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Technological Pedagogical Content Knowledge (TPACK) Based on HOTs: The Development and Validation of an Assessment Instrument for Preservice Teachers

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Abstract. This research aims to develop a HOTs-based TPACK instrument. The instrument is arranged based on seven domains, namely: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK) Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK) Technological Pedagogical Knowledge (TPK) Technological Pedagogical Content Knowledge (TPACK) . These seven domains are made into indicators with a 4 point scale rating. The research subjects were 111 prospective Mathematics teachers in Cirebon Regency and City. This research was designed to assess the TPACK of prospective mathematics teachers who have HOTs skills. Validity study using the Aikens formula. The research methodology used is Research and development (R&D). The model used in this research is the ADDIE model. (Analysis, Design, Development, Implementation, Evaluation). The research results stated that they were valid and reliable. With a reliability level of 0.95. So this instrument is suitable for use and this instrument can help LPTK in assessing the TPACK of prospective teachers.
Key Word: TPACK, Instrument Development, Preservice Teachers

INTRODUCTION

Technology is a necessity in education in the 21st century. This is proven by several studies which state that the role of technology in education is very crucial to the development of the world of education(Drummond & Sweeney, 2016; Graham, 2011; Douglas D. Agyei, 2012; Bakar et al., 2020). Prospective teachers are one of the factors of progress in education, according to research by Istianah (2013) which states that 56% of teachers in Indonesia use technology in learning and 44% of teachers still teach conventionally. We can say that the majority of teachers in Indonesia have integrated technology in learning. One of the subjects that integrates technology is Mathematics (Fujita, 2011; Bakar et al., 2020; Kaput & W. Thompson, 1994). It can be said that prospective mathematics teachers can integrate technology in learning. According to the results of a survey, researchers stated that at higher teacher education institutions in Cirebon City and Regency, especially in the field of mathematics education, 87.7% stated that lectures used technology, among the software used in learning were Geogebra, Win Geom, SPSS, Anates, Liserel, Macro Media. Flash and others. Based on this survey, it can be said that prospective teacher students have been given insight into educational technology.

To measure prospective teachers' knowledge in mastering technology, a special instrument is needed to measure prospective teachers' knowledge of Technology in Education. Several studies related to instruments that assess prospective teachers include D. A. Schmidt et al., (2009) This research develops a general measurement of prospective teachers' technological knowledge known as TPACK. All domains in the TPACK framework are structured to assess prospective teachers' knowledge in technology, pedagogy, and content and are not structured according to the specifications of prospective teachers' abilities. Other research related to the TPACK assessment instrument for prospective teachers includes Önal (2016) which developed the TPACK instrument specifically for assessing prospective Mathematics teachers, in this study divided one of the TPACK framework domains, namely online TPK and offline TPK so that there are 8 dimensions in the TPACK framework. Of these, no one has discussed the TPACK of prospective teachers which contains HOTs. Even though according to researchYati (2019) states that prospective teachers must have HOTs skills in using technology, including prospective teachers must be clever in choosing the right technology in learning.

 QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

The development of a Self-Assessment Instrument Technological Pedagogical Content Knowledge (TPACK) for Prospective Mathematics Teachers Based on HOTs is very much needed for prospective mathematics teachers. The preparation of this research instrument was built based on the TPACK framework which consists of seven dimensions. Each content-developed dimension contains HOTs. So this instrument can assess prospective teachers in their knowledge of Technology, Pedagogy, Content and the intersection of the three dimensions that make up TPACK at the top level (HOTs)

THEORETICAL FRAMEWORKS

Mishra & Koehler (2006) introduce the basic knowledge that must be mastered by teaching staff, namely: technological knowledge, pedagogical knowledge and content knowledge. These three knowledge are developments from research Shulman (1986) which initiated the basic knowledge of teaching staff, namely pedagogical knowledge and content knowledge. Then these two knowledge are combined into one knowledge called Pedagogical Content Knowledge (PCK). Along with the development of technology-based times, Mishra & Koehler (2006) added one type of knowledge, namely technological knowledge. From these three basic knowledge, three new knowledge emerged, namely Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK) and Technological Pedagogical Knowledge (TPK). So these six pieces of knowledge are combined into Technological Pedagogical Content Knowledge (TPACK).

