

Integrated of Technological Pedagogical and Content Knowledge (TPACK) for Pre-Service Science Teachers: Literature Review

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ABSTRACT

Teachers in the 21st century are like today at a very rapid technological development. Teachers not only have to master understanding the content of the subject matter but also need skills in using and operating technology in learning. So that we need teachers who can integrate content and pedagogical skills with technology. The TPACK was created as the knowledge that teachers generate simultaneously and are interdependent on content, general pedagogy, technology, and learning context. This study is a literature review on the integration of the technological abilities of pedagogical content knowledge (TPACK) in pre-service science teachers by analyzing journals with the aim of 1) investigating the distribution of journals, 2) investigating the types of journal research in a percentage of %, 3) investigating data collection methods in the journal as a percentage of %, 4) TPACK sub-dimension which is integrated with technology, and 5) the results of research related to pre-service science teacher TPACK, the analysis was carried out on 10 journals. The results of 1) the largest distribution of journals in 2016-2020 the percentage was 80%, 2) the type of research was dominated by quantitative research by 40%, 3) methods data collection for the whole journal using a questionnaire (survey), 4) sub-dimensions of the TPACK framework that integrates with technology, namely TK, TPK, and TCK, 5) technology integration is not influenced by gender differences and will increase through courses or training.

Keywords: *Technology, Pedagogy, Content, Pre-service teachers and TPACK*

1. INTRODUCTION

Teachers in the 21st century are a time of rapid technological development like today. It is not enough for a teacher to only have the content of learning material that must be mastered, but a teacher also needs to have skills in using technology that is applied to learning. This needs to be done because the development of the 4.0 revolution which demands all timelines for technology literacy is also in the field of education. Naturally, educational activities are needed to incorporate elements of technology and their applications. In the school environment, every element that exists there must integrate itself with technology[1]. Every element that needs to do so can be said to be a stakeholder. Stakeholders, namely administrators, teachers, students, and families who

have a significant interest in the incorporation of technology. Among these stakeholders, teachers have been given greater responsibility in using their teaching techniques to enhance student learning and higher-order thinking skills [2]

Because of this, where a teacher is required to have diverse competencies, namely pedagogical competence, professional competence, personality competence, and social competence. Every teacher who will teach must pass a teacher competency test to find out how his abilities and determines the quality of a teacher. In terms of understanding the subject matter, the teacher already has a good understanding. However, knowledge of how to teach requires the ability to use the right methods for teaching and how the right strategies to teach content

to students to make it more meaningful. Therefore, it is necessary to have professional knowledge of teachers about knowledge combined with the subject matter according to their fields by utilizing various technologies in teaching known as technological pedagogical content knowledge (TPACK)[3]. The TPACK framework combines pedagogical skills, content knowledge with technology. TPACK regulates the relationship between technology, curriculum content, and specific pedagogies regarding how teachers understand technology, pedagogy, and content in helping each other to produce effective disciplines with educational technology[4].

When using any technology tool in an educational context, a teacher must be able to combine his knowledge of technology and how to use technology in a particular educational context. In this case, the integration of technology will be effective in a subject that requires a combination of three important knowledge domain elements, namely technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). When these domains are combined, it will produce slices that form knowledge technology content (TCK), pedagogical knowledge technology (TPK), pedagogical content (PCK), and TPACK across the three knowledge edge domains[5]. The TPACK framework has been used frequently in the past decades in both the pre-service and occupational teacher knowledge studies[3].

Various studies on the ability of TPACK pre-service teachers have become benchmarks that an important teacher has the ability to integrate technology with pedagogical abilities and knowledge of material content. Such as research conducted by Chai, Koh & Tsai which reviewed 74 journals about TPACK regarding the investigation of ICT integration within the TPACK framework[6]. This will be important to do to find out the technology integration in the TPACK framework. Besides, investigations related to the distribution of journals are also needed, the types of research used, the data collection methods used in the research in the reviewed journals to open up opportunities for further researchers to conduct research that takes the topic of TPACK. The objectives of this study are: 1) investigation of journal distribution, 2) investigation of journal research types in percentage of%, 3) investigation of data collection methods in journals in percentage of%, 4) TPACK domain investigation that is integrated with its technology and indicators, and 5) research results related to pre-service science teacher TPACK.

