Professional Teachers using Technological Pedagogical Mathematics Knowledge, are Mathematics Pre-Service Teachers Ready?

Tommy Tanu Wijaya, Yimin Ning, Umi Salamah, and Neni Hermita

School of Mathematical Sciences, Beijing Normal University, China
department of mathematics and statistics, Guangxi Normal University, China
STAI Ma'had Aly Al-Hikam, Malang, Indonesia
PGSD Study Program, FKIP, Universitas Riau, Pekanbaru 28293, Indonesia

*Email: 202139130001@mail.bnu.edu.cn

Abstract. In today's information age, the informatization of education requires teachers to become a new type of teacher with information capabilities. The subject teaching knowledge of integrated technology is the knowledge basis for the professionalization of teachers in the information age. This research aims to analyze Pre-service teachers’ perception of Technological, Pedagogical, and Mathematical knowledge. This research adopts the case study method, using Questionnaires for data collection tools. The sample of this research is 84 pre-service teachers from Guangxi Normal University, China. The respondents are undergraduate and master students that are chosen randomly. The instrument used is 20 questionnaire items on pre-service teachers’ perception of their TPMK ability. The data was processed by using SPSS and Microsoft Excel. The research result shows that pre-service teachers have a good Technological Pedagogical Mathematical Knowledge ability but their Technological knowledge is still lacking. Teacher education programs should provide pre-service teachers with opportunities to develop TPMK to integrate technology into teaching effectively.

1. Introduction
In 2020, there are still students that have difficulties in solving mathematics problems. Students still feel that mathematics is a hard subject. Apsari et al [1] analyzed 32 5th grade students’ understanding ability on algebra and found that their understanding towards algebra was still lacking. Arifah and Retnawati [2] gave 5 polyhedron questions to see the difficulties faced by junior high school students towards geometry and analyzed it using Newman’s procedure. The research result shows that junior high school students still make mistakes in arithmetic operation, using polyhedron, and also in understanding the question. Astuti et al. [3] also made research to analyze 4th-semester university students by giving 4 probability questions to preservice mathematics teachers. However, most of them still had difficulties in solving the probability questions even though the question given were high school grade questions. Will these students be ready to teach after they graduate? This showed that mathematics is difficult not only for middle school or junior high school students but also for university students. This is why a model or a new teaching method is needed to improve students’ understanding ability towards a mathematics topic.

Pre-service mathematics teachers are pioneers and play an important role in the education field. Pre-service mathematics teachers should have 21st-century skills such as being able to use technology to improve students’ mathematical ability. The article studies the technical knowledge of teachers. More emphasis should be placed on teachers' technical knowledge, and a few references related to
"pre-service mathematics teachers using technology can promote teaching" should be added. For example, teachers should make rational use of tool resource design with the support of technology. Teaching activities enrich students' learning experience, prompting students to strengthen the connection between knowledge and the real world to realize the construction of knowledge meaning. According to NCTM [4], learning mathematics aims to improve problem-solving, reasoning and proofing ability, mathematical connection, representation, and communication ability. These skills are not only important but it serves as basic knowledge for students to face work in the future. There has been some research in 2019 and 2020 that showed that students still don’t have those skills [5,6].

The design and implementation of mathematics courses should reasonably use modern educational technology according to the situation. In some remote areas, they still use the traditional teaching method even though now is an era where more traditional learning is "changing towards the use of technology." Technology has become more known and often used in teaching [7]. The use of technology for learning purposes is not something unusual. Tablets, computer mathematics software are not only used by teachers to teach, but students can also use them in class. De porter’s [8] research proved that students who learn by doing can absorb more information than students who are passive in class. Also, students nowadays are more capable to use computers and technology compared to their parents. This situation made education more possible to be integrated with technology as it can improve student’s ability. From the overall situation, when teaching specific content, teachers require that the proportion of students using information technology is lower than the proportion of teachers themselves. Future teachers not only should they master the mathematics theory, but they should also know how to teach mathematics with their technological pedagogical mathematical knowledge skill.