Technological Knowledge (TK)

This knowledge is knowledge that prospective mathematics teachers must have in the form of teaching aids, media, the web, and mathematics software (Mishra & Koehler, 2006; Schmidt et al., 2009; Abbitt, 2011). Mastery of this dimension emphasizes prospective teachers' skills, expertise and accuracy in using technology.

Pedagogical Knowledge (PK)

Pedagogy is the most important aspect in classroom learning management, in this knowledge prospective teachers are required to be able to design learning, develop learning curricula, and evaluate learning (Graham, 2011; Schmidt et al., 2009; Mishra & Koehler, 2006; Abbitt, 2011).

Content Knowledge (CK)

Mathematics learning content is the core of teacher knowledge in mastering mathematics material. With this knowledge, prospective teachers can explore, develop and arrange stages in various lesson content (Mishra & Koehler, 2006; Schmidt et al., 2009;Abbitt, 2011).

Pedagogical Content Knowledge (PCK)

This knowledge is a combination of pedagogical and content knowledge. This idea was developed by Shulman (1986) who explained the importance of synergy between pedagogy and content. This knowledge emphasizes prospective teachers in learning practices with appropriate strategies or methods so that the material is conveyed and easily absorbed by students (Shulman, 1986; Mishra & Koehler, 2006; Schmidt et al., 2009; Abbitt, 2011).

Technological Content Knowledge (TCK)

This knowledge directs prospective teachers in mastering technology that can facilitate the material. This shows that prospective teachers understand the use of technology related to mathematics content, prospective teachers can also change the way they train students in understanding certain concepts and content(Mishra & Koehler, 2006; Abbitt, 2011; (D. Schmidt et al., 2009).

Technological Pedagogical Knowledge (TPK)

This knowledge is a combination of technological knowledge and pedagogical knowledge. To be able to apply this knowledge, prospective teachers must choose learning strategies that are supported by technology (Mishra & Koehler, 2006; Schmidt et al., 2009; Abbitt, 2011)

Technological Pedagogical Content Knowledge (TPACK)

the aforementioned knowledge is all combined in this knowledge, which we call TPACK. This knowledge is a combination of all knowledge that emphasizes prospective teachers to be able to integrate teaching technology in various content areas. The three components of basic knowledge are knowledge of technology, pedagogy and content (Mishra & Koehler, 2006; Schmidt et al., 2009; Abbitt, 2011).

TPACK relationship with HOTs

The integration of technology in learning is an ongoing innovation in the 21st century. Prospective teachers must of course have expertise and skills in using technology, this is supported by research which states that in

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

technology-based learning innovations, users must have Higher Order Thinking Skills (Yati, 2019). So it can be said that TPACK is closely related to HOTs.

METHOD

Instrument Development

The first step in preparing the instrument is to conduct a review of existing literature. Next, the researchers compiled indicators and created 36 bitems. In this research, the development of the scale instrument refers to the research conducted (D. Schmidt et al., 2009; Yurdakul et al., 2012; Önal, 2016). What is different about the preparation of this instrument is that it refers to the principles of Higher Order Thinking Skills. This instrument is prepared with 4 Likert scales, (4) Strongly Agree, (3) Agree, (2) Disagree, (1) Strongly Disagree.

The next stage, the researcher entered the instrument carefully into Google Form, and checked again by media and educational technology experts. Then the instrument is given to prospective teachers

Participants

Respondents were selected using a non-random sampling technique. Non-random sampling is a technique that is carried out if the researcher's assessment is that the sample is sufficiently representative of the population and meets the demands of the research (A. Adib Abadi, 2006). In this sampling, 111 respondents were obtained. 70.3% men and 29.7% women. All respondents have participated in the Teaching Experience Practice. This aims to provide prospective teachers with the opportunity to observe the learning process directly. Therefore, the sample size with these criteria can be analyzed.

