TPACK in mathematics teacher education: Are teachers ready to teach for ICT literacy?

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Abstract. TPACK is an effective combination of technological content knowledge, pedagogical knowledge, and content knowledge to understand the understanding of how the structure, representation, and adaptation of a topic, problem, and content are adapted according to the interests, technology, and abilities of teachers and presented in teaching. Mastery of teachers' ICT literacy is not possible without the TPACK that underlies the use of ICT. This article employed the relationship between TPACK and ICT literacy among Indonesian Mathematics Teachers in Senior School background. This research used a quantitative approach which focused on the survey as the chosen research design. The research procedures: 1) finding factor analysis of each construct; TPACK and ICT literacy with Exploratory Factor Analysis; 2) constructs the instrument by Confirmatory Factor Analysis to get a fit model; 3) structural Equation Model for the relationship between TPACK and ICT literacy. The model criteria obtained the fit index test; Chi-Square, Chi-Square/df, TLI, CFI, NFI, and RMSEA. The results of the study revealed that the TPACK construct consisted of 7 valid sub-constructs and ICT literacy consisted of 4 valid sub-constructs. Whereas, the analysis of the data shows a significant relationship between TPACK and ICT literacy with a strong contribution significant relationship between TPACK and ICT literacy ($\beta = .566$).

1. Introduction
With the emergence of the role of technology in daily life and education in the current era of technology, many researchers have begun to address the impact of teacher technology knowledge. While some researchers have begun to look at the crossroads of pedagogy and technology in the development of non-content specific knowledge domains such as pedagogical technological knowledge (PTK) [1], others have examined the crossroads of pedagogy and technology in the development of TPACK [2].

TPACK was introduced by Koehler [2], and these days are still being studied as well as giving the different concepts among researchers. Studies on TPACK are conducted in various forms of approach and viewed from various perspectives [3]. Shanmugam et al. [4] argue that in identifying the components of knowledge for teaching, and the use of technology in teaching, knowledge of content pedagogical technology becomes a priority for teachers.

TPACK is an effective combination of technological content knowledge, pedagogical knowledge, and content knowledge to understand the understanding of how the Structure, representation, and
adaptation of a topic, problem, and content is adapted according to the interests, technology, and abilities of teachers and presented in teaching [5]. Pedagogical content knowledge refers to concepts, procedures, misconceptions, types of understandings, mastery assessment techniques, and conceptual understanding possessed by teachers [6]. In contrast, the effectiveness of mathematics teaching requires the skills of providing continuous and varied training, enrichment activities and rehabilitation of classroom management, and evaluating mathematics contents and curriculum [7].

TPACK becomes a key ability for mathematics teachers to teach mathematics effectively [8]. With the same conveyed by Kim [9], TPACK is an understanding that arises from the interaction between content, pedagogy, and technological knowledge that is closely related to ICT literacy. Johnson et al. [10] give the general meaning of TPACK, which a component of teacher professionalism; professional competence involves more than just knowledge.

Some factors that complement TPACK include teaching experience and computer experience. Teachers who have been teaching for more than ten years use ICT literacy in the classroom only to send assignments to students, but do not use them in teaching concepts to students [11]. Besides, computer experience for teachers is another factor in TPACK. The findings of the study explain that mathematics teachers use ICT literacy only for teaching goals and assignments [12].

According to constructivist views, technological content knowledge is a dynamic trait that is actively built by teachers and students [13]. To understand how teaching and learning knowledge is integrated into technology, the teacher's must-have components of technology, such as ICT literacy [14]. The use of technology software is part of ICT literacy skills. In the teaching of mathematics, various software can be used that can be used, such as Inquisit 4 Web OSAN [15]. The software allows teachers to complete tasks independently from testers and calculate their scores and the various time required to complete each step solving a math problem.

Meanwhile, technological content knowledge (TCK) refers to the ability of teachers to make connections between mathematical topics learned through technology [16]. TCK is also a category used to differentiate the understanding characteristics of a mathematical content expert from a technology expert [17]. Teachers with good TCK can produce productive questions in the classroom [18].

