research related to the use of information technology in science and mathematics teacher education to develop TPACK abilities. The results showed that the pre-service science teachers had sufficient knowledge of content and pedagogical knowledge but were limited to the technology-related knowledge component of TPACK. Alayyar et al. (2012) reported the results of their research on the development of the TPACK framework supported by Blended Learning. The findings show that with the Blended Learning intervention, science teacher candidates will find it easier to integrate ICT in their teaching practice in the future.

Next, research findings by Canbazoglu Bilici et al. (2016) show that science methods courses that focus on TPACK have an impact on the TPACK of pre-service science teachers. The course helps teachers gain knowledge about the effective use of educational technology tools. Mishra et al. (2019) investigated the teacher's conception of technology in authentic scientific inquiry using TPACK. The results showed that science teachers needed information about the latest trends in modern research and technology and needed training to bring similar research into their classrooms. The four studies above are only at the stage of measuring the TPACK ability of science teachers.

Research using the TPACK framework also provides findings that the integration of ICT in learning is mostly only used to replace teacher instruction, not changing teaching and learning practices to support 21st century learning. This is supported by research by Pringle et al. (2015) which adopted the framework TPACK and assessed 525 science lesson plans designed by teachers after they attended a year-long professional development program using five levels with ICT integration. The findings of Pringle et al. (2015) show that most learning can be classified at three levels (adaptation) or below (entry or adoption). Only a few lessons (3.2%) were rated at the appropriation level and no lessons were rated at the discovery level.

Similarly, Yeh et al. (2014) assessment of the ICT mastery level of Taiwan science teachers with the adapted TPACK framework emphasizing practical learning also concludes that teacher mastery levels are mostly at modest adoption rates, where ICT is used to support practice-centered to the teacher (teacher centre). Voogt & McKenney (2017) also raise questions about the adequacy of current teacher education programs in preparing teachers to design ICT-integrated lessons. Therefore, these studies indicate that there is a need to further develop learning models with designs that can encourage the ability to design learning towards TPACK so as to support more innovative levels of learning transformation. In fact, teacher learning design skills have been identified as a third potential barrier to ICT integration (Koh & Chai, 2016). This is also supported by the research of Turmuzi & Kurniawan (2021) which shows that the competence of pre-service teacher students in the implementation of learning is lowest in learning planning, and the use of technology. From these results, it can be concluded that the pedagogic competence of pre-service teacher students still needs to be improved. Competencies that need to be improved, especially in the use of learning technology, learning planning, and TPACK knowledge.

Science teachers and pre-service teachers need to continuously improve their knowledge and skills to educate their students in the TPACK mindset in order to teach their students effectively. Through TPACK it will increase the accessibility of technology, so that more teachers and aspiring science teachers begin to embrace its use as essential for illustrating and reinforcing science concepts, promoting student learning, and improving problem solving and data analysis (Guzey & Roehrig, 2009; Slykhuis & Krall, 2011). The results of previous research indicate that the ability of TPACK teachers and pre-service science teachers is still not good. The results of this study are in line with Suyamto et al. (2020) who stated that based on the results of the research analysis, it can be concluded that the TPACK ability of biology teachers in Sragen is still quite adequate. Whereas TPACK supports teacher pedagogic changes (Koh, 2019) and affects the ability of teachers to design learning (Sholihah et al., 2016). The teacher's pedagogical and technological abilities also significantly affect learning outcomes. The higher the pedagogical ability, the higher the learning outcomes. Teachers' pedagogical and technological abilities are dominant factors in determining student learning outcomes (Susanto et al., 2020). The pedagogical competence and instructional quality of teachers also affect student learning achievement (König et al., 2021).

Based on the literature study conducted above, there are things that have not been done in previous research (both researchers in Indonesia and globally), namely implementing a model that can improve the mastery of TPACK science teachers so as to improve the ability to design science learning. The model implemented in this research is Project-Based Scaffolding TPACK (PBST). The PBST model is implemented by combining the advantages of the Scaffolded TPACK Lesson Design Model (STLDM) developed by Chai & Kohl (2017) with the Project Based Learning (PjBL) Model according to The George Lucas Education Foundation (2005). Modifications are made by adding the Modeling stage. The STLDM stages developed by Chai & Kohl (2017) include: identify goal, identify learner, identify learning objective, plan instructional activities, choose media/create ICT – based resources and develop assessment tools. The stages of the PjBL Model according to The George Lucas Education Foundation (2005) are start with the essential question, design a plan for the project, create a schedule, monitor the students and the progress of the project, assess the outcome, and evaluate. The PBST model combines the stages of STLDM with PjBL, so that the stages include orientation, exploration, workshop, modeling, peer review and evaluation. The implementation of the PBST model is expected to be a solution to improve the mastery of TPACK and the ability to design learning for pre-service science teachers. The specific objectives of this research were to analyse the improvement of the learning design ability and TPACK possessed by pre-service science teachers after taking lectures with the PBST model and analyse the correlation between TPACK and learning design abilities.