Data Collection and Analysis

At the data collection stage, the researcher withdrew the results of filling out the instrument from a Google form in Excel form, then the researcher analyzed the results of the prospective teacher's responses using the Aiken validity formula. Aiken's formula refers to (Merino Soto & Livia Segovia, 2009)

$$V = \frac{\bar{X}-l}{k}$$

Note: V = item suitability index based on expert judgment; X is the judge's score in the sample, l is the lowest possible score, and k is the possible range of Likert scale values used.

After carrying out the validity test, the researcher continued with the reliability test using the Cronbach's alpha formula. In testing reliability, researchers used SPSS 18. The Cronbach's alpha formula refers to Adamson & Prion (2013) sebagai berikut:

$$r = \left[\frac{k}{k-1}\right]\left[1 - \frac{\Sigma\sigma_b^2}{\sigma_t^2}\right]$$

Note:

$r = instrument\ reliability\ coefficient\ (croncach\ alpha)$

$k = many\ questions$

$\sum \sigma_b^2 = total\ item\ variance$

σ_t^2 = total variance

Reliability criteria refer to opinions (Hendriana & Soemarmo, 2014)

Table 1
Reliability Criteria

$R_{11} \leq 0,20$	Very low
$0,20 \leq r_{11} \leq 0,40$	Low
$0,40 \leq r_{11} \leq 0,70$	Currently
$0,70 \leq r_{11} \leq 0,90$	Tall
$0,90 \leq r_{11} \leq 1,0$	Very high

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

Procedure

In this research procedure, it is adapted to the ADDIE development model. The stages are explained in the following scheme.

The Analysis Stage is the initial stage carried out by researchers to collect literature and various information needed in a preliminary analysis from the Cirebon Mathematics Education Teacher Training Institute. **In the Design Stage**, the researcher designed the instrument by reviewing the literature, then the indicators were prepared as a standard instrument to be developed, then the indicators were validated by an expert who had researched TPACK and two mathematics education experts. **Development stage,** the researcher develops an instrument referring to the indicators that have been determined. Then the items that had been prepared were handed over to 7 instructors who were experts in the field of Mathematics Education, 2 people, Evaluation and Measurement, 2 people, who had researched TPACK, 2 people, one of whom was from abroad (Bakar et al., 2020). And an Educational technology expert. The researchers then revised the items according to their recommendations, and 36 items were usable. In the **Implementation Stage**, researchers tested the instrument prepared on 111 prospective teachers who had carried out practical teaching experience. **In the Evaluation Stage**, researchers analyzed the Instrument Validity and Reliability Test using Aiken's and Cronbach Alpha.

Based on the instrument development stage, the researcher determined that the product being developed had 36 valid and reliable items. This instrument can measure prospective teachers' TPACK self-knowledge based on Higher Order Thinking Skills (HOTs).

RESULT

The product of this research is the HOTs-based TPACK self-assessment instrument. This instrument was developed to measure the knowledge of prospective teachers. In the process of developing the instrument, researchers studied literature related to TPACK and HOTs in depth and consulted with experts. Then, researchers took 111 prospective teachers to test the validity and reliability of the instrument. The results of the development and validity of the instrument will be presented in tables 1 to 7 below:

Table 2
Field Validity of the TPACK Kindergarten Dimension Instrument Using Aiken's
Technological Knowledge

Item no	Statement	Validasi Aiken's	Cronbach's Alpha
1	I can utilize appropriate technology in Mathematics learning	0,41	0,728
2	I have difficulty connecting appropriate technology functions to the learning process	0.53	
3	I can choose the right props for learning mathematics	0.56	
4	I can adapt mathematics teaching aids in learning	0.59	
5	I have difficulty finding the advantages and disadvantages of the software used in learning	0.45	
6	I can choose software (media/applications) that suit the learning material	0.57	

This first domain is the prospective teacher's knowledge in the field of technology. Prospective teachers are expected to be able to utilize technology, choose the right technology, find the advantages and disadvantages of technology. This is stated in points 1 to 6 in table 1. These items were analyzed using Aiken's and were declared valid and reliable. Based on the reliability table, 0.728 is high reliability.

