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Research Artikel

THE CONTRIBUTION OF CONTENT, PEDAGOGY, AND TECHNOLOGY ON THE FORMATION OF SCIENCE TEACHERS' TPACK ABILITY

KONTRIBUSI PENGETAHUAN KONTEN, PEDAGOGI, DAN TEKNOLOGI TERHADAP PEMBENTUKAN TPACK GURU IPA

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Abstrak

Model integrasi teknologi mengalami perubahan dari model yang berfokus pada teknologi ke model yang berfokus pada pedagogi, salah satunya adalah TPACK. Informasi mengenai kemampuan TPACK guru IPA dan kontribusi pengetahuan konten, pedagogi, dan teknologi dalam pembentukan TPACK guru masih belum banyak tersedia. Oleh sebab itu, penelitian ini bertujuan untuk memperoleh informasi mengenai kemampuan TPACK guru IPA dan kontribusi pengetahuan konten, pedagogi, dan teknologi dalam pembentukan TPACK. Penelitian survei ini melibatkan 88 orang guru mata pelajaran IPA Kota Banda Aceh. Data mengenai kemampuan TPACK guru diperoleh dari soal tes berbentuk pilihan berganda. Penyebaran soal dilakukan secara langsung melalui kegiatan pelatihan. Analisis data dilakukan secara statistik deskriptif dan inferensial (pemodelan SEM-PLS). Hasil penelitian menunjukkan bahwa profil kemampuan TPACK guru IPA SMP di Kota Banda Aceh didominasi oleh pengetahuan konten (CK). Hasil analisis SEM-PLS menunjukkan bahwa CK, PK, dan PCK secara langsung dan tidak langsung berkontribusi dalam pembentukan TPACK guru IPA SMP di Kota Banda Aceh. Pemerintah dan penyelenggara pendidikan diharapkan dapat membantu guru untuk meningkatkan kemampuan menggunakan teknologi secara efektif dalam kegiatan pembelajaran agar terbentuk TPACK yang komprehensif.

Kata Kunci: *Pengetahuan konten; pengetahuan pedagogi; pengetahuan teknologi; TPACK guru IPA*

Abstract

The model of technology integration has changed from models that focus on technology to models that focus on pedagogy, one of which is TPACK. The information about science teachers' TPACK and the contribution of content, pedagogy, and technology on the formation of science teachers' TPACK is still limited. Therefore, this research aimed to obtain information about the science teachers' TPACK and the contribution of content, pedagogy, and technology on the formation of TPACK. This survey research involved 88 science teachers from Banda Aceh City. The data about science teachers' TPACK was obtained from multiple-choice test questions. The questions were distributed directly through training activities. Data analysis was performed by descriptive and inferential statistics (SEM-PLS modeling). The results showed that the TPACK ability profile of junior high school science teachers in Banda Aceh City was dominated by content knowledge (CK). The results of the SEM-PLS analysis showed that CK, PK, and PCK, directly and indirectly, contributed to the formation of the science teachers' TPACK in junior high school in Banda Aceh City. The government and education providers were expected to be able to help teachers to improve the ability to use technology effectively in learning activities to form a comprehensive TPACK.

Keywords: Content knowledge; pedagogical knowledge; technological knowledge; science teachers' TPACK

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INTRODUCTION

The technology integration model undergoes a transformation from a technology-focused model to a model that focuses on pedagogy. One integration model that focuses on pedagogy is Technological Pedagogical and Content Knowledge (TPACK) (Kabakci Yurdakul & Coklar, 2014; Yerdelen-Damar *et al.*, 2017). The TPACK model is an extension of ideas from pedagogical content knowledge by combining the relationship between content knowledge, pedagogical knowledge, and technological knowledge (Dalal *et al.*, 2017; Kabakci Yurdakul & Coklar, 2014).

In general, TPACK is referred to as a teacher's knowledge, skills, and competencies regarding the integration of technology into learning activities (Kabakci Yurdakul & Coklar, 2014). TPACK does not focus on the technology used, but how it is used in learning activities effectively (Alqurashi *et al.*, 2017; Deng *et al.*, 2017; Yerdelen-Damar *et al.*, 2017). Furthermore, TPACK emphasizes the integration of technological knowledge, content knowledge, and pedagogical knowledge. The TPACK framework is often used to determine how to integrate technology into effective teaching strategies and design pedagogical activities that are integrated with information and communication technology (Deng *et al.*, 2017; Kabakci Yurdakul & Coklar, 2014; López-Vargas *et al.*, 2017; Szeto & Cheng, 2017; Tondeur *et al.*, 2017; Yerdelen-Damar *et al.*, 2017).