TCK is practical knowledge for teaching by combining content and technology. The aspects of TCK are knowledge of approaches to specific mathematical topics, teacher teaching knowledge that includes effective technology planning procedures, practice in mathematics classrooms, classroom management techniques, and variations in the use of mathematical technology [9]. Understanding of technology also has a positive impact on ICT literacy [19]. Therefore, teachers should know the content of technology and ICT literacy in mathematical representation for emphasizing the content knowledge.

Subsequently, technological pedagogical knowledge (TPK) is one aspect of TPACK. TPK encompasses curriculum knowledge, including the selection and use of appropriate materials for use in the curriculum, while knowledge of technology refers to knowing how teachers think, teaching technology preparation, and mastering all forms of teaching technology delivery methods. TPK represents technological formulations that can be applied in teaching [20]. The TPK must contain the knowledge of teacher pedagogy, classroom teaching strategies, effective use of technology, technological literacy understanding [21].

Several researchers have researched the TPACK [8, 22–23]. Their study has the same purpose, which is to identify the components of pedagogical knowledge, as stated by Koehler [2]. They suggested the creation of teachers' ICT literacy in teaching across various aspects. In proposing a model describing the efficient use of educational technology, they called for the need to integrate three basic types of teacher knowledge; technological knowledge (TK), content knowledge (CK), and pedagogical knowledge (PK). The overlapping effects of these three elements are said to produce a variety of areas that represent specific skills.

A report from the Indonesian National Education Department [24] contributes to the technological knowledge of mathematics teachers in Indonesia. As many as 73% of teachers in rural areas do not have good technical knowledge. Furthermore, Destiana [25] revealed that teachers' knowledge of using computers is less than two years lower than teachers who have more than five years' experience in using
computers. According to Dinar [26], the experience of teachers using computers less than two years harms the relationship of TPACK to ICT literacy.

Also, the growing role of technology in daily life and work questions drives the skills and understanding needed for the effective use of technology. The range of ICT is growing, and the ability to obtain, manage, synthesize, analyze, and communicate information is constantly changing and adapting [27]. As technological capabilities change rapidly, the skills involved and understanding inevitably shift in response. TK and the use of technology in the teaching of mathematics encourage knowledge of pedagogy and mathematical content as well. Thus, TPACK becomes a key element in the application of ICT literacy in the classroom [28] as directed by Muhtadi [29], TPACK, as the ability to understand and use information in various formats from various sources when it is presented through a computer. The implications of the use of TPACK on ICT literacy involve the interaction and integration of several competencies, such as the efficiency of procedures with ICT tools, cognitive skills to use them effectively, and social and communication skills [30].

Terminology for ICT literacy is a source of disagreement among educators. ICT literacy practices are referred to by some researchers as new literacy or 21st-century technology skills or digital literacy [31]. ICT literacy is a new source of research that should be taken into account and identify its use in the world of mathematics education. Mastery of teachers' ICT literacy is not possible without the knowledge that underlies the use of ICT [32]. Collaboration such as the creation, sharing, and communication of texts that provide social aspects to ICT literacy [33].

The TPACK core is a major source of ICT literacy because of their height in the social, cultural, and economic world outside the school and because of their importance in using and obtaining information. Clark-Wilson [34] expresses a similar view on the importance of such knowledge of electronic technology, stating that there is an evolution in the way people create and represent meaning. Thus, the knowledge that can underlie the absolute use of technology is available to every teacher in the world of education.

TPACK teachers' relationship on ICT literacy in the teaching of mathematics is preceded by the teaching of chalk and writing boards so that the teaching period with digital boards gives the effect of teachers' TK. Studies compared to Dhakal [35] prioritize the importance of TPACK in the teaching of mathematics in this era of the industrial revolution. Teaching using mathematical software is the way teachers use their TK. But this does not happen to math teachers who have served for more than ten years. They argue that TK only brings negative effects to teachers because it does not provide a greater understanding of mathematics, but will only present another challenge. This collection includes teachers who are weak in ICT literacy to avoid teaching with mathematical research. It is similar to that produced by Gjonbalaj [36]; he illustrates that the TPACK is limited to the long time teachers use computers. Teachers who use computers every day are more open to teaching mathematical technology. Another difference is that teachers who do not communicate with ICT throughout the day ignore the role of ICT in teaching. Thus, this study also provides a new perspective to find out the relationship of TPACK to ICT literacy based on experience using computers among mathematics teachers in Banyumas region.

