Technological Pedagogical Knowledge Factors for Professional Teacher Candidates in Elementary Schools: A Structural Equation Model

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Abstracts: Technological pedagogical knowledge is quite a serious issue and is a problem today. This is based on conditions in the field which show that not all teachers are well prepared with this knowledge. This study aims to empirically find factors that influence the technological and pedagogical knowledge of prospective professional teachers in elementary schools. This research is survey research using a quantitative approach. This research design uses a structural equation model. This design involves four variables, namely content knowledge, technological knowledge, pedagogical knowledge and technological and pedagogical knowledge. The subjects of this research were participants in professional teacher education in Indonesia. The sample participants for this study were randomly selected as many as 151 participants. The data collection technique for this research was carried out using a questionnaire. The research instrument measures four variables using 12 measuring items which are indicators for variable measurement. Data were analyzed by structural equation model. The research results show that an important factor that has a dominant effect on the formation of teachers' technological pedagogical knowledge is good technological knowledge. In addition, pedagogical knowledge is also one of the triggers for technological pedagogy knowledge. Although based on empirical findings, the influence of this knowledge is not as great as technological knowledge. Furthermore, the factor of technological pedagogical knowledge is also indirectly shown in the content knowledge variable. The findings of this study explain that there is a fairly strong indirect effect.

Keywords: Technological Pedagogical Knowledge; Professional Teacher Candidates; Elementary Schools; Structural Equation Model.

1. INTRODUCTION

Pedagogy and technology are currently central issues that are much questioned in preparing qualified teachers [1]. Teachers are not only required to master the content of the material they will teach, but more than that. Teachers are expected to be able to design teaching materials so that they can be delivered successfully to their students [2]. This is not an easy matter for a teacher. To achieve this goal, teachers need to have good pedagogical skills and adequate mastery of learning technology [3]. This is very important because no matter how good the knowledge related to the content of the material from the teacher is, if it is not supported by educational abilities and mastery of technology, the learning objectives will not be achieved optimally [4].

Pedagogical knowledge is quite important for teacher candidates [5]. Through this ability, teachers can understand students by utilizing the principles of cognitive development of students and teachers can understand student personality development and reflect on it in the learning process [6]. This is very important because it is a special skill that must be possessed by teachers to carry out their learning with students and support the achievement of maximum learning outcomes [7].

Pedagogical knowledge is knowledge about learning for students such as learning methods, detailed learning theories and techniques for successful student learning [8]. Through good pedagogical knowledge from the teacher, students can fulfil their curiosity. Students have the courage to think and the ability to solve problems and feel more comfortable in their learning activities. In addition, if the teacher can understand the personality development of students and make use of it, students will have a stable personality and have self-confidence and students will easily adapt.

Apart from pedagogical knowledge, technological knowledge is also very important for teachers today. Understanding technology is as important as other aspects, which is very relevant to computer-based activities in schools today [9]. Therefore, content knowledge is also important for students so that teachers and students can collaborate and communicate more effectively. With the help of technology, students can learn at their own pace and focus on areas of improvement [10]. This can also help teachers understand students' individual needs and provide appropriate teaching materials. In line with (Tanak, 2018) which states that students who are able to utilize technology in learning can connect any material provided by the teacher with the understanding they gain themselves. Teachers can use this to measure the extent of students' ability to understand the information received.

Phenomena in the field show that knowledge of technology and pedagogy is still a record for prospective professional teachers to improve. Knowledge of technology and pedagogy is still considered not optimal and needs to be improved. In line with that, the trend of teachers in today's era is required to keep up with technological developments. In addition, through this technological knowledge it can be integrated with pedagogical knowledge so that it can deliver maximum lesson content to students. This is very important because the professional teacher is the center that determines the success of the learning process [11].

Scientific analysis and findings regarding the technological and pedagogical knowledge of prospective professional teachers are very important information for educational policy makers, including in Indonesia. The government needs to prepare professional teacher candidates to realize national education goals. Especially at the elementary school level, quality and professional teacher assistance is really needed. In theory, many factors have the potential to trigger increased technological knowledge and teacher pedagogy. This study aims to empirically find factors that influence the technological and pedagogical knowledge of prospective professional teachers in elementary schools.