The TPACK model consists of three main components and four integration components (a combination of the main components). The main components consist of Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). Furthermore, the integration component consists of Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological Pedagogical and Content Knowledge (TPACK) (Figure 1) (Dalal *et al.*, 2017; Gill & Dalgarno, 2017; Gonzalez & González-Ruiz, 2017; Kabakci Yurdakul & Coklar, 2014).

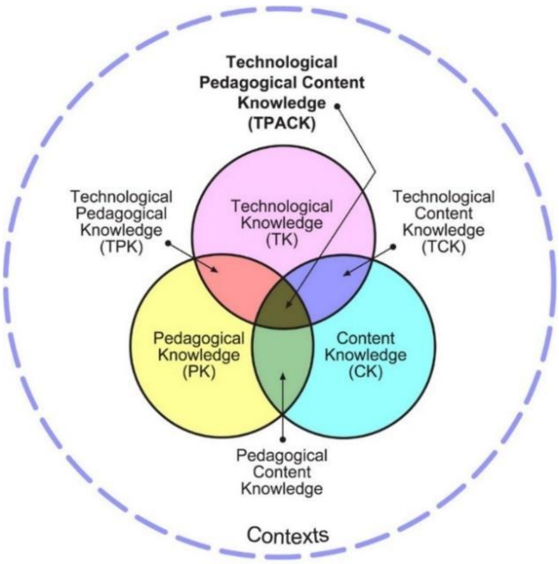

Figure 1. TPACK Framework Model and its Components (Source: Koehler *et al*., 2013).

According to Akturk *et al*. (2019), the TPACK framework can be used to see which components affect effectively integrating technology. Based on Figure 1, it appears that the three main components, namely content, pedagogy, and technology, intersect (integrated) with all components of integration. That is, the three components contribute to the formation of TPACK. The contribution of content knowledge, pedagogy, and technology to the preparation of TPACK can be identified through a statistical approach to Structural Equation Modeling - Partial Least Square (SEM-PLS).

Partial Least Square (PLS) is a non-parametric analysis method. It is not based on many assumptions, such as data that do not have to be multivariate normally distributed (indicators with a scaled category, ordinal, interval, until the ratio can be used on the same model) and do not require sample availability in large quantities. Besides functioning to confirm the theory, PLS can also be used to explain the presence or absence of relationships between latent variables (Ghozali, 2014; Latan & Ramli, 2013; Wong, 2013).

TPACK's ability can be used as an indicator of professional teachers because the TPACK component is composed of two competencies that are in the realm of teacher professional competence, namely pedagogical competence and professional competence (mastery of learning material) (Nofrion *et al.*, 2018). However, information about the ability of TPACK science teachers in Indonesia, especially in the city of Banda Aceh, is not yet available. Likewise, with information about the contribution of content knowledge, pedagogy, and technology in the formation of science teacher TPACK. Both of these information is very useful in helping teachers to improve the professionalism and quality of their learning.

In general, research on teacher TPACK that has been conducted is divided into four broad groups. First, research that focuses on identifying teacher TPACK abilities (Canbazoglu Bilici *et al.*, 2016; Jang & Tsai, 2013; Tondeur *et al.*, 2017; Yeh *et al*, 2017). Second, research aimed at developing TPACK instruments (Bilici *et al.*, 2013; Chai *et al.*, 2011; Giannakos *et al.*, 2015; Kabakci Yurdakul *et al*., 2014; Kaplon-Schilis & Lyublinskaya, 2019; Önal, 2016). Third, research that focuses on developing teacher TPACK, such as developing teacher TPACK using Scaffolded TPACK Lesson Design Model (STLDM) (Chai & Koh, 2017), video (Otrel-cass *et al*., 2012), and TPACK-based learning (Baran & Uygun, 2016; Tanak, 2018). Fourth, exploration of TPACK's relationship with other variables, such as TPACK with competence and attitude towards technology integration (Kabakci Yurdakul & Coklar, 2014; Yulisman *et al.*, 2019), cyber wellness (Chai *et al.*, 2012), self-regulation (Chen & Jang, 2018), self-efficacy and cognitive style (López-Vargas *et al.*, 2017), and student learning outcomes (Farrell & Hamed, 2017).