2. Method

2.1. Respondent profile
This study uses a quantitative method of a cross-sectional survey [37]. This method provides a more detailed picture of a problem being studied [37]. This study determines the relationship between the variables and proposes a model of structural equations; Specifically, this study involves the analysis of the relationship between beliefs, TPACK on ICT literacy in teaching in secondary school mathematics teachers in Banyumas, Indonesia. This study took a sample of 235 mathematics teachers in secondary schools.
2.2. Validation of the instruments
The study used reliability to test the response of respondents' responses to the measured items. This analysis is important to determine whether the instruments built in different cultures and education systems can be applied in the culture and education system. Since the selection of responses is according to the Likert scale for mathematical reliability instruments and mathematical experience, the Cronbach's alpha coefficient is used to obtain the instrument's internal reliability index [38]. Cohen [38] state that the Cronbach's alpha value is between 0 (indicates no internal reliability) and 1 (indicates perfect internal reliability). The generally accepted minimum of Cronbach's alpha value is 0.7 [39]. Therefore, the interpretation of the acceptable coefficient of reliability, according to social science researchers, is that the value of α exceeds 0.70. In this study, the Cronbach's alpha value used was 0.7 and above.

2.3. Exploratory Factor Analysis (EFA)
The construct validity of the questionnaire instrument was determined by conducting analytical factors on the data collected. We took into account the recommendations of Tabachnick and Fidell [40], which received a coefficient value greater than 0.3. Before completing the factor analysis, Barlett's test of Sphericity and Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) were conducted. A significant Barlett's Test of Sphericity \((p < 0.05)\) showed that the correlation between items was sufficient for factor analysis, while a KMO test with a value of more than 0.5 showed that the data had no multicollinearity problems and the items were suitable for factor analysis. Next, the varimax rotation test was conducted to see the validity of the construct and the validity of the items in the aspects specified in the questionnaire. Construct validity procedures for TPACK and ICT literacy have used the EFA procedure to review the diversity of dimensions or indicators that exist in both instruments. Items with a low loading factor \((β < 0.5)\) will be discarded in sequence [39]. Factor analysis is a procedure often used by researchers to identify, reduce, and organize a large number of questionnaire items into specific constructs under a dependent variable in the study.

2.4. Confirmatory Factor Analysis (CFA)
The formation of a structural model requires the filtering of data carried out through EFA, pooled validation factor analysis, validity index, reliability, and acceptable goodness of fit index for all instruments. In this study, the researcher refers to two modelling steps that have been proposed by Kline [41]: 1) test the measurement model first to get a match with the data, and 2) test the structural model formed by linking the measurement model with enablers change or between all measurement models. Pooled CFA was used to test the compatibility of the measurement model [41]. Hair et al. [39] stated that CFA analysis was used to confirm the extent to which the measurement model measures variables representing constructs. The CFA pooled results were used to test the validity and reliability of the construct. Items with a loading factor \((p < 0.05)\) will be discarded, and then the model will be evaluated statistically using a goodness-of-fit index to ensure the model has a good match with the respondent data. If the model has reached an acceptable fit, the analysis will continue to test the structural model.

In this study, there are three categories of equivalence indexes for measuring model equivalence with study data; they are absolute fit, incremental fit, and parsimonious fit. Absolute fit consists of the Root Mean Square of Error Approximation (RMSEA) and the Goodness of Fit Index (GFI) when the incremental fit consists of the Adjusted Goodness of Fit Index (AGFI), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI) and Normed Fit Index (NFI). Parsimonious fit also consists of Chi-Square/degree of freedom (Chi-square/df). GFI, CFI, TLI, NFI equivalency index values greater than 0.90 indicate a good fit when Chi-square/df is less than five, and RMSEA is less than 0.08 [39].