Table 3
Field Validity of the PK Dimension TPACK instrument Using Aiken's
Pedagogical Knowledge

Item no	Statement	Validasi Aiken's	Cronbach's Alpha
7	I can arrange the assessment form correctly according to the characteristics of the learning material	0,49	0.589
8	I can manage the class so that students do not get bored in learning	0.44	
9	I can choose learning strategies according to student needs	0.49	
10	I have difficulty arranging learning method steps to make it easier for students to understand the material.	0.40	

This second dimension refers to learning strategies. This dimension expects prospective teachers to be able to prepare various forms of assessment, manage teaching activities, choose appropriate learning strategies and create lessons that facilitate student understanding. This is as explained in points 7 to 10. These points are declared valid and reliable. Based on this table, the reliability is 0.589. With medium reliability category.

Table 4
Field Validity of the CK Dimension TPACK instrument Using Aiken's
Content Knowledge

Item no	Statement	Validasi Aiken's	Cronbach's Alpha
11	I can solve various kinds of mathematics problems from various mathematics content materials.	0.50	
12	I can develop various kinds of Mathematics solutions from low to high cognitive levels	0.51	0.700
13	I can make many variations of the correct assessment.	0.54	
14	I can evaluate students' understanding of content	0.54	
15	I have difficulty in preparing project and performance assessment forms to measure student skills	0.32	
16	I have difficulty developing test indicators to measure students' mathematical abilities	0.40	
17	I have difficulty creating math problems related to contextual problems.	0.34	
18	I can create math problems to measure math LOTs, MOTs, and HOTs	0.50	

Items 11 to 17 are dimensions that emphasize mathematical content knowledge. In this dimension, mathematics content is the basic knowledge that prospective teachers must master, these items can represent the content knowledge of prospective mathematics teachers. The items were declared valid and reliable with a reliability level of 0.700, categorized as high reliability.

Table 5
Field Validity of the TPACK TCK Dimension Instrument Using Aiken's
Technological Content Knowledge

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

Item no	Statement	Validasi Aiken's	Cronbach's Alpha
19	I can sequence math content combined with technology.	0.61	0.674
20	I can choose the right technology (visual aids/media/software) for the mathematical content.	0.67	
21	I can explain mathematical material by utilizing technology, including media, teaching aids and software	0.60	
22	I have difficulty preparing material using technology, both teaching aids/media and software	0.44	

In this domain, Technological Content Knowledge relates to how technology supports each mathematical content. Items 19 to 21 are declared valid and reliable, according to table 5, the reliability value is 0.674 with a medium level of reliability.

Table 6
Field Validity of the TPACK Dimension PCK Instrument Using Aiken's
Pedagogical Content Knowledge

Item no	Statement	Validasi Aiken's	Cronbach's Alpha
23	I can design material stages according to students' level of understanding based on their learning experience	0.51	0.765
24	I can choose appropriate learning methods to overcome students' difficulties in understanding the material.	0.63	
25	I can arrange the stages of the material correctly to support the explanation of the material being taught.	0.50	
26	I can design lesson plans using appropriate teaching methods and techniques to develop learning creativity.	0.63	

This dimension is a combination of pedagogy and content that focuses prospective teachers on mastering mathematical content with learning strategies. The items in table 5 are declared valid and reliable. The reliability level is 0.756 with high reliability criteria.

Table 7
Field Validity of the TPACK Dimension TPK Instrument Using Aiken's
Technological Pedagogical Knowledge

Item no	Statement	Validasi Aiken's	Cronbach's Alpha
27	I can design material stages according to students' level of understanding based on their learning experience.	0.69	0.733
28	I can choose appropriate learning methods to overcome students' difficulties in understanding the material.	0.66	
29	I can arrange the stages of the material correctly to support the explanation of the material being taught.	0.66	
30	I can design lesson plans using appropriate teaching methods and techniques to develop learning creativity.	0.52	

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

The Technological Pedagogical Knowledge dimension is a combination of technological and pedagogical knowledge, this dimension emphasizes prospective teachers integrating technology in learning. Points 27 to 30 are declared valid and reliable. According to table 7, the reliability value is 0.733 with a high level of reliability.