1.1. Theoretical TPACK

The TPACK level component that integrates with technology is TPACK which is a combination of technological knowledge, pedagogy, and content. TPACK is an understanding, knowledge, and communication of concept representations using technology, pedagogical techniques, knowledge of concepts whether difficult or easy to learn and knowledge of how to help and develop students[9]. However, the technological knowledge referred to in the TPACK study is general knowledge related to digital technology. For this reason, technological knowledge is largely seen as knowledge of computers, the internet/web, and digital materials[8]. So Technological Pedagogical and Content Knowledge (TPACK) is knowledge combining technology with pedagogical abilities and mastery of material content to be conveyed in learning

Knowledge is a collection of information needed to achieve functions and goals; the capacity to organize information based on data and turn it into useful and meaningful information; the capacity in which a person thinks creatively, interprets and acts, and an attitude that makes people want to think[9]. Therefore, TPACK combines integrated knowledge and forms of strategic thinking: to know when, where, and how to use certain knowledge domains and strategies when guiding students to learn by integrating appropriate information and communication technology[10]. If the integration of technology is carried out properly, TPACK will be able to support teachers to be able to organize, implement, criticize the results, and abstract a certain learning plan tailored to the needs of students.

The use of information technology is following that proposed by the Committee of Information Technology Literacy of the National Research Council (NRC). The following is a picture of the TPACK framework:

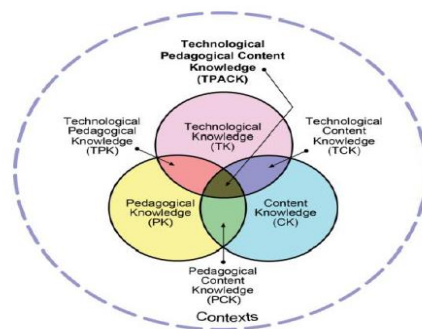


Figure 1. Schematic of the TPACK structure from Shulman [13]

The TPACK framework was developed by adding technological know-how to Shulman's idea of PCK. The TPACK framework consists of seven sub-dimensions of knowledge. The main components are technological knowledge (TK), pedagogy (PK), and content (CK). The main domain combination produces a cross between the domains namely pedagogical knowledge technology (TPK), technology content knowledge (TCK), pedagogical content knowledge (PCK). The merging of the three domains as a whole will result in knowledge of content pedagogical technology (TPACK) (Figure 1.). In science learning, technology pedagogic knowledge is needed to relate how knowledge about science content is learned by students, besides how pedagogical knowledge related to science content and how technology knowledge is used to find out which technology is suitable for teaching and learning science [12].

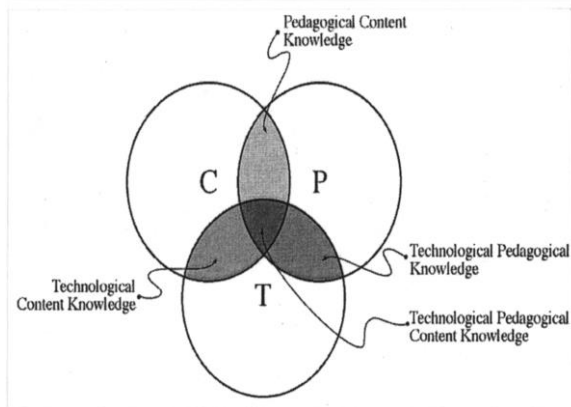


Figure 2. Components of technological pedagogical and content knowledge [13].

The intersection between the technological (T), content (C), and pedagogic (P) domains will be obtained by 3 sub domains if they are integrated with technology, namely technological knowledge (TK), technological pedagogical knowledge (TPK) and technological content knowledge (TCK).

2. METHOD

This study uses a literature study research design where in this study using a variety of literature both

Table 1. Distribution of research samples

No.	Reference	Year	Research design	Data collection technique
1.	[28]	2019	Quantitative	Survey (single survey and relational survey)
2.	[26]	2018	Correlational analysis	Survey (web 2.0 usage situation survey and TPACK self-efficacy confidence)

from articles, journals, and other relevant sources. The literature review is a statistical technique that combines various research results with similar problems, so that it will produce a combination of quantitative and systematic data, in order to draw conclusions. The process of analyzing articles or journals is carried out using 4 steps, namely formulating problems, searching for literature, evaluating and analyzing, and interpreting. In this literature study, data collection was carried out by collecting research results from related scientific articles about pre-service science teacher TPACK. Search for journals, articles, or essays that are conducted over the internet by searching for related pre-service science teacher TPACK abilities.