2. LITERATURE REVIEW

2.1. Content Knowledge

Content knowledge is knowledge or understanding of subject matter in a particular field of knowledge that is taught to students in relation to factual concepts, theoretical principles, and information related to that lesson [12]. As the party that provides information, the teacher needs to understand the subject being taught to students, so that they can convey the material clearly and logically and easily understood by students. Teachers with greater content knowledge have a greater impact on student achievement [13]. This means that the wider the knowledge of the subject matter possessed by the teacher, the more information is given to students so that it can improve student achievement. Everyone has different content knowledge according to the expertise they have [14]. Therefore, it is important for teachers to deepen their understanding of subject matter according to the field being studied or occupied.

One of the reasons for the lack of effectiveness of teaching in education in general is the teacher's lack of content knowledge [15]. Lesson-optimal learning takes place, no feedback is given by students. Content knowledge is generally required to perform certain activities, such as knowledge of rules, techniques, and tactics specific content knowledge involves knowledge of errors, content representations, and instructional tasks required to teach certain activities [16]. As in education, content knowledge is also needed to understand how to convey learning that can be easily accepted by students. Teachers who have a deep understanding of the subject matter must have different teaching strategies for novice students and students who are more advanced in the field [17].

2.2. Technology Knowledge

Technology knowledge is knowledge about technology that includes an understanding of the concepts, principles and applications of technology in various fields [18]. In the field of education, technological knowledge is used to facilitate learning. This technological knowledge can be addressed through creative work where the emphasis is on the creative process, not on the product [19]. Teachers can take advantage of technology by making learning content more varied and interesting which can help students learn efficiently. The technological

competence of teachers allows them to adapt other teaching strategies and approaches so that performance increases [20]. This shows the important role of technology in supporting learning which has an impact on student learning outcomes.

Along with the rapid development of technology, technological knowledge must continue to be developed to be able to adapt. One of the benefits of technology in education is to provide wider access to information [21]. Technology allows easy access to educational resources and seeks further information on certain topics as well as accessing relevant information [22]. In line with current learning that is based on the use of technology in the learning process such as ebooks, scientific journals, and learning videos that can be accessed easily. Students easily access learning and teachers can provide directions or facilitate students to find literature that is appropriate to learning that is in accordance with learning objectives.

2.3. Pedagogical Knowledge

Pedagogical knowledge is a teacher's in-depth knowledge about processes and practices or teaching and learning methods [23]. This includes an understanding of how students learn, how to deliver good learning material, and how to evaluate and improve their learning. High pedagogical knowledge will be in line with reflective abilities, where teachers can think critically to find solutions to previously encountered problems so that they can create effective learning [24]. This can assist teachers in developing teaching strategies that suit the needs of students. Teachers can use effective learning methods, choose the right resources, and present material in an interesting and relevant way. Having pedagogical knowledge is a way to reduce pressure in learning [25].

Teachers who have pedagogical competence will manifest themselves in learning interactions with students such as paying attention, serving, appreciating, listening, strengthening by giving positive words, being guided, and providing lessons that can develop their potential [26]. It can be seen that pedagogic ability is the art of teaching to provide a coherent learning experience for students. Pedagogic competence is the basis for preparing teachers who have formative ethics [27]. The inability to prepare good pedagogical competencies will have an impact on education in the next generation, because pedagogy in the role and function of teachers is the best method in the learning process and quality of education. In line with [28] which revealed that teachers' pedagogical practices are more influential in improving student learning than using specific curriculum materials.

2.4. Technology Pedagogical Knowledge

Technology pedagogical knowledge is an understanding of how to use technology to motivate students, improve teaching and for assessment activities [29]. Teachers are required to utilize technological tools and resources to create interesting learning designs. The application of technology in education is based on the assumption that technology can facilitate deep learning processes which should contribute substantially to students' academic success [30]. Through rapidly developing technology, various educational tools have been developed to provide students with more learning opportunities [31]. Therefore, teachers have an important role in the success and progress of the application of educational technology.