METHODS

The research used was quantitative research with non-equivalent control group design (Bloomfield & Fisher, 2019). The research design was shown in Figure 1. E_1 were the conditions of the experimental class before treatment, E_2 were the conditions of the experimental class after treatment, C_1 ware the conditions of the control class before treatment, C_2 were the conditions of the control class after treatment. These conditions were the ability to design learning and TPACK of prospective science students. X was a treatment in the form of implementing the PBST model in the experimental class while Y was a treatment in the form of lectures which is commonly used with the PjBL model.

Group	Pre	Treatment	Post
Experiment	E_1	X	E_2
Control	C^1	Y	C_2

Figure 1. Research Design

The implementation of the PBST model has orientation, exploration, workshop, modeling, peer review and evaluation stages. The syntax of the PBST model is shown in Table 1. The syntax was modification from STLDM syntax (Chai & Koh, 2017) and the PjBL model (The George Lucas Education Foundation, 2005) by adding the Modeling stage. The activities of the PBST model are also described in Table 1.

Table 1. PBST Model Activities in the Experimental Class

Syntax	Student Activities	Lecturer Activities
Orientation	Analyze the TPACK components of the lesson plan that provided by the lecturer.	Presents 2 examples of different learning tools (1 ordinary lesson pland and TPACK-based lesson plan) and an assessment guide for learning tools
Exploration	Learn the TPACK framework; Basic concepts and applications of CK, PK, TK, PCK, TPK. TCK, and TPACK in science learning	Provide an introduction to concepts related to TPACK framework in science learning which is carried out using a case study model.
Workshop	Arrange schedules and develop projects to make TPACK-based science lesson plan.	Gives project assignments to make TPACK-based lesson plan. Together with students compile project completion schedule, and monitor student project progress
Modeling	Observe to the best practices from senior teachers regarding the preparation of TPACK-based lesson plan and then revise the learning tools that have been made based on the results of best practices	Bring in senior teachers to provide best practices regarding the preparation of TPACK-based lesson plan
Peer Review	Present a lesson plan that have been made, conduct peer reviews of devices lesson plan that has been made by his friend, and revises the learning device based on input from his friend	Facilitate guides and assessment sheets for lesson plan components and TPACK, then provide suggest on lesson plan that have been developed by student
Evaluation	Present the final product of the lesson plan that has been made, then take a test to assess TPACK mastery	Conduct assessments and provide feedback regarding the ability to design lesson plan, then assess students' TPACK mastery

The research population used was pre-service science teachers who were taking Science Learning Strategy and Design courses at the Science Education Study Program, Universitas Negeri Semarang, Indonesia and Universitas Tidar, Indonesia. The samples selected were 4 classes of pre-service science teachers at Universitas Negeri Semarang (2 experimental and 2 control) and 2 classes of pre-service science teachers at Universitas Tidar (1 experimental and 1 control). All classes have been tested for homogeneity and obtained homogeneous results. The instrument used in this study consisted of a lesson plan assessment sheet and a TPACK evaluation test. The lesson plan assessment sheet is used to assess the learning design abilty for pre-service science teachers, Indonesia before and after treatment. The assessment sheet was in the form of a Linkert scale questionnaire 1 to 4 which is adjusted to the quality aspect of the lesson plan (see the assessment aspect in Table 2).

Table 2. Grid of Lesson Plan Assessment Sheet

Aspect	Assessment indicator
Learning objectives	Conformity of learning objectives with basic competencies and indicators, completeness of elements of learning objectives (audience, behavior, condition, degree), and use of operational verbs that are easy to measure.
Learning Materials	The suitability of the indicator learning material, completeness, breadth, and depth of the material.
Learning Strategies	The suitability and completeness of the selection of models, approaches, and learning methods. Application of active learning.
Learning Media	Completeness of learning media both ICT and non-ICT, the renewal of the media used.
Learning Resource	Completeness of learning resources, renewal of learning resources used.
Learning Evaluation	Completeness of the evaluation aspects of both cognitive, affective, and psychomotor. The suitability of the evaluation with the indicators and learning objectives. Completeness of evaluation tools.
Enrichment and Remedial Activities	Completeness of enrichment and remedial activities
TPACK Components	Completeness and suitability of the TPACK components in learning include CK, PK, TK, PCK, TCK, TPK, and TPACK.