All studies published in the period 2010-2020 or are studies conducted in the last 10 years with research results that can strengthen the author in conducting his analysis. The data collection process was carried out by identifying the observed variables through the coding method. The coding was carried out by adjusting the research variables, namely: research type and design, data collection methods, and research results on research related to pre-service science teacher TPACK.

After that, the data that has been collected will be analyzed using descriptive statistical techniques. The population in this study are all written documents regarding educational research that discuss the ability of pre-service teacher TPACK. The sample used in this study was 10 research articles. Sampling was done using purposive sampling. This is determined based on conformity with the theme of this research because data or information will be obtained through samples.

The data analysis in this study used quantitative analysis with percentages and qualitative data analysis with the data from the narrative study in the found studies. The journal analyzed were 30 journals but 10 articles that met the requirements or criteria were taken from national and international journals. The division of 10 articles of research subjects can be seen in the grouping Table 1.

No.	Reference	Year	Research design	Data collection technique
				scale
3.	[27]	2017	Descriptive quantitative	Simple descriptive survey
4.	[29]	2013	Development of the TPACK instrument to determine pre-service science teacher self-efficacy beliefs	Survey (questionnaire)
5.	[8]	2016	Development of the TPACK self-efficacy scale instrument for pre-service science teachers	Survey (questionnaire)
6.	[4]	2015	Comparison	Survey
7.	[25]	2020	Quantitative	Self-managed survey
8.	[3]	2019	Descriptive	Survey before and after the program (open questionnaire)
9.	[2]	2019	Quantitative	Survey
10	[14]	2017	Mixed (quantitative and qualitative)	Survey (open questionnaire), semi structured interview

3. RESULT AND DISCUSSION

The results of the literature study will be presented in 5 parts, namely the first part of the distribution of journals, the two types of research in journals, the third investigative data collection methods used in journals, the four TPACK domains that are integrated with technology and indicators, and finally the research results related to the TPACK ability of pre-service science teachers.

3.1. Journal Distribution Investigations

Distribution investigations are carried out to find out that research on TPACK is still a research trend every year. Data on the distribution of the 10 journals that were reviewed can be seen in table 2.

The data in Table 2 shows that the spread of research from the 2010-2020 range in the journals reviewed had the greatest spread in 2016-2020 with a

percentage of 80% who conducted research related to TPACK from 10 journals.

3.2. Investigating Research Types in Journals

Investigations of the types of research in journals are carried out to find out what types of research may be used in research that takes the topic of TPACK. From the results of the investigation it can be said that TPACK is a flexible research topic because it can be used for qualitative, quantitative, mixed, descriptive, descriptive, research types, correlation, instrument development and comparison.

The data in Table 3 shows that research on TPACK with the type of quantitative research and instrument development is the most widely used research to examine the TPACK ability of teachers by having a presentation of 40% and 20% of 10 articles. This shows that this research is still in great

Table 2. Journal distribution

No.	Year	Amount	Total Percentage (%)	Reference
1.	2010-2015	2	20	[4], [29]
2.	2016-2020	8	80	[2], [3], [8], [14], [25], [26], [27], [28]

Table 3. Category types of research in journals

No.	Types of research	Amount	Total Percentage (%)	Reference
1	quantitative	4	40	[2], [25], [27], [28]
2	Mixed (quantitative and qualitative)	1	10	[14]

3	Descriptive	1	10	[3]
4	Correlational	1	10	[26]
5	Instrument Development	2	20	[8], [29]
6	Comparison	1	10	[4]

demand by researchers, besides research by developing instruments that can be used as a measuring tool that can be used by further researchers to measure the teacher's TPACK ability by re-testing it on different individuals and numbers.

3.3. Investigative Data Collection Methods Used in Journals

The data in Table 4 shows that research on TPACK uses more of the data collection method using a questionnaire (survey) where 100% of the 10 articles use this method. Also, there are 10% of 10 studies that use more than one data collection method conducted by Levent that uses questionnaires and interviews [14]. The surveys used varied, from surveys using open questionnaires, simple descriptive surveys, single and relational surveys, self-managed surveys and surveys before and after participating in the program.

Formulas are used to obtain the presentation:

$$\frac{\text{Number of articles}}{\text{The total number of articles reviewed}} \times 100\% \quad (1)$$

The formula is used to find the percentage in percent (%) of each table that looks for percentage data.