Some research on TPACK that has been done in Indonesia still focuses on the description of TPACK's abilities and specifics on certain materials. For example, a study conducted by Lestari (2015) aimed at analyzing the level of TPACK capability of Biology teachers on nervous system material and Pusparini *et al.* (2017), which focuses on material circulatory and digestive systems. Both studies have shown the level of TPACK ability of teachers. However, the specifications of the material used narrow the TPACK information obtained from the teacher. Therefore, it is necessary to do a description on a broader scope; for example, in this case, it is a science subject. Besides, it is necessary to analyze the contribution of the components forming TPACK in order to obtain a comprehensive picture of the TPACK abilities of science teachers.

This study aims to obtain information about the ability of TPACK science teachers in Banda Aceh City and the contribution of content, pedagogy, and technology in the formation of TPACK. Information about TPACK's capabilities was obtained through descriptive statistical analysis. Furthermore, the contribution of content knowledge, pedagogy, and technology in the formation of TPACK was obtained through SEM-PLS modeling. The use of SEM-PLS involves the main components and integration of TPACK as a research variable. The results of this study will help build a more comprehensive picture of the model of the TPACK ability of science teachers, which in turn can improve the ability to integrate the technology of science teachers in the future. In line with these objectives, the following research questions are asked:

1. What is the science teacher's TPACK capability profile?
2. How do content, pedagogy, and technology knowledge contribute to the formation of the science teacher TPACK?

METHOD

This research uses a quantitative research approach with a survey research design. Samples were obtained using a total sampling technique involving 88 natural science teachers from 19 junior high schools in Banda Aceh City. Teacher data were obtained directly from the Banda Aceh City Education and Culture Office. For information deepening, interviews were conducted with two teachers who had training experience, namely instructors at the Subject Teachers' Consultative Program (MGMP) as well as the chair of one of the Science MGMPs in Banda Aceh City and instructors who often provided training in the use of multimedia in Aceh Province.

Data on the ability of TPACK teachers was obtained by using 43 multiple-choice test questions. The question indicators are based on the TPACK instrument for 21st-century skills (TPACK-21) (Valtonen *et al*., 2018; Valtonen *et al.*, 2017) and TPACK survey for Meaningful Learning (Chai *et al*., 2011; Deng *et al.*, 2017; Joyce Hwee Ling *et al.*, 2013). The instrument pays attention to four skills needed in the 21st century, namely communication skills, collaboration, critical thinking, and creative thinking (Valtonen *et al.*, 2017; Valtonen *et al*., 2015) and five dimensions of meaningful learning (2015) meaningful learning) such as active learning, cooperative learning, constructive learning, intentional learning, and authentic learning (Joyce Hwee Ling *et al.*, 2013). Specifically, for knowledge content (CK) and pedagogy (PK), the indicators used to refer to the Academic Qualification Standards and Teacher Competencies (National Education Standards Agency, 2007).

Before being used, the test questions were validated by expert lecturers and tested on 55 samples that had the same characteristics as the research samples, namely teachers who had or were teaching science, biology, physics, or chemistry. The trial instrument was distributed using the Google Form. The analysis shows that the instrument has high reliability (Cronbach's alpha = 0.847). Furthermore, the results of the validity test showed that two items were invalid so that the questions given to the teacher consisted of 43 items (the first instrument consisted of 45 items).

The distribution of questions was carried out directly (direct administration to a group) (Fraenkel *et al.*, 2012) through training activities conducted by researchers in collaboration with the Teaching and Education Faculty of Syiah Kuala University and the Banda Aceh City Education and Culture Office. Data analysis was performed in descriptive and inferential statistics. Descriptive statistical analysis is done by making the percentage of correct answers on each item. Next, the percentage of each TPACK component is determined based on the average percentage of the percentage of correct answers on each item. The inferential statistical analysis begins by adding up the correct answers for each TPACK component. Furthermore, the value of each component is evaluated using the Partial Least Square (PLS) approach supported by SmartPLS 3.2.8 software (Ringle *et al*., 2015).

