Technological, pedagogical, and content knowledge math teachers: to develop 21st century skills students

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Abstract. This study aims to describe the ability of Technological, Pedagogical, and Content Knowledge of mathematics teachers and the way mathematics teachers use Technological, Pedagogical, and Content Knowledge in developing 21st-century students' skills through math learning. This research was conducted in some junior high schools in Surakarta City. The subject of the research is the teacher of mathematics. The type of this research is qualitative research with case study approach. The data used were obtained from observations and interviews with 4 teachers. The results showed that the TPACK ability of all subjects at the medium level with a total mean of 2.75. The use of interactive media in learning, as well as the presentation of HOT problems through interactive media, can develop students' critical thinking skills and can bring students creativity and innovation towards mathematics learning. The use of the drill method and the scaffolding approach can develop students' critical thinking skills. Opening classes for discussion and question and answer can develop students' communication skills. The use of cooperative learning models can develop students 'collaborative abilities with their peers, while also developing students' communication skills.

1. Introduction
The biggest challenge of education in the 21st century is to apply technology in the learning process and develop 21st-century students' skills in order to compete in globalization. Learning practices in the 21st century prepare students to face greater global learning challenges which include international assessments, such as Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA) [1]. According to a study by the National Education Association [2] and Partnership for 21st Century Skills [3], the four most important and specific skills in 21st-century learning are critical thinking skills, communication skills, collaborative skills and creative and innovation skills (4C) [1]. Critical thinking Skill is the ability to understand a complex problem, connecting information one with other information so that eventually emerged various perspectives in solving the problem [2, 4]. Communication Skills refers to an individual's ability to communicate clearly, using spoken, written, and non-verbal language [2-4]. Collaboration Skills is the act of working together to achieve common goals [3, 4]. The Partnership for 21st Century Expertise says that mastering collaborative skills requires the ability to work effectively with diverse teams [2]. Creative and innovation skills are the ability to generate new ideas from existing ideas. Creativity depends on one's creative thinking, the process of thinking to create new ideas that lead to new discoveries and often called innovation [4].

There is an interesting fact in this 21st century, many students who better understand technology than teachers [5]. Getting teachers to use technology learning methods and to adopt 21st-century
teaching and learning methods also present a complex challenge [6]. This, of course, must be a trigger for teachers' enthusiasm, especially math teachers to better understand technology, and using technology in education. The National Council of Teachers of Mathematics (NCTM) Principles and Standards point out the role of the efficient use of technology in facilitating students' mathematics learning [7]. In line with technological developments, Technological Pedagogical Content Knowledge (TPACK) presents solutions to combine the application of technology with pedagogic and content in one learning goal. In TPACK, teacher knowledge for technology integration makes the learning effective and efficient [8]. TPACK can support the teachers to implement effective learning [9]. This knowledge is different from the general pedagogical knowledge which is used by the teacher, from the technology which needs specific expertise, discipline [10].

TPACK is commonly used for identifying the relationships among technology, pedagogy, and content as well as in studies focusing on the integration of technology [7, 10, 11, 12]. The TPACK framework emphasizes how the connections among teachers’ understanding of content, pedagogy, and technology interact with one another to produce effective teaching [5, 13, 14]. Even as a relatively new framework, the TPACK framework has significantly influenced theory, research, and practice in teacher education and teacher professional development [15]. TPACK is a framework developed by Mishra and Koehler based on Pedagogical Content Knowledge that was introduced by Shulman in 1986 and 1987 [11]. Specifically, three major knowledge components form the foundation of the TPACK framework as follows; 1) Content knowledge (CK) refers to any subject-matter knowledge that a teacher is responsible for teaching; 2) Pedagogical knowledge (PK) refers to teacher knowledge about a variety of instructional practices, strategies, and methods to promote students’ learning; and 3) Technology knowledge (TK) refers to teacher knowledge about traditional and new technologies that can be integrated into curriculum [15].

Four components in the TPACK framework follows; 1) Technological Content Knowledge (TCK) refers to knowledge of the reciprocal relationship between technology and content; 2) Pedagogical Content Knowledge (PCK) is to Shulman’s (1986) notion of “an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction” (p. 8); 3) Technological Pedagogical Knowledge (TCK) refers to an understanding of technology can constrain and afford specific pedagogical practices; and 4) Technological Pedagogical Content Knowledge (TPACK) refers to knowledge about the complex relations among technology, pedagogy, and content that enable teachers to develop appropriate and context-specific teaching strategies [15]. If we think of the teacher as key in the use of information communication technology (ICT) in pedagogy, then knowledge describes by the TPACK framework should be considered important [16].

This study aims to find out how high the TPACK skills of mathematics teachers and how mathematics teachers use TPACK to develop 21st-century skills of junior high school students.

2. Methods

The type of this research is qualitative descriptive research with a case study approach. This research was conducted in 4 junior high schools in the city of Surakarta. The subjects of this study were 4 mathematics teachers who taught in grade 8 junior high school in 4 different junior high schools in Surakarta city, Indonesia. The sample selected by purposive sampling with two main criteria, the teacher knows about TPACK and knows about 21st-century skills. Data validity used is data triangulation. The instruments used are observation sheets and interview guidelines. To see how high the teacher's TPACK ability is, observations are carried out with 5 scales; “1 = very bad”, “2 = bad”, “3 = average”, and “4 = good”, and “5 = very good”. The assessment used by researchers is to look at the average value obtained by each research subject. The assessment used is the scale; 4 < $\bar{x}$ ≤ 5 = very good/very high; 3 < $\bar{x}$ ≤ 4 = good/high; 2 < $\bar{x}$ ≤ 3 = enough/medium, 1 < $\bar{x}$ ≤ 2 = bad/low, 0 < $\bar{x}$ ≤ 1 = very bad/very low. The data in this study were collected based on the results of direct observations on how to teach mathematics teachers in grade 8 middle school.
3. Result and Discussion