While the TPACK evaluation test consisted of 68 multiple choice questions that have been previously validated by experts. The TPACK evaluation test was divided into 7 TPACK components with a proportional distribution (see Table 3). The TPACK test was carried out before and after treatment (pre-test and post-test). Examples of problem on this test are shown in Figure 2.

Table 3. Grid of TPACK Evaluation Test

TPACK Component	Number of problems
CK	10
PK	10
TK	10
PCK	10
TCK	10
TPK	10
TPACK	8

Table 3 shows the distribution of TPACK evaluation questions consisting of 7 TPACK components, namely Content Knowledge (CK), Pedagogical knowledge (PK), Technological knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK).

Example PCK Problem
Mr. Rudi is aware of Dewi's potential development. In dealing with Dewi who has high intelligence and is a fast learner, Mr. Rudi gives his best efforts in the classroom by doing the following, namely….

a. make Dewi a peer tutor during group learning
b. give the task to Dewi to deepen the material being taught
c. facilitate Dewi to develop materials according to Mr. Rudi's direction
d. provide enrichment material individually according to the curriculum material being taught
e. Facilitating Dewi to deepen the material taught according to her interests

Answer: a

Example TPACK Problem
Learning management system allows teachers to manage learning in one container. Mrs. Ani teaches science lessons in grade VII online. In managing learning to be more effective, Mrs. Ani can take advantage of ….

a. A: google doc
b. B: google class
c. C: google drive
d. D: google sheets
e. E: google slay

Answer: b

Figure 2. Example of Problem in TPACK Test

Figure 2 is an example of an evaluation question for the PCK and TPACK components. Examples of PCK questions to measure the ability of prospective science teachers are used to determine appropriate learning methods based on the characteristics of students. Then the sample TPACK questions are used to measure students' ability to use LMS appropriately in online learning.

Data analysis used was independent t test (Kim, 2019), N-Gain test (Bloomfield & Fisher (2019), and bivariate correlation test using SPSS (Perinetti, 2019). Independent t test was a hypothesis test used to see the difference in the average score of the learning design ability and TPACK between the experimental class and the control class. The hypotheses design is shown in Table 4.

Table 4. Hypothesis Design

Hypothesis	Information	Terms Accepted
Ho_1	The average results of leaning design ability in the experimental class were the same as the control class	$t_{count} < t_{table}$
Ha_1	The average result of leaning design ability in the experimental class were greater than the control class.	$t_{count} > t_{table}$
Ho_2	The average results of TPACK in the experimental class were the same as the control class	$t_{count} < t_{table}$
Ha_2	The average result of TPACK in the experimental class were greater than the control class.	$t_{count} > t_{table}$

In Table 4. The t_{count} value is calculated using the independent t test equation. Meanwhile, the t_{table} refers to the table of t which is adjusted to the degrees of freedom (df) and the level of significancy. In this study the level of significancy used is 0.05. The N-Gain test was used to see the improvement in the ability to design learning and TPACK after treatment (N-Gain categorization is shown in Table 5).

Table 5. N-Gain Categorization

Interval	Categorize
(N-Gain) > 0,7	High
0,3 ≤ (N-Gain) ≤ 0,7	Medium
0,3 < (N-Gain)	Low

Bivariate correlation test was used to see the relationship between TPACK and the ability to design learning. In the bivariate correlation test, if the significance value is less than 0.05, then there is a relationship between TPACK and the ability to design learning.

RESULTS AND DISCUSSION

The results of the lesson plan assessment before and after treatment and their improvement are shown in Table 6. Table 6 shows an increase in all classes, both the control class and the experimental class. In the experimental class the learning design ability gets an N-Gain score in the high category, while in the control class it gets a low to moderate category. These data indicate that the application of the PBST model can improve the learning design ability for pre-service science teachers better. Increased design learning ability in the experimental class was higher can be obtained because in the PBST model there are modeling and peer-review stages.

Table 6. The Lesson Plan Assessment Results

Group	Lesson plan 1	Lesson plan 2 (final)	N-Gain
Experiment 1	65.38	95.60	0.87
Experiment 2	68.29	95.79	0.81
Experiment 3	60.22	92.68	0.82
Control 1	62.06	72.51	0.28
Control 2	60.73	74.20	0.34
Control 3	63.99	73.95	0.28

In the modeling stage, students observe a lesson plan based on a demonstration by a senior teacher. In this stage, students will also revise the lesson plans that have been made previously. Then in the peer-review stage, students get a lesson plan assessment from their peers. In this stage, students will also revise the lesson plan for the second time until the final lesson plan product is obtained. So with the PBST model, prospective science teachers will revise the lesson plan 2 times during the lecture process. In a similar model, namely STLMD (Chai & Koh, 2017) there is no peer-review and modeling stage, while the ordinary PjBL model (Guo et al., 2020) used in the control class lesson plan revision is only carried out once during the lecture process, namely in the stage of testing project results.

