A measurement model of technological pedagogical content knowledge (TPACK) in Indonesian senior mathematics teachers’ scenario

W N Yanuarto¹²*, S M Maat¹ and H Husnin¹

¹Center of Teaching and Learning Innovations, The National University of Malaysia, Malaysia.
²Department of Mathematics Education, Universitas Muhammadiyah Purwokerto, Indonesia.

*Corresponding author’s email: P92896@siswa.ukm.edu.my

Abstract. The TPACK is one of the primary knowledge for teachers understanding technology in the era of the industrial revolution 4.0. In education, teaching technology in the classroom can apply by looking at the TPACK stages teachers have. Teachers who have high stages in TPACK will facilitate their steps and movements in exploring technology in the classroom. This study aims to validate the TPACK measurement model, which consists of 30 items. A quantitative method of the cross-sectional survey is applied in this study. We used the questionnaire for gaining the data. TPACK instruments were distributed to 235 respondents. The analysis of this TPACK measurement model testing uses exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). All constructs revealed acceptable internal consistency reliability. A good model fit found for measurement models of TPACK using several fit index tests like CMIN/DF, GFI, CFI, TLI, and RMSEA. The findings showed that all fit indices criteria were fulfilled. It is concluded that the TPACK measurement model pictures the TPACK level of the senior mathematics teachers in the Indonesian scenario.

1. Introduction
The Industrial Revolution 4.0 had a widespread impact on humans. Humans experience fundamental changes with changes in technology. Humans with the era of technology provide new colours for the development of human thinking and lifestyle [1]. With technology, humans think faster [2] and make life more practical [3]. The human lifestyles, the technological era also makes people change their lifestyles [4]. Technology has both positive and negative impacts on human lifestyles. The decisive role of technology makes human life helpful and provides fast and broad information. It gives space and time as if nothing exists between humans. However, this has a harmful impact, humans can no longer have personal space to store and process their lives without other interventions [5]. Besides, information is easily spread, both for useful information and incorrect information [6].

In the cast, reducing negative human behaviour towards technology, education becomes a tool to reduce the negative behaviour and effects of technology [7]. The technological movement also changes the direction of education. Education needs to develop along with technological development [8] because education and technology are like two fundamental parts [9]. The technology movement
provides a stimulus for educational change [10]. Therefore, all humans need to think about an educational movement towards technological education.

Talking about the changes in technology in education, every element of education needs to open up. The teacher has a role in opening up insights in receiving and walking together with technology education [11]. The development of technology provides a challenge for teachers to develop the ability and knowledge of technology [12]. The teacher always understands these changes, so they need to think about their development and quality. Improving the quality of self-related to technology for teachers requires them to have technological knowledge [13]. Koehler et al. [14] in his study, it was presented the three basics knowledge in technology: technological knowledge, pedagogical knowledge, and content knowledge.

![Diagram of Indonesian TPACK construct](image)

**Figure 1.** Indonesian TPACK construct [14].

According to Koehler et al. [14], the three main pieces of knowledge produced seven knowledge of technology, including technological knowledge, pedagogical knowledge, content knowledge, pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge. Maesuri et al. [15], in their study, said that technological knowledge gives colour to changes in education in the current technological era. In line with the statement presented by Supianti [16] and Othman and Maat [17], pedagogical knowledge integrated with technology makes teaching innovative. Other cases in Malaysia [18], and China [19], knowledge of content pedagogy and technological knowledge are the two core knowledge possessed by teachers in secondary schools.

Mastery of TPACK is also indicating the success of teachers in seeing the importance of technology. TPACK levels can see in various parts of Indonesia. Some of the research that has been done related to TPACK include Jogjakarta, Semarang, Bengkulu, and Manado. TPACK levels in the Jogjakarta area exceptionally high school mathematics teachers are at a high level [20]. It indicates that the teacher has proficiency in technology and its use in mathematics teaching. The same study was occurred out in the
Semarang area [21]. He indicated that TPACK in the region was at a high level. Middle school teachers in Semarang have a good understanding of the importance of technology and the acquisition of technological knowledge for educational success. Differences occur in the Bengkulu region [22] and Manado [23], which indicate TPACK in the two regions is at a modest level. Different demographic levels from the previous region also caused TPACK levels to experience differences as well.