Teachers with strong TPK can design technology tools and resources that suit specific content and learning goals (Lee et al., 2022). Teachers can design interactive learning with the help of technology to increase student understanding and encourage critical thinking, creativity, collaboration and problem-solving skills. Apart from that, teachers also need to understand which specific technologies are suitable for use in the learning they teach [32]. Understanding TPK means knowing the pedagogical capabilities and constraints of various technological tools related to pedagogical design and strategies that are appropriate to the discipline and development [33]. This is because technology programs are designed not only for educational purposes, but most software is also rarely created as a solution to a pedagogical problem.

3. METHOD

This research is survey research using a quantitative approach. The research approach was carried out to find empirical factors that influence technological and pedagogical knowledge of prospective professional teachers in elementary schools. This research design uses a structural equation model. This design involves four variables, namely content knowledge, technological knowledge, pedagogical knowledge and technological and pedagogical knowledge.

The subjects of this research were participants in professional teacher education in Indonesia. These participants are prospective professional teachers who are taking part in the teacher development program which is a national program of the Indonesian government. The research subjects used were 150 participants who were prospective professional teachers at elementary school level in Indonesia. The selection of these subjects was carried out randomly in the survey.

The data collection technique for this research was carried out using a questionnaire. The research instrument was designed in the form of an online form that participants could fill out online. This filling can be done via computer, laptop, smart-phone, or other online media. The research instrument measures four variables using 12 measuring items which are indicators for variable measurement. In the following, the distribution of measuring items in the research data collection instrument is presented.

Table 2: Distribution of measuring items in research data collection instruments

Codes	Indicators	Variables
CK1	Knowledge of the main subject being taught	Content Knowledge
CK2	Knowledge of the latest developments and applications in the area of content being taught	
CK3	Knowledge of the latest updated resources in the content area taught	
TK1	Knowledge of computer and laptop technical issues	Technology Knowledge
TK2	Knowledge of digital media	
TK3	Knowledge of internet and networks	
PK1	Knowledge of learning theories and approaches	Pedagogy Knowledge
PK2	Knowledge of student characteristics	
PK3	Knowledge of classroom management	
TPK1	Knowledge in choosing the appropriate technology for teaching approaches and strategies	Technological Pedagogical Knowledge
TPK2	Knowledge in using computer applications that support student learning	
TPK3	Knowledge in selecting technologies that are useful for a teaching career	

The collected research data was analyzed using structural equation modeling analysis. The significance of the effects between variables was tested using t-value. The effect size between variables was analyzed using factor loading. Furthermore, testing the suitability of the model uses the Root Mean Square Error of Approximation (RMSEA), p-value and chi-square criteria.

4. RESULT

The results of this research are presented based on the research objective namely, to prove the factors that influence the technological knowledge and pedagogy of prospective professional teachers in elementary schools. The characteristics of the sample in this study were participants in teacher professional education in Indonesia. These participants are prepared by the Indonesian Government to become professional elementary school teachers in the future. The research design was carried out using a structural equation model involving exogenous and endogenous variables. The exogenous variable in this research is content knowledge (CK). Furthermore, endogenous variables include technological knowledge (TK), pedagogical knowledge (PK) and technological pedagogical knowledge (TPK).

4.1. Results of Testing the Significance of Effects between Variables

The first analysis performed tested the significance of the effect between variables. This test is carried out using the t-value in the structural equation model. This is done to prove the significance of the effect between variables according to the structural equation model that has been developed theoretically. The findings related to the results of testing the effect between these variables are presented as follows.

