The integration of technology in teaching mathematics

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Abstract. This paper presents the Transformation of Technological Pedagogical and Content Knowledge (TPACK) of three pre-service math teacher. They participate in technology-based learning modules aligned with teaching practice taught school and became characteristic of teaching method by using the mathematical software. ICT-based learning environment has been the demands in practice learning to build a more effective approach to the learning process of students. Also, this paper presents the results of research on learning mathematics in middle school that shows the influence of design teaching on knowledge of math content specifically.

1. Introduction

The challenge of accelerating change in the field of education in the 21st century is to find and develop tools that can make the efficiency and value of teaching and learning [1]. Technology is having an impact and change in efficiency as a tool of knowledge that can change the way the subject matter taught in teaching practice facilitates teacher and student learning in using new technology as a tool for collecting, organising and evaluating information in solving problems and innovate the practical ideas in the reality of life [2, 3, 4].

Many math teachers are aware of the opportunities of technology, such as interactive whiteboards, graphics calculators, software mathematics dynamic, program graphics, the system of computer algebra and others, too because in learning [5, 6]. However, the quality of the use of technology not only use the technology itself but how the technology selected can be integrated into content particular in learning. A teacher with the knowledge TPACK assumed to be able to figure out how to integrate technology into specific content and can apply the pedagogy most appropriate. Teachers in the 21st century are expected to be able to find out how to integrate technology into every aspect of education such as curriculum design, implementation, management and evaluation [7]. Therefore, it is very important for a teacher to come with the knowledge TPACK to survive in the educational system in the future. Recommendations from the Associated Mathematics Teacher Educators [8], states that the teacher education programme should provide the opportunity, for teachers, gained the knowledge and experience necessary to incorporate the technology in context teaching and learning of Mathematics.
The theoretical framework of TPACK, built on the framework of PCK (Pedagogic Content Knowledge) belongs to Schulman [9, 10, 11, 12]. Basic assumptions of this framework are that the teacher side of knowledge about technology and optimization of combined in the classroom is a balanced combination of content, pedagogy, and technology [11, 12, 13]. Harris and Hofer [14] mention the TPACK as something special, the application of knowledge-based content that supports the high integration of technology.

Based on Figure 1, TPACK is the center of the model, a representation of the slices of the following Knowledge:

1. **PCK**: how to teach specific content-based materials;
2. **TCK**: how to choose and use technology to communicate with the knowledge content;
3. **TPK**: how to use a particular technology when teaching.

TPACK ability of a teacher can be achieved when the teacher knows: (a) how technology tools can change the pedagogical strategies and representations of content to teach a particular topic, and (b) how the technology tools and impact on representation understanding of students against the topic [15]. Therefore it is important for teachers to learn how to have the ability of particular content domain TPACK for learning to be more effective, and the need to develop a design-based guide to assist him in the TPACK the process of teaching.

![Figure 1. Components of the TPACK framework [11]](image)

TPACK framework concept can give a new direction to describe the instructional idea in solving problems related to the integration of technology into teaching and learning practices as the theoretical basis for developing curriculum in teacher education programme [3, 16]. Research on teacher education reported that the TPACK model could be used as a potentially useful framework for preparing and developing teacher competence in school teaching [17, 18].

The purpose of this research is to explore technology-based learning approach in the context of the preparation and development of the competence of pre-service mathematics teacher to face the challenges of the changing flow of information and communication technology move more quickly. This article presents an exploration of the transformation competence TPACK of pre-service math teacher and how to integrate technology into teaching and learning mathematics of high school students.
2. Method
2.1. Participants
Two hundred and seventeen pre-service math teachers at a University in the town of Tasikmalaya have been taking computer courses. For research, three pre-service math teachers in this program are invited to participate in a case study. Participants in the study this case study is one female and two males, and those aged 22 to 23 years. All of them have satisfactory basic ICT skills, but they do not have the experience of using ICT for experiments in and teaching mathematics in the past.

2.2. The use of mathematical software in learning
Participants are introduced to the use of mathematical software such as GeoGebra, Cabri, and Geometers Sketchpad as a tool and medium for learning mathematics. The module created presents examples of material that can be taught by using the software.

After completing the learning presentation using mathematical software, participants are encouraged into critical open discussion forums to consider the potential impacts of technology-based teaching methods based on the TPACK framework. The critical open discussions on this case are consistent with the criteria for ICT-TPACK consisting of (a) the identification of the appropriate topic to teach with technology; (b) identification of appropriate representation to change content; (c) identification of teaching strategies that are hard to do in the traditional way; (d) the selection of the right tools and pedagogical use of their capabilities; and (e) the identification of the right integration strategies [19].

2.3. Data collection
To investigate the TPACK transformation from three pre-service math teachers who participated in this research, two instructional design tasks by using mathematical software into practice teaching and the learning process of students. The task of designing the first given to a participant in the first week with learning materials using mathematical software, before the first case study presentations. At the end of the learning materials, participants are assigned to complete the task of designing the two using mathematical software into practice teaching and the learning process of students. Also, the results of the study conducted with high school students put on the units of analysis are related to present experimental results the use of mathematical software in teaching practices.