The results of the independent t-test hypothesis test are presented in Table 7. This hypothesis test aims to analyze statistically whether there is a significant difference between the learning design ability in the experimental and control classes as seen from the assessment scores of lesson plan 2 (final). Independent t-test was performed on classes that came from the same population. Experiment 1, experiment 2, control 1, and control 2 came from the population of students of science education at the Universitas Negeri Semarang, while experiment 3 and control 3 came from the population of students of science education at Universitas Tidar.

Table 7. Independent t test Result of Final Lesson Plan Score

Tested class	df	t_{table}	t_{count}
Experiment 1 and control 1	47	2.012	6.284
Experiment 1 and control 2	45	2.014	6.106
Experiment 2 and control 1	47	2.012	6.502
Experiment 2 and control 2	45	2.014	5.845
Experiment 3 and control 3	68	1.996	5.706

Based on table 7, the results of hypothesis testing show that the value of t_{count} is greater than t_{table} in all pairs of classes tested. This shows that there is a significant difference between the lesson plan scores in the experimental and control classes (Ha_1 is accepted). This power can be explained because the modeling and peer-review stages are very helpful in improving the lesson plan. With the modeling stage, students gain theoretical and practical knowledge related to the preparation of lesson plans (Evmenova, 2018; Vermunt et al., 2019; Backfisch et al., 2020). Meanwhile, with the peer-review stage, students get a lot of feedback from peers which is used to perfect the lesson plan (Ma et al., 2018; Tanak, 2020). The results of the pre-test, post-test, and the increase in TPACK of pre-service science teachers after treatment are presented in Table 8. Based on the results in Table 8 both the control and experimental classes have an increase in TPACK scores, but the increase in the experimental class is higher. In the three experimental classes the N-Gain score is in the medium category, while in the three control classes the N-Gain score is in the low category. These data indicate that the treatment of the PBST model has a positive effect on increasing the TPACK of pre-service science teachers.

Table 8. The Pre-test and Pos-test Results

Group	Pre-test	Post-test	N-Gain
Experiment 1	52.06	77.61	0.53
Experiment 2	49.82	75.04	0.50
Experiment 3	45.06	71.62	0.48
Control 1	44.61	54.41	0.18
Control 2	47.59	57.69	0.18
Control 3	42.11	54.95	0.22

Based on Table 8, the increase in TPACK in the experimental class is influenced by the learning stages contained in the PBST model. In the PBST model there are orientation and exploration stages. At the orientation stage, prospective science teachers are given activities to analyze the TPACK components in the lesson plan provided by the lecturer. In this activity, it is clear that they carried out activities to find out in advance about TPACK. In the orientation stage, basic questions are also explored as found in the usual PjBL syntax (Aldabbus, 2018). Fundamental questions related to TPACK become a stimulus for students to study TPACK more deeply. This is the beginning of their knowledge orientation related to TPACK. In the exploration stage, they were asked to explore and study the TPACK framework as well as the basic concepts and applications of CK, PK, TK, PCK, TCK, TPK, and TPACK in science learning. These exploration activities forced them to understand more deeply about TPACK than the control class which was only directly given a project lesson plan through the PjBL model without exploring more deeply related to TPACK. Exploration activities become the initial stimulus to understand the next material (Prayogi & Yuanita, 2018; Thorngate, 2018). The exploration stage is also a combination of 3 stages of identification in the STLDM model, namely identification of goals, identification of learners, and identification of learning objectives (Chai & Koh, 2017). The STLDM model (Chai & Koh, 2017) only has an initial identification stage, whereas in PjBL there are only initial essential question stages (The George Lucas Education Foundation, 2005; Aldabbus, 2018). The novelty of the PSBT model is that it combines the identification stage in the STLDM (Chai & Koh, 2017) model and the essential question stage in PjBL (The George Lucas Education Foundation, 2005; Aldabbus, 2018) into an orientation and exploration stage. The combination of these two stages is significant for increasing the TPACK of prospective science teachers. Testing the increase in TPACK for prospective science teachers is not enough to use N-Gain alone, the researchers conducted a hypothesis independent t-test to see if there was a difference in post-test scores between the experimental and control classes. Independent t-test was performed on classes that came from the same population. Experiment 1, experiment 2, control 1, and control 2 came from the population of students of science education at the Universitas Negeri Semarang, while experiment 3 and control 3 came from the population of students of science education at Universitas Tidar. The test results are presented in Table 9.