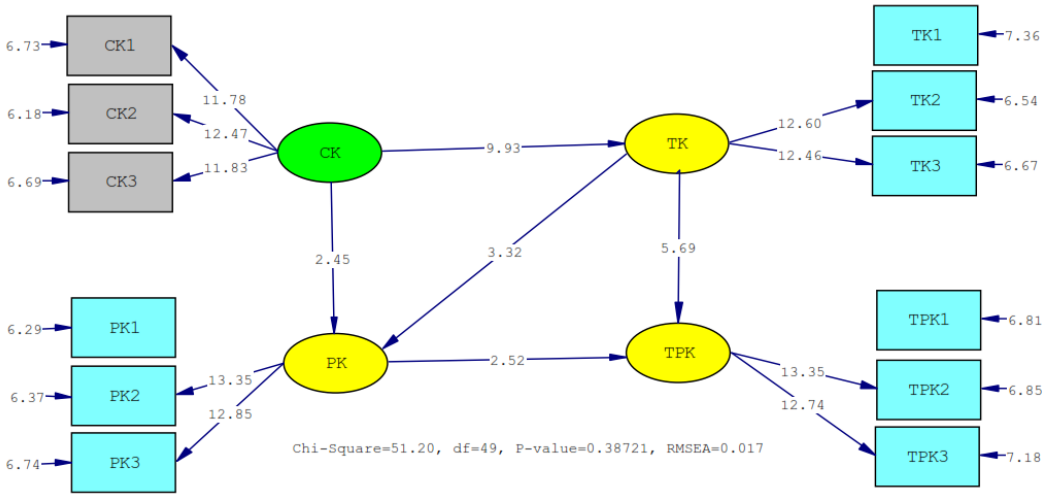

Figure 1: Results of testing the significance of effects between variables with t-value

Figure 1 presents the results of the analysis of significance testing for effects between variables based on the t-value parameter. If viewed based on the t-value, the effect of the exogenous variable can be said to be significant on the endogenous variable if the t-value coefficient is more than 1.9 [34], [35]. Therefore, based on the information presented in Figure 1, it can be explained that all relationships between variables in this research design have a significant effect. This means that there is no relationship between variables that is not significant.

If explained in detail, it can be explained that content knowledge has a significant direct effect on technological knowledge. Second, content knowledge has a significant direct effect on pedagogical knowledge. Third, technological knowledge has a significant direct effect on pedagogical knowledge. Fourth, technological knowledge also has a significant direct effect on technological pedagogical knowledge. Fifth, pedagogical knowledge has a significant direct effect on technological pedagogical knowledge.

4.2. Results of Factor Loading Analysis of Effects between Variables

The findings based on the results of the previous analysis show that all pathways have a significant effect from exogenous variables to endogenous variables. The next thing analyzed in this research is the magnitude of the effect of exogenous variables on endogenous variables. This is done through factor loading analysis between variables. In summary, the findings related to the factor loading analysis are presented as follows.