2.4. Data analysis
For analyzing transformation competence of TPACK three pre-service math teachers, using the analysis of the contents in writing systematic design tasks. The coding system of the rubric with the TPACK framework developed and then encoded based on the design of the tasks the seven categories defined by the TPACK framework, namely CK, PK, TK, PCK, TCK, TPK, and TPACK.

3. Result
3.1. TPACK transformation of pre-service math teacher
3.1.1. The 1st Pre-service Math Teacher (PMT-1)
PMT-1 is male 23 years old, has no teaching experience, has no work experience, proficient using excel, and can use GeoGebra. Mathematical instructional design tasks with the TPACK framework can be summarized in Table 1.
Table 1. Summary of TPACK component for the 1st pre-service math teacher

| Design of Learning Mathematics (DLM) | TPACK Components |
|-------------------------------------|------------------|
|                                     | CK   | PK   | TK   | PCK  | TPK  | TCK  | TPACK |
| DLM-1 (cube)                        | x    | x    | x    | x    | x    | x    | x     |
| DLM-2 (surface area of a cube)      | x    | x    | x    | x    | x    | x    | x     |

Note: Pn = perceptional levels, Cn = conceptional level, An = action level, Nn = no perception

For the preparation of instructional design, PMT-1 chooses flat-side geometry topics with the material properties of the cube for DLM-1 and the surface area of the cube for instructional DLM-2. On DLM-1, PMT-1 identifies content from the properties of the cube, such as the shape of the side of the cube, the positions of the sides, and the position of the ribs. PMT-1 describes learning cube properties by observing the shape of the side of the cube, the positions of the sides of rib and positioning objects that exist in the classroom or instructional media are presented. The use of software GeoGebra also shown to have more details about the properties of the cube especially avoid misconceptions students at space position of divination orthogonal. However, the PMT-1 did not explain the link between content and presentation, how to use GeoGebra software in learning. The third component of this given the PMT-1 alternative nature functioned as a supporting idea (supporting the idea) in justifying the previous explanation.

On DLM-2, the PMT-1 describe the surface area of a cube (CK-Pn), how to find the surface area of the cube (PK-Pn) as well as the use of GeoGebra to explain the steps of determining the surface area of the cube (TK-Pn). The relationship between the content and pedagogical knowledge explained that to be able to find the surface area of the cube, the students should understand the breadth of each side of the cube (PCK-Cn). The area on each side of the cube it will easily be understood when it is displayed in the net-mesh cubes served in GeoGebra (TCK-Cn). However, the PMT-1 did not explain in detail about the steps the presentation of this topic in GeoGebra. Transformation on the use of technology emerging from the results of students’ difficulties in the identification of the observation of the media presented (TPK-Pn). The PMT-1 conceptual relationship between mention content, pedagogical and technological in DLM-2 (TPACK-Cn), i.e., by revealing the need for technology to represent the shape of the surface of the cube, so that facilitate students in identifying the area of each side of the cube.

3.1.2. The 2nd Pre-service Math Teacher (PMT-2)

PMT-2 is a 22-year-old female, private tutor, does not have the experience of teaching in schools, can use excel, and know the software GeoGebra but have never used. Mathematical instructional design tasks with the TPACK framework can be summarized in Table 2.

Table 2. Summary of TPACK component for the 2nd pre-service math teacher

| Design of Learning Mathematics (DLM) | TPACK Components |
|-------------------------------------|------------------|
|                                     | CK   | PK   | TK   | PCK  | TPK  | TCK  | TPACK |
| DLM-1 (Integer Operations)          | x    | x    | x    | x    | x    | x    | x     |
| DLM-2 (Linear equations of one variable) | x    | x    | x    | x    | x    | x    | x     |

Note: Pn = perceptional levels, Cn = conceptional level, An = action level, Nn = no perception
On DLM-1, PMT-2 identify materials about calculating integer operations (CK-Cn) and how to transform the operations of subtraction, multiplication, and division into the summation operation, as well as using the inductive way to indicates that the negative multiplication by negative is positive (PK-Pn). CK needs to be delivered through the use of computer technology (TCK-Pn), like GeoGebra, Cabri or GPS, so the shape of the operation of subtraction, multiplication, and division and does not appear as though it has been superseded by the operation of addition (TPACK-Pn). The use of computer technology is meant to visualize forms of positive numbers and negative numbers (TCK-Pn) so that the students can distinguish between the sign of the number with the mark operation (PCK-Pn).

On DLM-2, the concept of the linear equations of one variable (LEOV) identified by PMT-2 about the use of the concept of operations to calculate an integer (CK-Pn). Because the term segment is a new concept for the students classes VII, a representation of a segment must be changed into another concept that is easy to understand students (PCK-Pn), i.e. through a visual representation (TCK-Cn) so that the term variables and constants are perceived by the students as if real (TK-Pn). Students must have the perception that the addition and subtraction of a variable are essentially the same with the addition and subtraction of constants (PK-Pn). Computer animation is very supportive towards learning this because representation variables and constants are easy to modify (TPK-Pn). By showing the relationship between CK, PK, and TK, PMT-2 has a good understanding of how the integration of content and technology, pedagogy (TPACK-Cn) so that the delivery of the material linear equations one variable (LEOV) the nature of mind-on can be a hands-on activity.