The research variables consist of three exogenous variables (the main component of TPACK) and four endogenous variables (the TPACK integration component). Further explanation regarding variables, indicators, and indicator codes used in SEM-PLS is shown in Table 1.

Table 1. Variables, Indicators, and Research Indicator Codes

Variable	**Indicator**	**Code**
TK	The skill of using technology efficiently	TK1
	Interest in following the latest technological developments	TK2
CK	Understand the concepts, laws, and theories of Natural Sciences and their application	CK1
	Able to develop science learning materials	CK2
PK	Mastering the characteristics of students	PK1
	Organizing educational activities that educate	PK2
	Developing students' potential (critical thinking, creative thinking, collaboration, communication)	PK3
	Communicate effectively, empathically, and politely with students	PK4
	Carry out assessment and evaluation of processes and learning outcomes	PK5
PCK	Able to develop science learning materials that support the potential of students (critical thinking, creative thinking, collaboration, communication)	PCK1
	Able to carry out learning activities that are following science learning materials	PCK2
TCK	Able to use technology to represent science material	TCK1
	Able to use technology to develop science learning materials	TCK2
TPK	Able to use technology to support learning activities	TPK1
	Able to use technology that supports the independence and communication of students	TPK2

Variable	Indicator	Code
	Being able to use technology that supports students' thinking skills (critical and creative thinking)	TPK3
TPCK	Able to carry out technology-based learning activities following science learning materials effectively	TPACK1
	Able to develop and share information about productive technology-based learning activities	TPACK2

Model evaluation in PLS includes two stages, namely, evaluation of the measurement model and evaluation of the structural model. Evaluation of the measurement model consists of convergent and discriminant validity and reliability. Convergent validity is seen from the loading factor and average value extracted (AVE). Discriminant validity can be seen from the value of cross loading and comparison of AVE square root with the correlation value between constructs. Reliability can be seen from the value of composite reliability (CR). Next, the structural model evaluation is seen from the value of R^2 for endogenous variables, effect size (f^2), and Q^2 to see the relevance of predictions from the model being built. The evaluation criteria for the PLS model (Ghozali, 2014; Ghozali & Latan, 2015) are shown in Table 2.

Table 2. Summary of Rule of Thumb Evaluation of Measurement and Structural Models

Criteria	Rule of thumb
Evaluation of Measurement Models with Reflexive Indicators	
Loading factor	0,50 - 0,60
AVE	> 0,50
Cross Loading	>0,70
AVE square root and correlation between latent constructs	AVE square root > correlation between latent constructs
CR	> 0.60
Evaluation of Structural Models	
R^2	0.67 (strong), 0.33 (moderate), and 0.19 (weak)
f^2	0.02 (small), 0.15 (medium) and 0.35 (large)
Q^2	Q2 > 0 has predictive relevance Q2 < 0 lacks predictive relevance

RESULT AND DISCUSSION

Based on the research question, the results and discussion are carried out in two stages. The first stage is a descriptive statistical analysis that is used to answer the first question. Next, inferential analysis is used to answer the second question.

Descriptive Statistics Analysis Results show that content knowledge (CK) is a component with the highest percentage among the main components and integration components. Furthermore, the three main components have a high percentage compared to the integration component. These results indicate that the ability of teachers to master learning material is higher than other professional abilities. In accordance with the results of the interview, high content knowledge is caused by three factors. First, the teacher considers that learning activities will be more natural to carry out if the teacher has good content knowledge. Second, the MGMP activities carried out focus on increasing content knowledge. Third, the teacher considers pedagogical and technological knowledge can be improved if the content knowledge is excellent.

Furthermore, according to Faisal & Martin (2019), external factors such as the National Examination (UN) and the National Standard School Examination (USBN) also have an impact on strengthening teacher content knowledge. These two factors force the teacher to carry out test-oriented learning activities. That is because both tests will have an impact on school performance. Therefore, teachers are very concerned about their content knowledge (CK).