The world’s attention given to the education field is to integrate technology into the education system both for social and science. Universities and professional researchers prepare the next generation so that they can integrate technology into education. As a learning media, technology has been developed and implemented in mathematics learning. There has been some research in the world that is developing artificial intelligence for education [9,10]. There are some benefits of using technology such as increasing students’ learning interest [11], finding out students’ difficulties, solve hard mathematics problems, explore and improve students’ mathematical thinking ability [12], visualize geometry figures [13], explain abstract mathematics theories, simulate a phenomenon that is too big or too much. All these will be easier to understand with the help of technology. An important benefit of using technology is that it can improve students’ mathematical understanding of a certain theory. There are a few pieces of research that proved that using technology can help students in improving their mathematical abilities. If pre-service teachers are still comfortable with the old way of teaching and do not learn how to use technology in education, they will be left behind.

Technological pedagogical mathematical knowledge is one of the frameworks from TPACK and was developed specifically for mathematics [14]. TMPK describes the relationship between technological knowledge (TK), pedagogical knowledge (PK), and mathematical knowledge (MK). TMPK framework is a knowledge structure model that mathematics teachers should have in the context of informationized classrooms. It consists of three basic elements: mathematical knowledge (MK), teaching knowledge (PK), and technical knowledge (TK). It also includes four Interactive elements, namely, integrated technical mathematical knowledge (TMK), technical teaching method knowledge (TPK), teaching knowledge (PMK) and integrated technical mathematical teaching knowledge (TPMK). This framework is usually aimed at mathematics teachers as a reference to improve teaching skills by integrating it with technology. Figure 1 shows 7 knowledge domain that focuses on making TPMK ability. The specified definition that is from the previous analysis can be seen below.

- Technological Knowledge (TK): the ability to use various forms of technology like computers, gadgets, tablets, handphones, applications, software, and the internet.
- Pedagogical Knowledge (PK): the ability to teach a theory by using various models and learning strategies, lesson plans, and time management.
- Mathematical Knowledge (MK): the basic knowledge and basic concept of mathematics and how to solve mathematics problems.
- Technological Mathematical Knowledge (TMK): the ability to apply technology into mathematics when explaining a certain theory such as visualizing the model or shape, making learning videos, using dynamic mathematics software to explain mathematics.
- Pedagogical Mathematics Knowledge (PMK): the ability to transfer mathematics’ basic concept or knowledge to students by using a suitable approach or learning model so that students will be able to understand the concept of knowledge.
- Technological Pedagogical Knowledge (TPK): the ability to apply technology on a certain subject such as making an interesting learning video, making interesting game-based learning.

![Figure 1. TPMK framework](image)

Researchers found out that the use of technology in mathematics learning (TMPK) is very important. Without realizing it, the development of technology and mathematics education is moving towards TMPK. There have been a lot of researches on the development of learning media that uses mathematics software [15,16]. Even China has developed its dynamic mathematics software which is Hawgent [17]. Researchers used Hawgent to develop a learning video and also developed a game-based learning media that can catch students’ attention [18]. A technology-based learning media can increase students’ learning interest in mathematics and they will not be scared of mathematics. There have been various researches on the development of technology-based learning media but there is no research on whether pre-service teachers have mastered the TPMK ability. Knowing the importance of TPMK ability and the benefit of technology on students’ skills, researchers took samples from a university in China and analyzed how much pre-service teachers master the TPMK ability and whether the curriculum can help them improve pre-service teachers’ TPMK ability. The focus of this research is to analyze the Technological Pedagogical Mathematical Knowledge (TPMK) of pre-service teachers in China. The result of this research can serve as information and evaluation material to improve the pre-service teachers’ TPMK ability.

The methods of TPMK ability measurement mainly include the self-report method, performance evaluation method, observation method, etc. Such research mostly adopts subjective report-style questionnaire survey method to understand the status quo of ability. The quality of the survey depends on the level of pre-service teachers’ evaluation of their knowledge. Factors such as its honesty and integrity cannot reflect the actual situation to a certain extent. There are few comprehensive status surveys supplemented by other methods such as qualitative material analysis. Therefore, this study adopts qualitative interview research methods to study the technical teaching mathematics of pre-service teachers. This research focus on Pre-service teachers from Guangxi Normal University’s perspective towards TPMK ability and their preparation to become a professional teacher with a good TPMK ability.
2. Method
This research used a combination of quantitative research method. The quantitative research method used a questionnaire to analyze pre-service teachers’ perception of technological, pedagogical, and mathematical knowledge. This research was done from December 2020 until February 2021. The population of this research is 84 students from Guangxi Normal University, China wherein most of them are female students (69.05%). This is because Guangxi Normal University is a university that focuses on creating prospective teachers that are why most of the students are female. There are 80.95% undergraduate students and 19.05% graduate students. 51.14% of these students are from rural areas and 42.86% of them are from an urban area (can be seen in Table 1). Universities in China usually require students to live on campus during their study period.