Other areas of Indonesia, such as Banyumas, located on the island of Java, have different demographic factors than the others. With an area of Banyumas, which is only half the area of Semarang has complete characteristics, namely urban areas and areas outside the city. Another difference is that the Banyumas region has highland and lowland areas [24]. Besides, the Banyumas region is consists of 17 subdistricts, and 94 secondary schools, where 45% of schools (urban and sub-urban) [24]. The position of the region can expect to have different TPACK levels from other regions of Indonesia. Therefore, in this study, the researcher deems it necessary to know the stages and levels of TPACK that exist in the Banyumas region, Indonesia.

2. Methods

2.1. Research design

This study employed a quantitative method of the cross-sectional survey [25]. This method provides a more detailed picture of a problem study [25]. Another justification for this cross-sectional survey has its advantages in collecting and analyzing data that can produce stronger and better quality research [26]. All data collected for the TPACK instrument analyzed using SPSS software before the SEM-AMOS version 24 application was analyzed. SEM-AMOS is a multivariate analysis technique that combines regression analysis, factor analysis and structural models [27]. SEM-AMOS also has several advantages that can test the relationship between complex and dynamic variables simultaneously, comprehensive model testing, allows the development of existing theories, models and concepts into a new structural model [27]. In this study, we refer to two modelling steps proposed by Chua [25] and Kline [28]. Firstly, test the measurement model to get compatibility with the data. Secondly, test the structural model formed by the measurement model changed. Pooled CFA was used to test the compatibility of the measurement model [28]. Hair et al. [27] stated that CFA analysis was used to confirm the extent to which the measurement TPACK constructs model.

2.2. Validation construct

The validity of the questionnaire instrument was determined by performing a factor analysis on the data collected from the study. The researcher takes into account the recommendations of Tabachnick and Fidell [29], which accept coefficients greater than 0.3. Before completing the factor analysis, Barlett’s test of Sphericity and Kaiser-Meyer-Oikin Measure of Sampling Adequacy (KMO) performed. The significant Barlett’s Test of Sphericity (p<0.05) indicated that the correlation between items was adequate for factor analysis whereas KMO tests with values greater than 0.5 indicated that the data had no multicollinearity problem and that the items were suitable for factor analysis. Subsequent varimax rotation tests were performed to see the validity of the construct and the validity of the items in the aspect specified in the questionnaire.

2.3. Instrument development

In this study, the reviewer adapted the instruments from Koehler et al. [14] (see figure 1). The reviewer also took a reserve and other viewpoints from the previous study [30]. Therefore, the researcher identified seven aspects in technological pedagogical content knowledge; 1) content knowledge (CK); 2) pedagogical knowledge (PK); 3) technological knowledge (TK); 4) pedagogical content knowledge (PCK); 5) technological pedagogical knowledge (TPK); 6) technological content knowledge (TCK); and 7) technological pedagogical content knowledge (TPACK). Because the items in the survey are adapted, pre-processed, a factor analysis test is carried out to ensure that it has construct validity. They
are required to answer 30 items of the TPACK survey with a five Likert scale from 1 for Strongly Disagree to 5 for Strongly Agree.

2.4. Participants and data collection
This research is a quantitative study using the method of periodic review. The population of this study refers to secondary school mathematics teachers in the Banyumas region, Indonesia. A total of 235 secondary school mathematics teachers spread across the Banyumas region sampled to get to know TPACK’s measurement model in that region. The total sample consisted of 48.94% male teachers and 51.06% female teachers. While by region, some 45.53% of teachers teach in secondary schools in urban areas, the remaining 54.47% teach in suburban areas. For interpreting the data, we used the Garth min score [31]. The mean score of the TPACK stage is less than 2.33, and it means that the TPACK level of teachers brings interpretation that teachers have no knowledge to combine the three components of knowledge in TPACK and always need guidance to foster teaching activities. A minimum score of 2.34 to 3.66 also shows that the TPACK teachers have at a moderate level. When the mean score exceeds 3.67, it also shows that the teachers’ TPACK is at a high level with recognized for teacher's skills and always being a source of reference.