2.5. The contribution value
The value of contribution can be interpreted into three levels of contribution: 1) small contribution for a value less than 0.10; 2) medium contribution level for \(β\) value of 0.10 to 0.50, and 3) high contribution level for \(β\) value greater than 0.50 [41]. The level of small contribution \((β < 0.10)\) and negative was
considered insignificant. Thus, $\beta$ less than 0.10 and negative will not be accepted and reject the hypothesis even if the p-value is significant.

3. Result and discussion

3.1. EFA for TPACK and ICT literacy constructs

The results of the analysis found that the Kaiser Meyer-Olkin (KMO) value of the items in the TPACK construct with 30 items showed 0.720, and the ICT literacy construct with 21 items showed 0.823, which exceeded the value of 0.50, showed the data did not have serious multicollinearity problems and the item is suitable for factor analysis. Barlett's test of Sphericity showed a significant value of 0.000 ($p < 0.05$), indicating that the item was sufficient for factor analysis. To ensure the number of key factors extracted as the main factors in the TPACK and ICT literacy instruments, the researcher examined the graph scree plot of the two instruments tested. Thus, TPACK is divided into seven aspects: technological knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). The aspects of TK consists of 4 items (Pk1, Pk2, Pk3, and Pk4), CK consists of 4 items (Pk5, Pk6, Pk7, and Pk8), PK consists of 5 items (Pk9, Pk10, Pk11, Pk12, and Pk13), PCK contains five items (Pk14, Pk15, Pk16, Pk17, and Pk18), TCK consists of 4 items (Pk19, Pk20, Pk21, and Pk22), TPK consists of 5 items (Pk23, Pk24, Pk25, and Pk26), and TPACK contains four items (Pk27, Pk28, Pk29, and Pk30).

Meanwhile, ICT literacy is divided into four aspects: (1) understanding the operation and use of ICT (LiPO); (2) pedagogy rich in ICT and teaching environment (LiPK); (3) teaching and professional involvement (LiPP), and 4) social ecology of life and ICT teaching (LiES). LiPO consists of 5 items: Li1, Li2, Li3, Li4, and Li5. LiPK consists of 4 items: Li6, Li7, Li8, and Li9. LiPP contains 6 items: Li10, Li11, Li12, Li13, Li14, and Li15. LiES consists of 6 items: Li16, Li17, Li18, Li19, Li20, and Li21.

3.2. CFA for TPACK and ICT literacy constructs

Preliminary findings of the CFA for TPACK show that the GFI, AGFI, CFI, TLI, and NFI compatibility index tests do not meet the criteria requiring values greater than 0.90. Figure 1 has been repeated several times, including dropping six items (Pk5, Pk10, Pk12, Pk17, Pk18, and Pk19) due to regression coefficient values less than 0.4 [40] and linking covariance between e1 and e2, e23 and e24, e28 and e30, and e10 and e13. Figure 1 shows the TPACK measurement model to obtain the value of the proposed measurement model significantly and adequately results in the goodness of fit.

![Figure 1. The finalized CFA model for TPACK construct](image-url)
The correlation index values such as Chi-Square/df = 1.385 are less than 3, GFI = 0.934, AGFI = 0.912, CFI = 0.917. Meanwhile, preliminary findings of the ICT Literacy CFA show that the GFI, AGFI, CFI, TLI, and NFI compatibility index tests do not meet the criteria requiring values greater than 0.90. Therefore, the analysis has been repeated several times, including dropping four items (Li1, Li2, Li14, and Li15) due to regression coefficient values less than 0.4 [40] and linking the covariance between e7 and e9, e10 and e11, e17 and e19, and between e19 and e20. Figure 2 shows the ICT literacy measurement model to obtain the value of the proposed measurement model significantly and adequately the results of the goodness of fit.

![Figure 2. The finalized CFA model for ICT literacy construct](image)

Correlation index values such as Chi-Square/df = 1.841 are less than 3, GFI = 0.941, AGFI = 0.917, CFI = 0.930, TLI = 0.912, NFI = 0.860.