In the TPACK integration component, pedagogical content knowledge (PCK) is the component with the highest percentage compared to other TPACK integration components (Figure 2). PCK ability is a good indicator of the quality of learning done by teachers and illustrates the ability of teachers to carry out learning following the thematic approach (Putra *et al.*, 2017). These results indicate that teachers can carry out learning activities that are appropriate between the content being taught and the principles of pedagogy and show good quality of learning. Based on the results of interviews, the high PCK is influenced by the habits of teachers to exchange information about how to teach particular material when they gather at Course-Based Teacher's Learning Community (MGMP) activities.

The results of this study indicate the existence of two anomalies. First, the high percentage of main components does not make the percentage of integration components also high. Second, all integration components that intersect with the technological knowledge component have a low percentage.

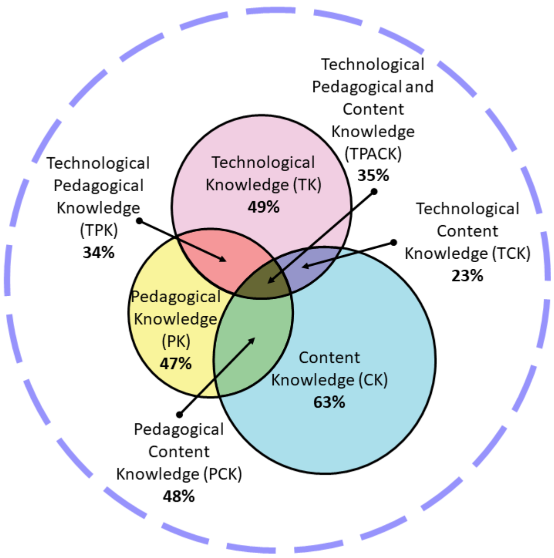

Figure 2. Capability Profile of Banda Aceh Science Teacher TPACK

The first anomaly shows that the high percentage of main components does not make the percentage of integration components also high. Koh *et al.* (2010) show that a high percentage of the main components does not necessarily result in a high percentage of integration components. That is, teachers do not have enough ability to combine the three knowledge to help their learning activities. For example, a high percentage of CK and TK does not make a high percentage of TCK. This is caused by teachers not yet fluent and flexible in combining the main components and integration, so they have not been able to carry out activities based on these integration components (Kimmons, 2015). Research conducted by Pusparini *et al.* (2017) also showed the same results, namely high TK did not make TCK also high. Based on these results, the problem is caused by the sample still confused in choosing the appropriate technology for the learning material.

The second anomalist shows that all components of integration that intersect with the components of technological knowledge have a low percentage. The technology knowledge component (TK) of teachers has the second-highest percentage after the component of content knowledgeability (CK). These results indicate that teachers cannot use technology to support learning activities or support them in preparing learning materials.

Based on the results of interviews with teachers, information was obtained that the problem was caused by age factors of teachers and technology training that teachers often followed. Activities carried out often focus on how to use technology, rather than focusing on how to integrate technology into learning activities.

Other results show that age and the form of training support are two factors that significantly influence the ability of teachers to integrate technology into learning activities, where the age factor has a negative relationship. That is, the higher the teacher's age, the lower the ability to integrate technology (Hwee & Koh, 2011; Karaca *et al.*, , 2013; Joyce Hwee Ling *et al.*, 2014; Luik, Taimalu, & Suviste, 2018; Vongkulluksn *et al.*, 2018).

The above description shows several anomalies that need to be explained further. The explanation is focused on how the three main components contribute to the formation of the TPACK for science teachers. Further explanation regarding the formation of TPACK capability is explained using the SEM-PLS approach.

Results of Inferential Statistical Analysis Using the SEM-PLS Approach consist of an evaluation of measurement models and structural models. Evaluation of the measurement model (outer model) is used to evaluate the relationship between the construct and its indicators. Evaluation of the measurement results model is focused on testing the validity and reliability of each construct presentations. Evaluation of measurement models is divided into two, namely convergent validity and discriminant validity. Convergent validity is evaluated through two stages, namely measuring the loading factor value and the extracted average variance (AVE) value. Furthermore, discriminant validity is evaluated through 2 stages, namely by measuring the cross-loading value and comparing the correlation between constructs and the roots of AVE. Furthermore, the reliability test is carried out by looking at composite reliability (Ghozali, 2014; Ghozali & Latan, 2015; Wong, 2013).