2.5. Statistical analysis
To develop the TPACK construct, we used statistical inference analysis to test the TPACK measurement model. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were used in testing this TPACK measurement model. The purpose of using this EFA analysis is to subtract the number of items in a construct that can increase the value of variance and trustworthiness and identify the dimensions contained in a construct [32]. CFA is the second analysis used to validate the model developed in the EFA. The method which can validate that the items keep the factors measured by using CFA [27]. In running the CFA according to Hair et al., [29] states that the test commonly used to determine whether there is a good model is the comparative fit index (CFI), root mean square error of approximation (RMSEA), goodness-of-fit (GFI) and Tucker Lewis Index (TLI). However, researchers chose the equivalency tests commonly used in most studies such as normed Chi-Square and freedom classes, CFI, TLI, GFI, and RMSEA [25]. All of the equivalence indices must meet the criteria for a model match size for the absolute fit index, incremental fit index, and parsimonious fit index categories [29]. The recommended CFI, TLI, and GFI values exceed 0.90. In contrast, the justified RMSEA value for meeting the model equivalency requirements is in the range of 0.03 to 0.08.

3. Results and discussion
The results of this study consist of the reliability value for each component in TPACK, obtained EFA, TPACK level, and the results of CFA.

3.1. TPACK level
Overall, the TPACK level shows the majority of secondary school mathematics teachers are as many as 195 people, or 82.98 % have a high level of TPACK when as many as 40 teachers or 17.02% have the moderate level. It depicts that 82.98% of teachers have extensive and in-depth knowledge in combining the three components of knowledge in TPACK, their proficiency is recognized, and they are always a source of reference. The remaining 17.02% of secondary school mathematics teachers know about combining the three components of knowledge in TPACK but sometimes need guidance in producing activity in their teaching [33].

3.2. Reliability
Byrne [30] states that Cronbach’s alpha value is between 0 (showing no reliability) and 1 (showing perfect reliability). The minimum accepted Cronbach alpha value is 0.7 [27]. Therefore, the most acceptable interpretation of trust that follows the practice of investigations in social science is that the value of α exceeds 0.70. So, in this study, the Cronbach alpha value used is 0.7 and up. Table 1 is the
final result of parameter, reliability, and validity (CR values, AVE values, and Cronbach alpha values) as a result of TPACK’s factor analysis measurement model.

Table 1. Testing result of parameter, reliability, and validity for CFA.

| TPACK constructs                        | Cronbach Alpha | CR > 0.6 | AVE > 0.5 | Criteria |
|-----------------------------------------|----------------|----------|-----------|----------|
| Technological Knowledge (TK)            | 0.780          | 0.843    | 0.542     | Passed   |
| Content Knowledge (CK)                  | 0.741          | 0.874    | 0.642     | Passed   |
| Pedagogical Knowledge (PK)              | 0.779          | 0.748    | 0.553     | Passed   |
| Pedagogical Content Knowledge (PCK)     | 0.762          | 0.890    | 0.596     | Passed   |
| Technological Content Knowledge (TCK)   | 0.788          | 0.824    | 0.604     | Passed   |
| Technological Pedagogical Knowledge (TPK)| 0.793          | 0.798    | 0.543     | Passed   |
| Technological Pedagogical Content Knowledge (TPACK) | 0.768 | 0.827    | 0.672     | Passed   |

3.3. Exploratory Factor Analysis (EFA)
The analysis found that the value of Kaiser Meyer-Okin (KMO) for TPACK with 30 items showed 0.720, which exceeds the 0.50 value indicating the data did not have serious multicollinearity problems and the items were suitable for the factor analysis. Barlett’s test of Sphericity showed a significant value of 0.000 (p < 0.05) indicating that the item was sufficient to be a factor analysis. The results of the seven-factor extract have contributed 52.733 percent change in the overall variance construct of TPACK. Subsequently, to ascertain the number of significant factors in the construct of TPACK, the construct has examined the scree plot graph in figure 2. The scree plot graph shows that seven main factors make a significant contribution to changes in overall variance in the construct of TPACK.

Figure 2. Scree plot of the TPACK construct.