3.4. TPACK Domain Investigation That is Integrated with Its Technology and Indicators

This section provides an overview of the TPACK framework that integrates technology in pre-service teachers. Within the TPACK framework, three

Table 4. Data collection methods in journals

No.	Methods	Amount	Total Percentage (%)	Reference
1.	Survey	10	100	[2], [3], [4], [8], [14], [25], [26], [27], [28], [29]
2.	Interview	1	10	[14]

3.4.2. Technological Pedagogical Knowledge (TPK)

The TPACK level integrates technology with pedagogic, namely technological pedagogical

TPACK levels integrate with technology, namely TK, TPK, and TCK. Each TPACK level that integrates with technology has various indicators that can be used to determine the TPACK ability of pre-service teachers.

3.4.1. Technological Knowledge (TK)

The TPACK level which integrates technology furthermore technological knowledge (TK) is the expertise in technology related to information and skills in using certain technologies [15]. Ability in technology or technological knowledge cannot be separated from the subject. Technology that can range from low technology with pencil and paper to digital technology [8]. Information technology knowledge (TK) contains multimedia and PowerPoint. Apart from that, digital technology can also be in the form of the internet, digital video, interactive whiteboards, and software programs [16].

Teachers who have extensive knowledge about the productive use of technology can help students learn more effectively and solve problems than those without technology knowledge[18]. So it can be said that technological knowledge (TK) is information knowledge and skills in using technology both from low technology to digital technology such as the internet and must pay attention to subjects that will make a teacher productive in helping student lessons more effectively. The TK indicators according to Chai C.S, Koh, Tsai, & Tan, and Seyit A.K are shown in Table 5. [18][8].

knowledge (TPK). Technological Pedagogical Knowledge (TPK) refers to knowledge of how various technologies can be used in teaching or teaching[20]. Besides, to understand that using technology can affect there are ways teachers teach[16]. Teachers who feel sufficient in terms of

TPK must have the ability to decide which technological devices are suitable for educational use. At the same time, they must be able to integrate the technology they are most comfortable with with the most appropriate teaching strategy, method, technique, model or theory. Similar to this, teachers must be able to integrate technology in education using measurement and assessment methods and techniques, in the use of technology teachers must be able to adapt to differences in individual student abilities, and have the ability to manage the classroom environment. In short, the TPK is related to the presentation of pedagogical strategies and technology integration[20]. So in other words the ability of technological pedagogical knowledge where a teacher can customize the model, method, learning strategy must pay attention to the right technology that must be used in learning.

The use of technology in teaching is changing teaching methods and promoting the benefits of learning. Combining pedagogical knowledge and technological instruments, curriculum design can be more disciplined and effective in addressing the real needs of students[17]. The TPK indicators according to Chai C.S, Koh, Tsai, & Tan and Seyit A.K are shown in Table 5.[19][8].

3.4.3. Technological Content Knowledge (TCK)

The TPACK level that integrates technology with content is technology content knowledge (TCK). Knowledge of the material relationship between learning and technology includes certain material content that has been explored by using and using technology[21]. Also, there is a knowledge of technology content that can provide a new representation for certain content. When the teacher's understanding of using technology shows that the teacher can create or change the way students learn to understand the concepts in certain content[16]. How to choose the technology that can best embody and support specific content-based teaching[19]. Knowledge of integrating existing technology to specific subject matter knowledge which does not

include pedagogical purposes, knowledge of the application of simulations to inform development [22].

Practitioners in content disciplines such as data collection and analysis tools (digital probes and spreadsheets by scientists) and knowledge of technology tools illustrate content technology knowledge (TCK)[2]. TCK is knowledge using technology to denote specific content areas [24]. By taking advantage of advances in technology, teachers can use new perspectives to describe phenomena in the content area [17]. The TCK indicators according to Chai C.S, Koh, Tsai, & Tan and Seyit A.K are shown in Table 5. [18][8].

3.5. Research Results Related to The Ability of Pre-Service Science Teacher TPACK

The results of the analysis obtained from journal investigations related to the results of research on the integration of technological knowledge and content pedagogy (TPACK) in pre-service science teachers can be seen in table 6.

The belief in the self-efficacy of pre-service science teachers on the ability of TPACK teachers can be influenced by the frequency of use of social media in kindergarten, TPK and TPACK[25]. However, it is not specifically influenced by gender differences[4]. However, this is different from the research conducted by Belgin Wright that there are differences based on gender in the 6 sub-dimensions of TPACK except in technological knowledge (TK)[26]. Also, the courses or training carried out can contribute to the development of TPACK for pre-service teachers, especially in the sub-dimensions T, TCK and TPK. [27][14]. The teacher's ability at each TPACK level can be a higher impact on student academic achievement which explains 12% of the influence on student academic achievement [28].