Evaluation of the measurement model is carried out twice. In the first evaluation, the researcher issues an indicator that has a loading factor value below 0.5 (Figure 3). This is done because if it still maintains an indicator with a value of 0.5, the composite reliability value will be below 0.6. After all indicators with values below 0.5 have been issued, re-estimation is carried out. The re-estimation results (Figure 4) of the measurement model are as follows.

The first requirement that must be fulfilled in SEM-PLS analysis is the value of convergent validity in the form of the loading factor value (the correlation between the indicator and its latent construct) for each indicator used in the model must be higher than 0.60. The results of the evaluation that have been carried out (Table 3) show that there are no indicators with values below 0.5. Furthermore, the AVE value for each construct that is required must be greater than 0.5. Table 3 shows that all constructs have AVE values greater than 0.5. This shows that the convergent validity value is appropriate for the next stage of the calculation.

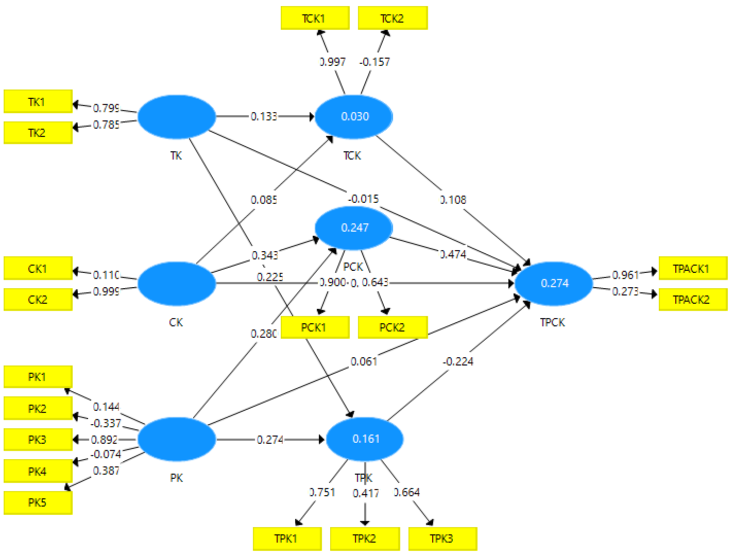

Figure 3. Path Chart with Loading Values

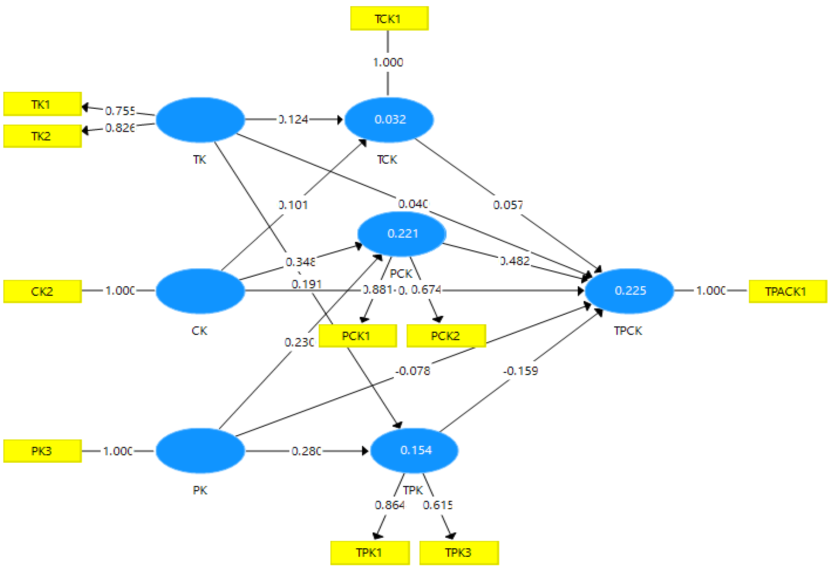

Figure 4. Final Path Chart of Re-estimation Results

The reliability value in this study is seen from the composite reliability value, not the Cronbach's alpha value. This is due to the value of Cronbach's alpha in SEM-PLS is lower (under-estimate) compared to the value of composite reliability (Ghozali & Latan, 2015; Wong, 2013). Based on Table 3, all research variables have values greater than 0.7. This shows that all variables have good reliability and can be continued for further calculations.