3.4. Confirmatory Factor Analysis (CFA)
The CFA was used to test the suitability of the measurement model [28]. Hair et al. [27], state that CFA analysis is used to validate the extent to which the measurement model measures variables that represent
constructs. CFA pooled results were used to test validity and reliability. Items with loading factors (\( <0.05 \)) will be discarded, and the model will statistically be evaluated using the goodness-of-fit index to ensure that the model has a good fit with the respondent data. To complete the EFA technique, a CFA analysis in this study has been carried out by analyzing the TPACK construct simultaneously. The corresponding index values such as Chi-Square / df = 1.385 are less than 3, GFI = 0.934, AGFI = 0.912, CFI = 0.917. Table 2 is an index of equivalence for the measurement model of TPACK. The TLI and NFI values did not reach the specified value (> 0.90). However, the equivalence index values of these three categories have reached a significant equivalence stage to conclude that the TPACK measurement model is following the data.

**Table 2. The index of equivalence for the measurement model of TPACK.**

| Index of equivalence | Category | Level of index | Value  | Decision |
|----------------------|----------|----------------|--------|----------|
| RMSEA                | Absolute fit | < 0.08         | 0.033  | accepted |
| GFI                  | > 0.90   | 0.934          | accepted |
| AGFI                 | Incremental fit | > 0.90       | 0.912  | accepted |
| CFI                  | > 0.90   | 0.917          | accepted |
| Chi-Square/df        | Parsimonious fit | < 3.00      | 1.385  | accepted |

Besides, figure 3 shows the measurement of the TPACK model and it has been repeated several times including dropping four items (Pk5, Pk10, Pk12, Pk17, Pk18, and Pk19) because the regression value is less than 0.4 [25], and connects covariance between e23 and e24, e28 and e30, and e10 and e13.
The measurement model of TPACK in this study consists of seven constructs: 1) technological knowledge (TK); 2) content knowledge (CK); 3) pedagogical knowledge (PK); 4) pedagogical content knowledge (PCK); 5) technological content knowledge (TCK); 6) technological pedagogical content knowledge (TPK); and 7) technological pedagogical content knowledge. The CFA conducted found that the content model of TPACK in Indonesian Senior Mathematics Teachers met all the requirements of the index of compatibility used in studies that included CMINDF, TLI, GFI, and RMSEA. It means that the model corresponds to the collected data. Each construct of TPACK also has excellent build reliability and extracted variance values.

Further, covariance analysis relationship PK and TPK, as well as TCK and TPK, are the highest correlated of all. The findings in this study are in line with Puspitarini and Sunaryo [34]. Their study found that increased PK as a teacher can influence the TPK. In comparison, TCK in mathematics teaching can also influence the TPK. The high value of the relationship between the two types of teachers is likely to enable teachers to master mathematical teaching technology. Teachers are expected to master teaching pedagogy as a tool for teaching math using technology. Whereas, the TCK and TPK may be due to the alignment between the knowledge gained and the way that knowledge is delivered using technology. There is no denying that teachers are good at solving technology problems and can apply technology to mathematics teaching. It is in line with a study by Maesuri [15] that found that teachers use some mathematical software such as Praxis to teach mathematics. The TCK of mathematics teachers has much emphasis on teaching technology-based mathematics. It also supports the teachers’ TPK.

The simple relationship occurs between PK and PCK as well as PCK and TCK in this study. One of the factors that may be contributing to this relationship is that the problems in teaching teachers are less concerned with pedagogical knowledge, teacher misconceptions, and lack of teacher sensitivity to the level of difficulty of pedagogical content [21]. While PCK is related to TCK and it’s essential for teachers to develop a deep understanding and be able to identify the types of knowledge that teachers have with the TCK [33]. Without a solid knowledge of all aspects of TPACK, they have difficulty delivering mathematics lessons in the classroom. It is because teachers need a combination of pedagogical and technological knowledge. In line with the findings of this study that the low relationship between pedagogical knowledge and technological knowledge. Dicky [22], teachers; however, the PK was influenced by the knowledge gained when starting the teaching profession. The more knowledge on technology, the more benefit on assessment [35].