3.1 Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK)

From the observations of the four research subjects (S1, S2, S3, and S4), the results of the TK, PK, and CK of the subjects will be displayed in Table 1.

| Observation point                          | Skor |
|-------------------------------------------|------|
| TK1: Can operate various computer devices | S1   |
|                                            | S2   |
|                                            | S3   |
|                                            | S4   |
| TK2: Can use Microsoft Office             | 3    |
| TK3: Can use other computer programs      | 2    |
| TK4: Can use the internet                | 4    |
| PK1: Can provide value to student performance | 4    |
| PK2: Can adjust clothes based on the student's condition | 3    |
| PK3: Can assess students in various ways  | 3    |
| PK4: Can manage the learning time        | 3    |
| CK1: Teacher understands mathematics      | 4    |
| CK2: Teacher understand the basic theory of mathematics | 3    |
| CK3: Teacher gives a different math problem | 2    |
| CK4: Teacher can answer each student's questions correctly | 3    |

Table 1 shows that the TK of all subjects is good/high level, with a total mean score of 3.18. PK of all subjects is good/high level with a total mean of 3.18. CK of all subjects medium level with a total mean of 2.77.

3.2 Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Pedagogical Content Knowledge (PCK)

From the observations of the four research subjects (S1, S2, S3, and S4), the results of the TCK, TPK, and PCK of the subjects will be displayed in Table 2.
From Table 2, it can be seen that TCK all subjects at the medium level with a total mean of 2.31. From Table 2, it also can be stated that mathematics teachers with good CK and TK abilities from each subject do not guarantee that the entire TCK subject is also good. The TPK was at the medium level with a total mean of 2.83. Even though it is at the medium level, all subjects have been able to use their technology and pedagogic well. The PCK of all subjects is good with a total mean of 3.41. If we see the mean difference between TPK, TCK, and PCK, the application of technology in learning is still relatively low. From the observations, it is known that the relationship between PK and CK is better than TK and PK or CK. This result is in line with previous research [12, 17] which indicates that pedagogical choices are content-related.

3.3 Technological Pedagogical Content Knowledge (TPACK)

From the observations of the four research subjects (S1, S2, S3, and S4), the results of the TPACK of the subjects will be displayed in Table 3.

From Table 3, it can be seen that the TPACK ability of all subjects at the medium level with a total mean of 2.75. TPACK1 and TPACK2 showed that the application of technology in the process of learning mathematics and the assessment of students' mathematical abilities were good enough. However, TPACK3 and TPACK4 also showed that the subject's ability to apply technology to get closer and help students in solving students' math problems was still lacking. From the observation result, it can be stated that S3 and S4 subjects have better TPACK compared to S1 and S2 subjects.
3.4 Using TPACK to develops 21st-century skills student

With the ability of TPACK from research subjects who are at the medium level, of course, this is worthy of being used as capital to find out more about how junior high school mathematics teachers develop 21st-century students' skills through TPACK. The data used is data from interviews with all subjects. The results of the interview include; 1) critical thinking and problems solving skills; 2) communication skills; 3) collaborative skills; and 4) creative and innovative.

In order to develop students 'critical thinking skills, all subjects agree that using the drill method with a scaffolding approach can develop students' critical thinking skills. Scaffolding approach in applying TPACK in class can help students think and reflect better [17]. In addition to using the drill method and S4 scaffolding approach also added that using questions based on Higher Order Thinking (HOT) will be able to develop students' critical thinking skills. In developing student communication skills, a good relationship is needed between the teacher and students in the learning process. In applying TPACK, this will certainly have a significant effect on the development of students' ability to communicate. A good relationship is needed between the teacher and students so that the learning of mathematics in the classroom becomes harmonious. By freeing students to ask and express opinions in the learning process will develop students' communication skills well. Discussing with teachers is also a factor that can develop students' communication skills.

The pedagogic teachers of mathematics in utilizing the TPACK framework is an important factor in developing 21st-century students' skills. The insertion of cooperative learning in the implementation of TPACK can help students to collaborate with their peers and communication skills during the presentation. Communication improved through planned cooperative and collaboration sessions [18]. If TPACK is presented with a variety of creative interactive media, it will increase students' desire to learn mathematics. HOT type math problem is presented in interesting media can develop students' creativity and innovation in mathematics learning.

4. Conclusion

The results of this study indicate that ability TK of the four subjects is good/high level, with a total mean score of 3.18. PK of all subjects is good/high level with a total mean of 3.18. CK of the four subjects can be categorized into the medium level with a total mean of 2.77. TCK all subjects at the medium level with a total mean of 2.31. TPK of all subjects was at the medium level with a total mean of 2.83. PCK of all subjects is good with a total mean of 3.41. TPACK ability of all subjects at the medium level with a total mean of 2.75.

The pedagogic ability of mathematics teachers is very influential in the application of TPACK in developing 21st-century students' skills. However, mastery of technology and content also cannot be separated from efforts to develop 21st-century students' skills. Based on the results of research as well as technology, pedagogic, and knowledge of mathematics teacher content, there were several ways that were in line with TPACK to develop 21st-century students' skills. This method can be shown by the three main components of TPACK, namely TK, PK, and CK. The use of interactive media in learning, as well as the presentation of HOT problems through interactive media, can develop
students' critical thinking skills and can bring students creativity and innovation towards mathematics learning. The use of the drill method and the scaffolding approach can develop students' critical thinking skills. Opening classes for discussion and question and answer can develop students' communication skills. The use of cooperative learning models can develop students' collaborative abilities with their peers, while also developing students' communication skills.

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