Table 3. Convergent Validity and Reliability

Variable	Indicator	Loading	AVE	CR
CK	CK2	1,00	1,00	1,00
PCK	PCK1	0,88	0,62	0,76
	PCK2	0,67		
PK	PK3	1,00	1,00	1,00
TCK	TCK1	1,00	1,00	1,00
TK	TK1	0,76	0,63	0,77
	TK2	0,83		
TPCK	TPACK1	1,00	1,00	1,00
TPK	TPKI	0,86	0,56	0,71

The next requirement is that each discriminant validity value for each construct must meet the requirements, cross-loading value > 0.70, and the AVE root value of each construct must be higher than the correlation value between each construct. The cross-loading value is not displayed because the value is the same as the loading value (Table 3). Next, the comparison between the correlation value between constructs and AVE square root is as follows.

Table 4. Correlation Value between Constructions

	CK	PCK	PK	TCK	TK	TPCK	TPK
CK	1,00	0,41	0,29	0,13	0,24	0,22	0,39
PCK	0,41	1,00	0,33	0,08	0,24	0,44	0,40
PK	0,29	0,33	1,00	0,03	0,36	0,07	0,35
TCK	0,13	0,08	0,03	1,00	0,15	0,07	0,24
TK	0,24	0,24	0,36	0,15	1,00	0,11	0,29
TPCK	0,22	0,44	0,07	0,07	0,11	1,00	0,06
TPK	0,39	0,40	0,35	0,24	0,29	0,06	1,00

Table 4 shows that all AVE root values are higher than the correlation values between constructs (Table 5). This shows that all variables meet the discriminant validity criteria so that they can proceed with the next calculation phase.

Table 5. AVE Roots and Discriminant Validity

Variable	AVE Roots	Discriminant Validity
CK	1	Satisfied
PCK	0,79	Satisfied
PK	1	Satisfied
TCK	1	Satisfied
TK	0,79	Satisfied
TPCK	1	Satisfied
TPK	0,75	Satisfied

The structural model (inner model) is a model that describes the relationship between latent variables that are evaluated using R^2, f^2, and Q^2, and path coefficients. In the SmartPLS software, R^2 and f^2 values are obtained through PLS Algorithm, and path coefficient values are obtained through bootstrapping. Next, the Q^2 value is obtained using formula (1).

$$Q^2 = 1 - \left(1 - {R_1}^2\right)\left(1 - {R_2}^2\right)\left(1 - {R_3}^2\right)\left(1 - {R_4}^2\right) \ldots (1)$$

Table 6. R^2 Value and Rating Between Variable Relationships

Variable	R^2	Rate
PCK (R_1)	0,22	Weak
TCK (R_2)	0,03	There is no relationship
TPK (R_3)	0,15	There is no relationship
TPCK (R_4)	0,23	Weak

Based on Table 4, the model built is only able to describe the relationship between PCK and TPCK. R^2 for PCK is 0.22, which means that the variability of the PCK construct that can be explained by the PK and CK constructs is 22%. Furthermore, the R^2 value for TPCK is 0.23, which means that the variability of the TPCK construct that can be explained by the constructs of CK, PK, TK, TPK, TCK, and PCK is 23%. Based on formula (1), a Q^2 value of 0.505 > 0 is obtained, which means the model has a predictive relevance or is able to show the reality of phenomena in the field (Jaya & Sumertajaya, 2008). Next, the significance test is obtained through the structural model path coefficients (Table 7).