Table 5. Indicators of TK, TPK and TCK

Aspect	Indicator
<i>Technological Knowledge (TK)</i>	Able to use the internet / web in biology learning (ex: blog, Facebook, wiki) Able to use technology easily and have the ability to use technology techniques Able to use work applications (MS Word, Excel and Power Point) Able to use software and applications in learning (ex: MSN Messenger, Skype, Yahoo, IM) Able to use learning resources on the website

<i>Technological Pedagogical Knowledge (TPK)</i>	<p>Able to use information and communication technology for discussion in forums with students</p> <p>Able to use technology that supports student independence and communication</p> <p>Able to use technology that supports students' thinking skills (critical and creative thinking)</p> <p>Able to adjust the use of technology that has been learned in various teaching activities</p>
<i>Technological Content Knowledge (TCK)</i>	<p>Able to use appropriate technology (eg multimedia resources, simulations) to represent course content</p> <p>Able to choose appropriate learning basic competency materials in teaching using technology</p> <p>Able to determine learning materials that require technological facilities to facilitate students in lessons</p>

Table 6. Analysis of research results

Reference	Result indicator	Research result
[28], [3], [25], [4]	Self-efficacy beliefs through social media, as a predictor of academics and based on gender	<p>Social media: frequency of use has a high correlation with self-efficacy at TK, TPK, and TPACK statistically (high correlation with $r > 0.5$)</p> <p>Predictors of student achievement: teacher TPACK level, student self-efficacy, academic, social, and emotional explained 12% of student academic achievement. Teacher's TPACK level has a higher impact on student academic achievement.</p> <p>Gender: gender differences do not affect the level of self-efficacy of pre-service science teachers on technology integration statistic even though they differ in mean scores</p>
[26], [2]	Reliability and response of prospective teachers	<p>Scale reliability: Cronbach alpha (α) results with the internal consistency factor of the scale of 0.989 on self-efficacy beliefs. Meanwhile, Cronbach alpha (α) in the use of web 2.0 applications ranging from 0.716 is said to be reliable because Cronbach alpha (α) from the use of web 2.0 applications is 0.936.</p> <p>Teacher candidate responses: 1) in general, the TPACK scale of teacher self-efficacy beliefs was found in PK with the highest average (7.9822) and kindergarten with the lowest average (7.1683) and the answer scale on the highest TPACK self-efficacy belief in "me sure I can "with an average of 7,8340. 2) The level of confidence level of TPACK self-efficacy based on gender on 6 subdimensions was found to have a higher score for women than men ($p < 0.05$) except in kindergarten.</p>
[27], [14]	TPACK pre-service science teacher with courses	<p>1) The ability of TPACK pre-service science teachers is increased by taking courses or training from grade 1 to grade 4 (through technology courses and material design that have an active role in software development) in integrating technology.</p> <p>2) The implementation of courses contributes to the development of pre-service teachers especially in the sub-dimensions T, TCK, and TPK.</p>
[8], [29]	Validity, Reliability, and Results	<p>Validity: carried out with construct and content validity. A scale with 55 items was determined and confirmed by confirmatory factor analysis. On the TPACK-SeS scale with 52 items using EFA and CFA analysis.</p> <p>Reliability: Cronbach alpha (α) value with internal consistency factor on subdimension above 0.70.</p> <p>Results: 1) scale development by classifying technology from traditional to digital and the internet. The advantages of the scale are the literature with the names of the technology listed, 2) TPACK-SeS can function to evaluate the self-efficacy beliefs of pre-service science teachers for teachers, researchers and educators.</p>

4. CONCLUSION

Based on the results and discussion, the conclusions are as follows:

- a. The largest distribution of journals in the 2016-2020 period with a percentage of 80%
- b. The type of research that many journals use in this literature study is quantitative research with

a percentage of 40% and was followed by the development of the TPACK instrument.

- c. Data collection methods that are widely used in journals are dominated by serving or almost all journals that are carried out by literature studies.
- d. In the integration of technology within the TPACK framework, there are 3 technology-integrated sub-dimensions, namely technological knowledge (TK), technology pedagogic knowledge (TPK), and technology content knowledge (TCK).
- e. Technology integration within the TPACK framework can be increased with pre-service science teachers conducting training or technology integration courses in TPACK. Besides, self-efficacy beliefs can also affect the integration of technology and also the use of social media. However, it is not specifically affected by gender differences. Teacher's TPACK levels can also affect student academic achievement.

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