Table 9. Independent t test Result of TPACK Post-test

Tested class	df	t_{table}	t_{count}
Experiment 1 and control 1	47	2.012	6.787
Experiment 1 and control 2	45	2.014	6.205
Experiment 2 and control 1	47	2.012	6.604
Experiment 2 and control 2	45	2.014	6.045
Experiment 3 and control 3	68	1.996	7.303

Based on table 9 shows that there is a significant difference in the average TPACK score between the experimental and control classes. This is indicated by all test data obtaining a t_{count} value of more than t_{table}, which means that H_{a2} is accepted. This difference is caused by the PBST model, science teacher candidates gain more knowledge related to TPACK in the orientation and exploration stages. Especially at the exploration stage, students analyze science content in the junior high school science curriculum as a CK application (Carlson et al., 2019), analyze PK such as models, strategies, approaches, methods, and 21st century learning and learning techniques (Neumann et al., 2019). They also analyzed kindergarten such as the use of ICT and non-ICT tools in learning (Alt, 2018). In addition, knowledge about the integration of these three knowledges into PCK, TPK, TCK, and TPACK was also explored.

The results of the bivariate correlation test between TPACK and the learning design ability of pre-service science teachers are presented in Table 10. The variables tested were the TPACK post-test score and the final lesson plan score.

Table 10. Result of Bivariate Correlation Test

Group	Post-test TPACK	Lesson plan 2 (final)	Sig.
Experiment 1	77.61	95.60	0.02
Experiment 2	75.04	95.79	0.03
Experiment 3	71.62	92.68	0.02
Control 1	54.41	72.51	0.03
Control 2	57.69	74.20	0.01
Control 3	54.95	73.95	0.03

Based on Table 10, the significance value is less than 0.05, which means that there is a correlation between TPACK and learning design ability. This correlation can be explained because in preparing lesson plans, pre-service science teachers apply their TPACK. A good lesson plan implements the 7 components of TPACK that appear explicitly. The results of further analysis based on further interviews with pre-service science teachers obtained the relationship between 7 components of TPACK and 8 aspects assessed in the lesson plan presented in Figure 3.

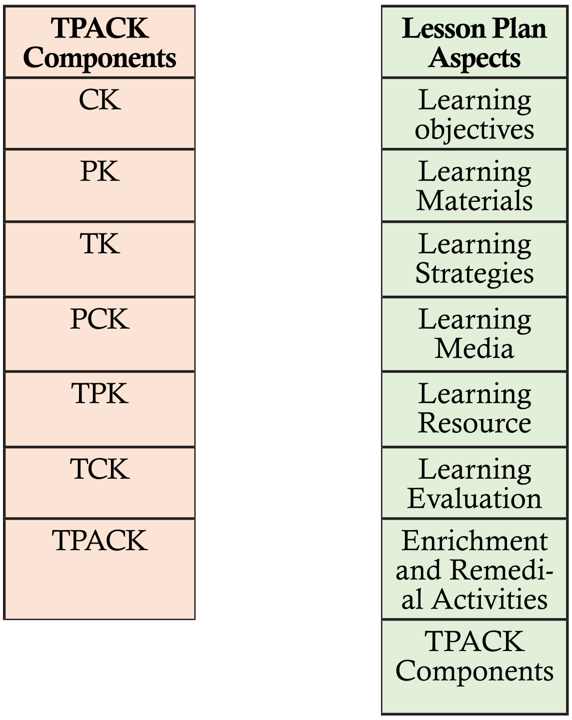

Figure 3. Correlation between TPACK Components and Lesson Plan Aspects

Based on this correlation, it can be concluded that the TPACK of prospective teachers is closely related to their ability to design learning. The higher the TPACK of a pre-service teacher, the ability to design learning will be very good as well (Schmid et al., 2021). Teachers who can integrate technology in learning will find it easier to design technology-based learning in line with the demands of the 21st century (Janssen et al, 2019; Bergeson & Beschorner, 2020).

CONCLUSION

Model The PBST model can be implemented to improve the learning design ability and TPACK for pre-service science teachers. The results showed that there was an increase in the high category for the learning design ability and the medium category for TPACK. After being given PBST model treatment in the experimental class, there is a significant difference in the learning design ability and TPACK between the experimental and control classes. In addition, the results also show that there is a correlation between TPACK and learning design ability. The PBST model is expected to be a solution offer to prepare pre-service science teachers in designing science learning and mastery of TPACK in line with the demands of 21st century learning based on technology integration.

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