Table 7. Structural Model Path Coefficients

Relationship	SD	T count	P Values
CK □ PCK	0,08	4,19	0,00*
CK □ TCK	0,11	0,93	0,35
CK □ TPACK	0,09	0,93	0,35
PCK □ TPACK	0,10	4,61	0,00*
PK □ PCK	0,10	2,28	0,02*
PK □ TPACK	0,11	0,68	0,50
PK □ TPK	0,12	2,36	0,02*
TCK □ TPACK	0,10	0,58	0,56
TK □ TCK	0,12	1,07	0,28
TK □ TPACK	0,11	0,36	0,72
TK □ TPK	0,14	1,41	0,16
TPK □ TPACK	0.16	1,03	0,31

Note: * = there is a significant influence

Table 7 shows that there are four relationships between variables that have a significant influence, namely the relationship between PCK and TPCK, CK with PCK, PK with TPK, and PK with PCK. The results of this study indicate that content knowledge (CK) and pedagogical knowledge contribute indirectly to the formation of science teacher TPACK. This is shown by CK and PK influencing PCK, where PCK directly contributes to the formation of teacher TPACKs. Next, to see how big the significance of the relationship is, continue with the f^2 test. The results of f^2 are as follows.

Table 8. f^2 values for each relationship between variables

Relationship	f^2	Description
CK□PCK	0,143	Small
CK□TCK	0,010	There is no effect
CK□TPACK	0,007	There is no effect
PCK□TPACK	0,220	Intermediate
PK□PCK	0,062	Small
PK□TPACK	0,006	There is no effect
PK□TPK	0,081	Small
TCK□TPACK	0,004	There is no effect
TK □ TCK	0,015	There is no effect
TK□TPACK	0,002	There is no effect
TK□TPK	0,037	Small
TPK□TPACK	0,023	Small

Based on Table 8, it is known that all variables that have a significant relationship show a small effect size, except the relationship between PCK and TPACK, which has an effect size with an intermediate category. These results show that the TPACK ability of science teachers in Banda Aceh is indirectly determined by CK and PK. Furthermore, the TPACK teacher's ability is directly determined by the PCK's ability. According to Widodo (2017), "although PCK may not be directly related to the quality of teacher teaching, however, PCK can be a good indicator of the potential of teachers to deliver quality teaching." Based on the findings and discussion above, junior high school science teachers in Banda Aceh City need to focus on improving the ability to use technology effectively in learning activities to form a comprehensive TPACK.

The results of modeling using SEM-PLS are in line with the results of descriptive statistics. These results can be seen from all components that intersect with technology (TK) shows a low percentage. This shows that technological knowledge (TK) did not contribute to the formation of the TPACK for junior high school science teachers in Banda Aceh City. That is, teachers cannot determine technologies that are appropriate to the content and pedagogy effectively. According to Baturay et al. (2017), daily computer use can positively predict computer use competencies. This means that the low ability of teachers in TCK, TPK, and TPACK is due to the low frequency of using technology in learning activities.

The results of this study differed partially from the results of research conducted by Nordin *et al.,* (2016), where the relationship between TPK and TPACK, and TCK with TPACK has a significant relationship. Furthermore, the results of this study indicate that there is a significant relationship similar to the findings of researchers, namely the relationship between PCK and TPACK, meaning that PCK is an indicator in compiling TPACK capabilities.

The results of other studies conducted by Hwee & Koh (2011) show that TK, PK, and CK are significant indicators of TPACK, where PK is the component with the most influence. The results of this study partially support the findings of this study, where PK and CK are influential components in shaping the ability of TPACK teachers.

According to Kaplon-Schilis & Lyublinskaya (2019), TPACK's ability is different from content knowledge (CK), pedagogy (PK), and technology (TK) individually. TK, PK, and CK knowledge are independent types of knowledge. The independent development of TK, PK, and CK teacher knowledge does not guarantee the overall development of their TPACK. Therefore, teacher TPACK development must be carried out comprehensively and comprehensively, not based on the separate TPACK component.

CONCLUSION

Profile of TPACK ability of junior high school science teachers in Banda Aceh City is dominated by content knowledge. Furthermore, pedagogical content knowledge (PCK) is the component with the highest percentage compared to other TPACK integration components. The results of the SEM-PLS analysis showed that there was a significant relationship between PCK and TPCK, CK with PCK, PK with TPK, and PK with PCK. That is, the components of content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK) contribute to the formation of a junior high school science teacher TPACK in Banda Aceh City.

The results of this study provide information that teachers already have the ability of CK, PK, and PCK, who directly and indirectly contribute to the formation of their TPACK. However, they still need attention and guidance in improving their technological knowledge (TK). Therefore, the government and education providers are expected to assist teachers in providing facilities and training in the effective use of technology in learning activities.

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