Table 1. Sample research data of pre-service mathematics teachers in Guangxi normal university.

| Category         | Sum (n) | Percentage (%) |
|------------------|---------|----------------|
| Gender           | 84      |                |
| Male             | 26      | 30.95          |
| Female           | 58      | 69.05          |
| Grade            |         |                |
| First year       | 10      | 11.90          |
| Second-year      | 30      | 35.71          |
| Third-year       | 12      | 14.29          |
| Fourth-year      | 16      | 19.05          |
| Graduate student | 16      | 19.05          |
| Residency        |         |                |
| Urban area       | 36      | 42.86          |
| Rural area       | 48      | 57.14          |

The instrument used in this research is a questionnaire that was given to pre-service mathematics teachers. The questionnaire consists of 20 items that use 4 scales on the TPMK ability which are very good, good, poor, very poor. The questionnaire data collected were processed further using Microsoft excel and SPSS to be able to know pre-service teachers’ TPMK ability. The data interpretation method can be seen in table 2. We can know the pre-service teachers’ TPMK ability from the average score.

Table 2. Questionnaire data interpretation on TPMK ability [19].

| Scale            | Interpretation |
|------------------|----------------|
| 3.26 < X < 4     | Very good      |
| 2.51 < X < 3.25  | Good           |
| 1.76 < X < 2.5   | Poor           |
| 1 < X < 1.75     | Very poor      |

3. Results and discussion
The questionnaire starts with pre-service teachers’ basic knowledge of TK, PK, MK (see table 3). The results show that, on the whole, pre-service teachers’ understanding and application of teaching knowledge and mathematical knowledge are relatively good, and their understanding and application of technical knowledge is significantly lower than that of teaching knowledge and mathematical knowledge, indicating that junior high school mathematics teachers use technical knowledge. Knowledge is most lacking. Pre-service teachers’ perspectives on technological knowledge are still poor and improving this knowledge is not easy as we can see from table 1, most of the pre-service teachers are from rural areas where the use of technology is not commonly used. For schools and
students in remote rural areas, the equipment for schools and families to integrated technology in learning is not enough. The government is still trying to improve and develop technology, the internet, and connections in rural areas. Another reason is that in China, elementary students to high school students don’t use phones often to prevent students from playing games all day long. In China, the use of phones and students’ playing time is strictly controlled by parents so the use of phones is very effective. This can be proved when one of the researchers went to one of the elementary schools in Guilin, China. When researchers asked 5th-grade students about what is a phone and what’s its use, students answered that the phone is used to watch school-related videos and to communicate to parents and teachers. Based on this reason, the Chinese government made a policy on internet usage to develop learning media that serves as a tool to help students from elementary school to university.

### Table 3. Observation result for TK, PK, and MK.

| No   | Statement                                                | m    | Sd   | Alpha | Interpretation |
|------|----------------------------------------------------------|------|------|-------|----------------|
| TK-01| Can operate computer, laptop, gadget properly           | 2.17 | 0.93 |       | Poor           |
| TK-02| Can operate dynamic mathematics software                 | 2.37 | 0.86 |       | Poor           |
| Sub TK|                                                         | 2.27 | 0.02 | 0.95  | Poor           |
| PK-01| Can use various teaching methods                         | 2.90 | 0.55 |       | Good           |
| PK-02| Can manage time                                          | 2.81 | 0.63 |       | Good           |
| PK-03| Can improve students’ mathematical ability               | 2.67 | 0.72 |       | Good           |
| Sub PK|                                                         | 2.79 | 0.01 | 0.91  | Good           |
| MK-01| Mastered mathematics theories                            | 2.95 | 0.62 |       | Good           |
| MK-02| Mastered basic concepts of mathematics theories           | 2.88 | 0.55 |       | Good           |
| MK-03| Can answer all of the students’ questions correctly      | 2.45 | 0.70 |       | Poor           |
| Sub MK|                                                         | 2.76 | 0.07 | 0.90  | Good           |

Pre-service teachers’ perspective on Pedagogical Knowledge is good. PK ability is one of the abilities that should be mastered by teachers to be able to teach a theory. The lack of teachers’ PK ability will make students have difficulties in understanding basic concepts or even mathematics formulas. Another effect is students will find mathematics difficult and boring or even scary. Most of the mathematics curriculum in China focuses on the way of teaching and various interesting teaching model. They have adopted ways of teaching from other countries and even developing teaching methods to be better and one of them is the six-questions cognitive model. It is a teaching model from Mc. Carthy and was developed further by Y Zhou [20].