The role of technology in the world of education is certainly in line with the development of technology that has become a friend for every human being. Teachers are one of the elements of education which must know and understand technology development [35]. Therefore, TPACK is must-have knowledge for every mathematics teacher to maximize the role of technology in the era of the industrial revolution of 4.0 [36]. The high level of TPACK in this study refers to the ability of teachers to help make sense of the mathematical titles taught through technology. TPACK also helps teachers identify errors and provide students with appropriate explanations and models as well as responding to student questions and asking them questions. The findings of this study are in line with Valtonen et al. [2] and Kim [37]. According to Valtonen et al. [2], Teachers who have high PTK can produce productive questions for students. While the findings of Kim [37], The TPACK show that a high level of understanding of technology also has a positive impact on teacher teaching knowledge which includes effective technology planning procedures, math classroom practices, classroom management techniques, and variations in the use of mathematical techniques.

According to Galleto [38], high levels of TPACK can combine CK and PK represent technology formulations that can use in the classroom. Also, Puteh [39], states that high of TPACK shows that teachers understand how technology, pedagogy, and content are interrelated, and create a form of knowledge that goes beyond three basic knowledge bases (TK, CK, and PK). Additionally, teachers with high TPACK can teach with clear technology that explains how the technology is effectively integrated with various pedagogical approaches and content areas.

Judging from the results, the TPACK level of the Banyumas region is mostly at a high level (82.98%). It is also following the levels occurring in the Semarang [21] and Yogyakarta [20] regions with TPACK
proficiency levels of 83.87% and 84.08%. This situation implies that the ability of mathematics teachers in the three regions is ready to face the era of technology and be able to use technology in learning. However, it is different in the Bengkulu region [22] and Manado [23] with only a quarter of each mathematics teacher having a high TPACK level. This result implies that the demographic location can contribute to TPACK levels in an area [40]. According to Fitri [41], the mean scores of PCK dare to go beyond the limits or limitations of content knowledge and pedagogy in decision making. Noor [42] and Wahyuni [43], in their findings on high mean scores on TPK, indicate that teachers are skilled in accepting technological stimulus and processing it by shaping and reusing the technological stimulus provided in teaching. The high TPACK mean score according to Yudi [20] is the highest feature for teachers to develop ideas spontaneously as accepted technological interpretations and pedagogical creativity can be demonstrated by teachers given the originality of the content that is closely linked to the idea of product ideas in creative teaching.

In addition to this, several studies have shown that TPACK has a multi-correlation structure as conducted by Sintawati and Indriani [44] and Agustiani [45]. The revenue presented has more than half of the relationships that occur between the TPACK components. It is different from the income presented in TPACK in the Banyumas region, with only seven components of TPACK correlating more than 0.5. This indicates that 33.33% of the components that correlate above 0.5 ($r > 0.5$). Analysis conducted by Noor [41] also indicates that from each component of TPACK, there is a weak correlation. In line with the results conducted by Zainal [1], with only 22% of the TPACK component highly correlated. There is content knowledge that correlates negatively with knowledge of content technology pedagogy. In contrast, TK and CK are both very low correlated. The high correlation occurs between knowledge of technological content and knowledge of technology pedagogy. Furthermore, knowledge of pedagogy and knowledge of technology pedagogy also have a high correlation. Several factors can occur to determine the relationship between each component. Kim [37] said that the level of basic knowledge, the stability of technology access, and school support influence the TPACK skills of teachers. Besides, the school’s geographical location and teaching experience also influence the TPACK level of each teacher [43]. Also, the experience factor in using computers for teachers contributes to the interaction of components in TPACK [46].

From the test results of the study found that the TPACK reliability value has a strong and good value with a value above 0.7. It can interpret that the scale used has met the reliability requirements. While from the results of the confirmatory factor analysis that has been done, the seven components presented in TPACK produce fit criteria. So that this research is following research conducted by previous researchers that the TPACK component can explain in seven constructs: TK, PK, CK, TPK, PCK, TCK, and TPACK. They are technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPACK).

4. Conclusion
As a result, it found that the reliability results met a reliable result; it indicates that the TPACK component in high school mathematics teachers in Banyumas, Indonesia, is acceptable. At the same time, the results of the EFA and CFA analysis in this study show tangible evidence and can be used to describe the TPACK measurement model in the Indonesian context. Onwards, judging from the results of the TPACK level that occurred, the majority of secondary school mathematics teachers in Banyumas are at a high level. It is used as a basis for further research development in looking at the level and measurement models of TPACK in other parts of Indonesia.

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