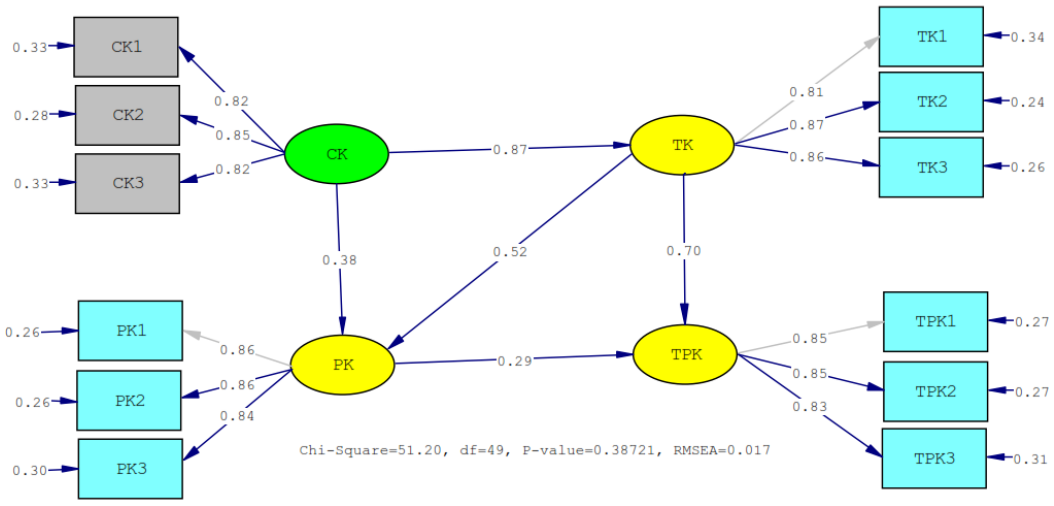

Figure 2: Results of factor loading analysis

Figure 2 presents the results of the loading factor analysis for all variables observed in this study. Based on the information from Figure 2, it can be classified that the strength of the effect between variables was found to vary. Variations in the strength of these effects range from moderate effects to strong effects. If we look at the technological pedagogical knowledge variable as the main focus, it can be found that technological knowledge has the strongest effect on influencing the technological pedagogical knowledge of prospective professional teachers in elementary schools. This is indicated by the factor loading coefficient which is quite high, namely at a score of 0.7. Apart from that, pedagogical knowledge also has an effect on technological pedagogical knowledge, but the loading factor is only 0.29, not as big as technological knowledge.

Previous findings show that technological knowledge has a strong effect on technological pedagogical knowledge. However, it also needs to be understood that technological knowledge is also influenced with quite a high effect by the content knowledge variable. This result is proven by the finding of a loading factor coefficient of 0.87. This figure is quite high. This means that content knowledge also contributes to strengthening the technological knowledge of prospective professional teachers in elementary schools. Apart from that, the results of the analysis also found information that pedagogical knowledge was also supported by elementary school teachers' content knowledge and technology knowledge.

4.3. Summary of Total Effects between Variables

The previous section has described some information related to the direct effect between the variables observed in this study. However, in more detail, the effect between variables is not only based on direct effects. In addition to direct effects, the relationship between variables can also be triggered by indirect effects. This section describes the results of the total effect summary between variables in this study. This was done to find clearer conclusions regarding the relationship between variables based on the research design that has been prepared. The results related to the total effect summary are described as follows.

Table 3: Summary of Total Effects between Variables

No	Effect Path	Direct	Indirect	Total Effect
1	CK – TK	0,87	-	0,87
2	CK – PK	0,38	-	0,38
3	CK – TPK		0,71	0,71
4	TK – PK	0,52	-	0,52
5	TK – TPK	0,70	0,15	0,85
6	PK – TPK	0,29	-	0,29

Table 3 presents information related to direct effects and direct effects between variables. These two things are the basis for the total effect between variables. Based on this information, it can be explained that technological pedagogical knowledge is influenced by technological knowledge with quite strong effects. Even though pedagogical knowledge also has a significant effect on technological pedagogical knowledge, the effect of this variable is not very strong. An interesting point found based on the results of this analysis is the existence of the content knowledge variable. In the analysis findings, the content knowledge variable also has a high effect even though this variable only has an indirect effect. This situation also needs attention in developing technological pedagogical knowledge towards its maximum potential.

4.4. Model Fit Test Results

One aspect that is quite important to review in a structural equation model is testing the goodness of fit model. This is done to find and prove whether the theoretical model that has been prepared previously has a match with the empirical data that has been used in this study. This test was carried out using the Root Mean Square Error of Approximation (RMSEA), p-value and chi-square criteria.

Based on empirical testing, the results show that the RMSEA model coefficient is 0.017 with a p-value of 0.38 and a chi-square coefficient of 51.2. These results indicate that the empirical findings obtained from this study have compatibility with the theoretical model hypothesized in the previous theory. This is based on the fact that the RMSEA is smaller than 0.08, the p-value is greater than 0.05 and the chi-square is smaller than 2df. Therefore, in general the model formulated in this study meets the goodness of fit model criteria.

5. DISCUSSION

This research was conducted on the basis of the importance of teacher pedagogical and technological knowledge in educational and learning practices in the field. This is supported by the trend of the times, the role of technology in community activities is increasingly important. Likewise in the field of education and pedagogy specifically. Technology is the basis of knowledge that must be owned by a teacher. The Indonesian Government's national program has prepared prospective professional teachers to educate the next generation of the Indonesian nation. One of them is the Teacher Professional Education Program. This program was held to prepare and control prospective teachers who will serve in educational institutions and schools, including elementary schools.