The research result and survey showed that pre-service teachers’ mathematical knowledge is good. Mathematics problems are not a difficult thing for students in china. Based on the PISA 2015 and 2018 results, the mathematical ability of students in China is in the top rank [21]. A good teaching method and a good basic concept understanding make students also have a deep understanding of mathematics’ basic concept which resulted in students not fooled by a wide range of problems. Chinese students who participated in the International Mathematical Olympiad (IMO) always bring home a gold medal and became a world spotlight [22]. Researchers found out that pre-service teachers get mathematics and mathematics Olympiad courses 3 hours per week. China prepares its teachers to teach and find students who are talented in the mathematics Olympiad.

According to table 4, pre-service teachers’ technological mathematical knowledge is 2.46 or it’s below 2.5 which falls in the poor category. This is in line with research that stated that TK has an impact on TCK and TPACK. In table 3, we can see that pre-service teachers’ technological knowledge is still low which causes their TMK to be also below 2.5. However, pre-service teachers’ pedagogical mathematical knowledge is in a good category. They were able to use various teaching methods to teach basic mathematics concepts. Pre-service teachers were also trained to use various creative ways and methods by using a problem-based learning approach and link mathematics problems with daily problems. In the third and fourth year, pre-service teachers in china are required to do an internship for
3-5 months depending on the situation and condition. This internship program allows students to apply their knowledge and also train their TPMK ability. After the internship, students are required to make a final report on the lesson plan they made, problems that arise when they were teaching, and how to solve the problems. From this internship report, pre-service teachers stated that the facility and infrastructure of the school still can’t support the use of technology which means that they need to think of another learning activity that can still be interesting for students. There are four reasons why the TPMK ability of pre-service mathematics teacher is at an intermediate level: First, pre-service mathematics teacher have acquired certain teaching techniques, teaching methods and professional knowledge, but they lack the skills to integrate them systematically; second, most education and teaching The courses are all offered in the second semester of the junior year, and pre-service mathematics teacher do not have enough time for the integration training of subject knowledge and pedagogy; third, lack of practical experience, only the senior education practice provides a place for teacher students to practice education and teaching, and practice There are also fewer practical teaching opportunities in the process; fourthly, lack of objective understanding of one's TPMK level, lack of external evaluation of one's information technology and curriculum integration ability, and unable to conduct targeted training and improvement.

| Criteria | Statement                                                                 | m    | Sd  | alpha | Interpretation |
|----------|---------------------------------------------------------------------------|------|-----|--------|----------------|
| TMK-01   | Using technology to teach mathematics                                     | 2.35 | 0.78|        | Poor           |
| TMK-02   | Making learning videos to teach mathematics                               | 2.50 | 0.78|        | Poor           |
| TMK-03   | Able to use mathematics software to explain mathematics theories          | 2.55 | 0.84|        | Good           |
| Sub TMK  |                                                                            | 2.46 | 0.01| 0.96   | Poor           |
| PMK-01   | Able to explain mathematics theory according to the students’ condition  | 2.99 | 0.57|        | Good           |
| PMK-02   | Help students to master mathematics basic concepts                        | 2.57 | 0.73|        | Good           |
| PMK-03   | Have various way and method to explain mathematics theory                | 2.64 | 0.72|        | Good           |
| Sub PMK  |                                                                            | 2.73 | 0.05| 0.93   | Good           |
| TPK-01   | Able to combine software and teaching method to explain mathematics theory| 2.68 | 0.71|        | Good           |
| TPK-02   | Using learning video according to students’ needs                         | 2.70 | 0.77|        | Good           |
| Sub TPK  |                                                                            | 2.69 | 0.00| 0.97   | Good           |