3.1.3. The 3rd Pre-service Math Teacher (PMT-3)

PMT-3 is a man of 23, have teaching experience, be able to use excel, and GeoGebra. Mathematical instructional design tasks with the TPACK framework can be summarized in Table 3.

| Design of Learning Mathematics (DLM) | TPACK Components |
|-------------------------------------|------------------|
|                                     | CK Pn Cn PK Pn Cn TK Pn Cn PCK Pn Cn TPK Pn Cn TCK Pn Cn TPACK |
| DLM-1 (geometry)                    | x x x x x x x |
| DLM-2 (ball)                        | x x x X x x x |

Note: Pn = perceptional levels, Cn = conceptional level, An = action level, Nn = no perception

On DLM-1, PMT-3 identifies the difficulty students on the material geometry in determining the corresponding position, either side of a corresponding or corresponding angle (CK-Cn). The result triggered the use of computer technology to a clip-right position between waking up so that the corresponding position (TK-Pn). Thus students can easily observe a corresponding side (TCK-Pn) to form the equation geometry is right (PK-Pn). Students can easily change the position of some images being mutual position corresponds to the way some wake that will be adjusted (TPK-Pn). The way is a technique that is good especially for students with low space divination (PCK-Pn). PMT-3 has a good understanding of the relationship between the PK, CK, TK, and delivery of TPACK (TPACK-Cn).

On DLM-2, PMT-3 identify the concept of balls (CK-Cn) is an abstract concept compared to wake up other spaces. PMT-3 looked at that space is a vast awake pedestal x-height (when the sockets and its roof congruent) and 1/3 wide x base x height (when only has the base and had no roof) (PK-Pn). The ball appears to be different from the other room, but PMT-3 has the perception that the concept could be applied to other room wake up to find the formula volume sphere (PCK-Cn). When the bottom quadrilateral is input pine on blankets and its vertex at the point the ball is placed in the center of the ball through the virtual image (TK-Pn), then students will easily that pedestal of n is a square.
blanket pine fruit balls (TCK-Cn). Furthermore, students will immediately be able to find the volume of the fruit n pine quadrilateral, i.e., $4\pi r^2 \times \frac{1}{3} \times r$ (TPK-Cn). PMT-3 identifies the relationship between CK, PK, and TK which is actionable in the real implications in learning (TPACK).

3.2. Implementation of learning at school (the result of a research class of pre-service math teacher)

Implementation of learning at the school of the three prospective mathematics teacher is teaching practice in experiment results of applying learning by using the mathematical software [20]. The findings in the field show that understanding TPACK pre-service math teachers affect the practice of teaching mathematics in the classroom and instructional practices affect the conceptual understanding of middle school students in the field of mathematics.

4. Discussion

Empirical findings provide evidence that understanding TPACK conceptual of the third pre-service math teachers have undergone a transformation and improvement of knowledge that is generated by the following training using learning software-math. Also, the findings also show that math teacher candidates on TPACK task design both have a higher level of competence than the first design task. In more detail, it is interesting to note that prospective teachers of mathematics one have resulted in the perception of the PCK, the conception of TPK and TCK, for the development of competencies at the level of the conception of TPACK. Also, evidence that TPK and TCK PMT-2 has changed the perception of the level of conception similar to the PMT-3 who has changed PCK, TPK, and TCK at the perception level to the conception level. According to the transformation of their knowledge, the level of competence of the TPACK for PMT-2 and PMT-3 need to be developed to a higher level, from perception level to conception and action respectively.

The results of this research show that the technology-based learning has a positive impact on the development of the competence TPACK of a pre-service mathematics teacher. The result is because the use of technology-based learning materials for model TPACK pre-service teacher something to do with the knowledge content with changing shape significantly TPACK [16, 21, 22]. Moreover, consistently, research findings stating that technology-based teaching for teacher professional competency development led to a significant change in the learning activities of high quality.

5. Conclusion

This paper reports the use of technology-based learning approach to developing the competence of pre-service math teacher TPACK and transforming knowledge in integrating technology into practice teaching mathematics after technology-based learning training. In an effort to better serve the needs of the high-quality mathematics teachers, the result of this case study illustrates that competence TPACK can, in particular, be regarded as core attributes for future math teachers. The result of learning model with using the tools of technology can help students develop an understanding of mathematics and mathematics teaching method practices affect for teachers. Also, the competency of the TPACK mathematics teacher can have a direct impact on student learning in mathematics lessons. The results of this study show that the technology-based learning approaches can be an effective role in preparing and enhancing competency TPACK for teachers of mathematics.

Acknowledgments

The researcher thanks to supervisors and also the research fund, BPPDN KEMENRISTEK DIKTI. Hopefully, the results of this study can have a positive impact on the author in particular and the world of education in general.
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