3.3. Structural Equation Model (SEM)

After the CFA process to get rid of items and gain high validity and reliability, a model for predicting the factors influencing ICT literacy among secondary school mathematics teachers was developed. Model estimation using the Maximum Likelihood method, Figure 3 shows a structural model in a standardized form. The structural model in this standard form is used to view standardized estimates, measurement errors (\(e\)), overall variation (\(r^2\)), and model compatibility indices. Based on the analysis of structured equations, the model has a positive degree of effectiveness (\(df\)) (16), and the chi-square value is 18.198, \(p = 0.000\), \(p < 0.05\).

Once the model is confirmed to have a match with the respondent data on the matching index, an assessment of each coefficient of coefficients should be conducted in the next step to test the research hypotheses related to the relationship of the variables involved. The significant value for hypothesis testing is \(p < 0.05\), and hypothesis testing is one end because the direction of the relationship has been determined, i.e., a positive relationship. There are four path coefficients observed in the analysis of the variables studied.
The findings of the structural equation analysis in Figure 3 show that the root value of Mean Square of Error Approximation (RMSEA) is 0.067, which is less than 0.08, and the value of \( \chi^2/df \) is 1.096, which is less than 3.0. The GFI, AGFI, CFI, TLI, and NFI compatibility indices all exceed 0.90, which is 0.932, 0.906, 0.914, 0.937, and 0.968. Table 1 shows the review of the correlation index of the revised structural equation model.

### Table 1. The equivalence index result

| Equivalence index       | Category       | Level  | Value  | Result |
|-------------------------|----------------|--------|--------|--------|
| RMSEA                   | Absolute fit  | < 0.08 | 0.004  | Achieved |
| GFI                     |               | > 0.90 | 0.921  | Achieved |
| AGFI                    | Incremental fit| > 0.90 | 0.904  | Achieved |
| CFI                     |               | > 0.90 | 0.916  | Achieved |
| TLI                     |               | > 0.90 | 0.933  | Achieved |
| NFI                     |               | > 0.90 | 0.965  | Achieved |
| Chi-Square/df           | Parsimonious fit| < 3.0  | 1.137  | Achieved |

3.4. The relationship between TPACK and ICT literacy

The findings of this study indicate that the potential knowledge of TPACK is required in ICT literacy. It is in line with the statement of Drijvers et al. [42] and Valtonen et al. [18], who stated that TPACK is a technological, pedagogical, and content response that involves mathematical, consistent, and strategic cognitive processes on pedagogy and technological skills. According to Lamichhane [27], among the knowledge of content involving mathematical cognitive processes involved consistently and strategically on abstract pedagogy and logic. For example, in this study, TCK questions 2 and 4 that teachers have good teaching and knowledge in finding, evaluating and using online mathematical applications. While Valtonen et al. [18] knowledge of mathematical content synergistic with dynamic technology. For example, question 2 of TCK in this study i.e. teachers can select several digital technologies to convey the mathematical process.

Drijvers et al. [42] argue that CK processes such as visualization of mathematical relationships with everyday problems should be trained more vigorously and become key skills in relationships outside of mathematics. For example, in this study, questions 1 and 2, mathematics is used to solve problems in...
everyday life and beyond mathematics. According to Muhtadi [29], teachers can train ICT literacy skills to involve technology in the teaching of mathematics as a function of content knowledge in solving problems outside of mathematics.

In terms of PK, the findings of the study of Borromeo et al. [28] drawing every thought or idea from a teacher about the pedagogical process is important to make the teacher think outside the box, use imagination, rational thinking, and focus on more challenging activities in classroom teaching. The situation is supported by ICT literacy until teaching to be creative will not be successful if teachers do not have ICT literacy skills. For example, in this study, questions 1 and 3, teachers use technology skills to improve teaching and teachers implement teaching approaches as well as integrate mathematical context with technology.

Based on the TPACK model, it shows that the components of knowledge, the use of technology, and pedagogical technology for teaching. To understand teaching knowledge integrated into technology, teachers must have the concept of pedagogical techniques such as ICT literacy [2]. TPK lies in the intersection space between pedagogical content and technology used in teaching and is not separated from the domain of knowledge at all. TPK becomes a prerequisite for teacher planning, reflection, and teaching adaptation that depends on teachers' understanding of ICT literacy [43].