Another interesting fact is that even though pre-service teachers do not have good technological knowledge which means that they are not proficient in using mathematics software and make learning videos, but their TPK still shows a good result. This is because even though they are not very fluent in using dynamic mathematics software or making learning videos, but they use their creativity to teach students and look for another way to teach using technology. One of the ways they use is downloading another teachers’ learning video on the internet, study them, then use the learning video to teach their students. It’s also the same with the use of dynamic mathematics software. They use teaching material that is made by teachers or their classmates, save it in a .gif extension so that the illustration can move and become interesting. This is in line with a research result by Lijie Z et al. [12], that she downloaded a learning video made by her friend to explain the basic concept of the triangle and investigate the effect of the learning video on students’ mathematical problem-solving ability. Researchers concluded that even though pre-service teachers can’t use dynamic mathematics software properly or can’t make their learning videos, they still can use the data or download an existing learning video to teach mathematics.
### Table 5. Observation result for pre-service mathematics teachers’ TPMK ability.

| No   | Statement                                                                 | m   | Sd  | alpha | Interpretation |
|------|---------------------------------------------------------------------------|-----|-----|-------|----------------|
| TPMK-01 | Teachers use technology and learning models to teach mathematics          | 2.50 | 0.66 |       | Poor           |
| TPMK-02 | Teachers use teaching approach with the help of technology to improve students’ mathematical ability | 2.51 | 0.85 |       | Good           |
| TPMK-03 | Teachers use learning video or software to help students studying         | 2.52 | 0.83 |       | Good           |
| Sub   |                                                                         | 2.51 | 0.01 | 0.96  | Good           |

Overall, pre-service teachers’ perspective towards TPMK is good. Even though it falls in the good category, but it should be improved so that the average score will be higher. From table 5 we can see that teachers can’t combine the teaching model with technology as it falls in the poor category. Based on the data analysis on the pre-service mathematics teachers’ TPMK ability, researchers concluded that they have a good TPMK ability and are ready to teach and integrate technology in teaching students in school. This research is continued to see how Guangxi Normal University trains pre-service teachers’ TPMK ability from various aspects.

### 4. Conclusion

This research aims to analyze pre-service mathematics teachers’ perception of their TPMK ability and elaborate on how universities in China help pre-service mathematics teachers to improve their TPMK ability by using technology before they work and become a professional teachers. Based on the quantitative analysis data result from the questionnaire, researchers concluded that pre-service mathematics teachers from Guangxi Normal University have a good TPMK ability. Pre-service mathematics teachers’ weakness is in the technical knowledge and the use of technology in explaining mathematics subtopics (TMK). There is still much room for improvement. Pre-service teachers need to be familiar with information technology first and break the original knowledge structure to re-integrate. In this process, some factors may limit or hinder the development of teacher TPMK. For example, the construction of the information environment is not in place, the concept of pre-service teachers is not in place, the internal motivation of pre-service teachers themselves is insufficient, etc., which link is out of touch, will directly affect the overall development of pre-service teachers TPMK. Of course, the various component dimensions of pre-service teacher's TPACK also show different levels. Actual teaching is a complex system. Pre-service teachers need to comprehensively consider the relationship between technology, teaching and curriculum and integrate them reasonably and effectively to achieve high-quality informatized classrooms.

The level of student TPMK is one of the indicators to measure the quality of teacher training in normal colleges. Improving the level of TPMK will help improve the quality of talent training in normal colleges. Normal students, as pre-service teachers, at the social level, train middle and primary school students with excellent information literacy. The important condition is the key factor to realize the informatization of education in our country. This research can serve as a reference and input for universities to always help improve pre-service mathematics teachers’ TPMK ability. Guangxi Normal University’s method can also be adapted and developed to become better in the future. Considering that in the 21st century the use of technology will keep on developing to become better.

The limitation of this study is that this study investigates the TPMK ability of pre-service mathematics teachers in their perception. There is a chance that pre-service mathematics teachers are not confident. Seeing that the development of technology in China is growing rapidly, so there are presumptions that their technological knowledge is good in every aspect. From this researcher suggested making further research that can test pre-service mathematics teachers’ TPMK ability. Other than that, the researcher only took samples from Guangxi Normal University which can’t represent everyone in China knowing that Guilin is not a big city and Guangxi Normal University is not in the top 5 universities for mathematics education in China. Future research can consider testing...
5. References

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