Table 8
Field Validity of the TPACK instrument Using Aiken's
Technological Pedagogical Content Knowledge

Item no	Statement	Validasi Aiken's	Cronbach's Alpha
31	I have difficulty combining technology with the methods used to teach mathematics content	0.43	0.755
32	I can evaluate mathematics learning combined with technology based on indicators	0.64	
33	I can connect technology (visual aids/software) into various mathematics content teaching'	0.66	
34	I can choose the right media, teaching aids and applications to solve mathematical problems.	0.63	
35	I can assess students' work in solving mathematics problems	0.50	
36	I can prepare the use of certain technologies for solving mathematical problems	0.56	

The seventh domain of knowledge is the final prayer. This domain refers to prospective teachers' knowledge in combining the seven domains of the TPACK framework. The items in this domain are declared valid and reliable with a reliability level of 0.755. Included in the high reliability category.

Discussion

The development of the TPACK framework has been discussed in related research (Graham, 2011; Önal, 2016; D. A. Schmidt et al., 2009; Yurdakul et al., 2012) Most research focuses on general measurements that refer to the TPACK dimensions. The TPACK dimensions are the starting point of the TPACK framework (Mishra & Koehler, 2006). In this research, the TPACK instrument was developed specifically to assess the self-knowledge of prospective teachers. The developed instrument contains the operational verb HOTs as described in the top level of Bloom's taxonomy (Darmawan & Sujoko, 2013).

In the Technological Knowledge dimension in table 2, Items 1 to 6 contain the operational verbs HOTs, namely Integrating and Comparing. In the Pedagogical Knowledge dimension in table 3, the items arranged contain the operational verbs HOTs, namely designing and directing. In this dimension, the validation value obtained is. Meanwhile, in the Content Knowledge dimension in table 4, the items arranged contain the operational verbs HOTs, namely Solve, Design, and Create. The Technological Content Knowledge dimension in table 5, the items arranged contain the operational verbs Designing and analyzing. Pedagogical Content Knowledge Dimensions in table 6, the items arranged contain the operational verbs Designing and Arranging. The Technological Pedagogical Knowledge dimension in table 7, the items arranged contain the operational verbs connecting and choosing. The Technological Pedagogical Content Knowledge dimension in table 8, the items arranged contain the operational verbs designing and choosing. All of the Hots operational verbs that have been mentioned are contained in indicators prepared referring to the Technological Knowledge theoretical framework from several studies (Abbitt, 2011; Mishra & Koehler, 2006; D. A. Schmidt et al., 2009; Graham, 2011; Shulman, 1986).

This research seeks to develop a self-assessment instrument to measure the TPACK of prospective teachers based on HOTs with valid and reliable instrument findings.

QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

Conclusion

The development of the instrument prepared in this research is specifically to measure prospective teachers' TPACK knowledge containing Higher order Thinking skills. This instrument was prepared based on theoretical studies (Önal, 2016; D. A. Schmidt et al., 2009; Yurdakul et al., 2012). From this theoretical study, indicators were developed that can define the dimensions of TPACK. After the indicators were arranged, the researcher carried out expert validation. After carrying out the expert validation test, the researcher developed the items referring to the indicators. Then field validation was carried out on 111 respondents. After carrying out the analysis, it was found that 36 items were declared valid and reliable. The author plans to conduct a longitudinal study with prospective mathematics teachers aimed at finding out what factors support TPACK. The research plan also involves prospective mathematics teachers who have carried out direct learning practice in the classroom. For future research, apart from analyzing factors, researchers suggest developing the TPACK instrument in more depth to find a model of the relationship between TPACK dimensions using Structural Equation Modeling (SEM) analysis.

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