This research focuses on the subject of prospective professional teachers who will work in elementary schools. If it is related to the findings of this research empirically, the technological pedagogical knowledge of the prospective professional teacher participants who are the subject of this research is more dominantly influenced by technological knowledge. This means that if teachers want to have good technological pedagogical knowledge, they must be prepared to have strong technological knowledge. Technological knowledge is very important for teachers today. Understanding technology is as important as other aspects, which is very relevant to computer-based activities in schools today [9]. Even after the pandemic hit the whole world, technological knowledge became the main need for teachers in carrying out their learning [3]. This is very important because it can help teachers understand students' individual needs and provide appropriate teaching materials.

Apart from technological knowledge, teachers need to be prepared to have pedagogical knowledge to support technological pedagogical knowledge. The empirical findings of this research also prove that there is a significant effect. Although the effect is not as large as technological knowledge, the effect of pedagogical knowledge also seems to be significant. This supports the importance of pedagogical knowledge for prospective professional teachers in elementary schools.

Pedagogical knowledge helps teachers to create an interactive learning environment and encourage active student participation. This is because pedagogical knowledge contains various methods that teachers can use to provide effective feedback [36]. A teacher must strategically plan which ambiguities and decisions students will face [37]. Teachers need to understand the diversity of students starting from differences in understanding material, learning styles, special needs to cultural backgrounds so that they can design learning that is comprehensive and

responsive to all student needs. This is in line with [38] which reveals that pedagogical competence has become a scientific tool and method that bridges the achievement gap and intrinsic quality due to social and economic inequality and improves personal quality and learning achievement.

The combination of technological knowledge and pedagogical knowledge is very important in forming technological pedagogical knowledge. This means that this knowledge needs special attention in the national teacher professional development program. Developing an understanding of technology requires the ability to learn and adapt to new technologies because technology changes frequently [39]. Various models of technology in learning are widely offered in the educational environment, waiting for teachers to be ready to adopt technological innovations in schools. Therefore, in technological pedagogical knowledge the teacher understands the planning and use of digital technology and decides on an effective plan organized by learning activities and content objectives [40]. Consistent with a framework that emphasizes content, pedagogy and technological knowledge [41]. In this case the teacher focuses on learning objectives, then selects and uses digital tools and other resources to help achieve learning goals.

Referring to the structural model developed in this study, content knowledge is one of the supporting variables for developing technological pedagogical knowledge. Although this variable does not have a direct effect, in the implementation of this study it becomes a variable that has a high indirect effect with a strong influence. This indicates that a teacher must have content knowledge to solidify technological pedagogical knowledge. With content knowledge, teachers can form technological pedagogical knowledge steadily.

Teachers with strong content knowledge can quickly detect student learning difficulties and provide appropriate interventions [42]. Teachers can develop different learning strategies to meet the individual needs of students. Understanding the diverse characteristics of students requires extensive content knowledge [43]. This can be developed through continuous professional learning such as training, seminars, reading various literature or collaborating with colleagues [44]. By increasing teachers' understanding of learning content, it can help meet students' needs for quality education and have a positive impact on their future.

CONCLUSION

This research has proven that an important factor that has a dominant effect on the formation of teachers' technological pedagogical knowledge is good technological knowledge. With technological knowledge, teachers will directly form technological pedagogical knowledge more easily. Basic knowledge of technology is very important for today's teachers. In addition, pedagogical knowledge is also one of the triggers for technological pedagogy knowledge. Although based on empirical findings, the influence of this knowledge is not as great as technological knowledge. Even so, pedagogical knowledge is an important trigger for teachers to pay attention to. Furthermore, the factor of technological pedagogical knowledge is also indirectly shown in the content knowledge variable. The findings of this study explain that there is a fairly strong indirect effect. This is the basis that content knowledge will support maximum technological knowledge so that this dominant effect can be used optimally in supporting technological pedagogical knowledge.

This study recommends strengthening technological pedagogical knowledge in national programs implemented to prepare prospective professional teachers, especially for elementary schools. This is very important to support the achievement of educational goals. The government must facilitate teachers in developing their technological knowledge. This is very necessary in undergoing and adapting to the times in various fields. Further studies are recommended in the area of strengthening content understanding. Studies on this topic are needed to strengthen the findings of this research and become an effort to develop a theory of professional development of the teaching profession.

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