However, reviewing the findings of the interviews, teachers, especially from rural schools, were found to be less interested in teaching using their TPACK. It is due to the lack of school facilities that make it difficult for teachers to develop the technology. Without good school facilities, interview participants found it difficult to maximize technology for learning and, subsequently, ICT literacy. It is because of the lack of technology in rural schools is believed to interfere with the development of TPACK (content, technology, and pedagogy) of teachers, as emphasized by previous researchers [44]. On the other hand, interview participants from urban schools were not negative about technological developments and further improved their ICT literacy. The positive relationship between TPACK and ICT literacy in mathematics teachers in urban schools is believed to make the teaching process. Therefore, it can be explained that the TPACK shows a positive and significant relationship to ICT literacy is because the mathematical content process is synergistic with dynamic technology, dynamic content knowledge to technology applied in ICT literacy.

3.5. The Power of Interactions

The interactions that exist in structural models are complex. However, each such relationship can be distinguished by the standard regression weighting coefficient, \( \beta \), as the strength of the contribution. In this study, the strength of the contribution between the two variables in a structural model provides alternative answers to how TPACK affects ICT literacy. In the structural model, there is a relationship that has been confirmed to be significant \( \beta = .565 \).

Besides the perspective of variables, TPACK has a great influence on ICT literacy. The high value of \( \beta \) for TPACK shows that these variables play an important role in influencing ICT literacy. The role of TPACK becomes more meaningful because these variables not only show the contribution of strength, but it is directly related to ICT literacy [30]. The role of TPACK as a necessary factor in assignments involving ICT literacy has been stated in the Technology Acceptance Model (TAM). According to TAM, TPACK is known as a process that participates in completing technology tasks such as processing, remembering, quick decision making, and generating ideas [45]. Teachers' TPACK model on technology places TPACK as a key component in the specific domain because TPACK owned by teachers leads to creative efforts in using ICT literacy [46]. Based on the description in the TPACK Model in Misfeldt Technology, it can be understood that TPACK processes information applied in technology and has a great influence on ICT literacy. It may explain why TPACK's power over ICT literacy is dominant in the resulting structural model. The generation of abundant and extraordinary knowledge required in technology assignments is very helpful in the production of ICT literacy.

The findings of this study give the implication that TPACK is a skill that needs to be developed and polished so that the goal of improving ICT literacy can be achieved. The TPACK in mathematical assignments plays a role in ICT literacy. Therefore, nurturing the knowledge of content pedagogical
technology should be in line with the mastery of the content of the lesson. Many opinions are stating that content technology skills need to be fully mastered among math teachers [27]. The findings of this study provide knowledge to teachers with the development of technology has an impact on the contribution of the strength of TPACK to ICT literacy. For example, the focus can be on improving PK to improve technical skills and subsequently on PCK that influences TCK. By giving this gradual and objective focus, the teacher's efforts are more focused and systematic because they already know what the relationship is more dominant.

4. Conclusion
As a result, the measurement models tested before being combined and analyzed in structural models are constructs and indicators that have high validity and reliability. The validity and reliability of TPACK and ICT literacy constructs were obtained using expert validation and pilot studies and subsequently strengthened by using pooled CFA to ensure the item measures the constructs to be measured. This measurement model can contribute through indicators that represent each construct. These indicators can be used as guidelines on things that need to be emphasized if they want to be improved in the teacher. For example, this study gives the implication that teachers want to cultivate TPACK among teachers, so teachers need to understand the concepts of content, technology, and pedagogy. These skills allow teachers to accept every idea generated and not consider every idea of the content concept, technology, and pedagogy to be futile. The structural equation model constructed shows that the interplay between aspects of TPACK influences the ICT literacy of secondary school mathematics teachers. This model can benefit teachers, schools, and the ministry of education and culture to increase the determination to cultivate professional teachers and assist teachers in the aspects of TPACK and ICT literacy. Future research is needed, and the researcher hopes that the findings of this study can benefit other researchers who are interested in conducting new research or continuing existing studies related to the ICT literacy model.

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