

An analysis of Technological, Pedagogical, and Content Knowledge (TPACK) competencies of mathematics teachers in Sumatra in terms of gender

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ABSTRACT

This research aims to analyze the TPACK competencies of mathematics teachers in Sumatra based on gender differences. Using a sequential explanatory mixed method approach, this study collected data through questionnaires and interviews to test hypotheses using two-way analysis of variance (ANOVA). The results indicate that mathematics teachers in Sumatra have a high level of TPACK competencies, with gender influencing the pedagogical knowledge and content knowledge domains. Specifically, male teachers exhibit higher competency in these domains compared to their female counterparts. Additionally, male teachers more frequently utilize technology in teaching and exhibit greater variability in integrating TPACK compared to female teachers. The implication of this research provides valuable insights for the development of teacher training programs that consider gender factors in enhancing TPACK competency, which is crucial for effective technology integration in mathematics education.

Analisis kompetensi *Technological Pedagogical and Content Knowledge* (TPACK) guru matematika di Sumatra ditinjau dari gender

Kata Kunci:

Gender
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ABSTRAK

Penelitian ini bertujuan untuk menganalisis kompetensi TPACK guru matematika di Sumatra berdasarkan perbedaan gender. Menggunakan metode Sequential Explanatory mixed method, penelitian ini mengumpulkan data melalui kuesioner dan wawancara untuk menguji hipotesis menggunakan analisis varian dua arah (ANOVA). Hasil penelitian menunjukkan bahwa guru matematika di Sumatra memiliki tingkat kompetensi TPACK yang tinggi, dengan adanya pengaruh gender pada domain Pengetahuan Pedagogis dan Pengetahuan Konten. Secara khusus, guru laki-laki menunjukkan kompetensi yang lebih tinggi dalam domain ini dibandingkan dengan guru perempuan. Selain itu, guru laki-laki lebih sering menggunakan teknologi dalam pembelajaran dan lebih bervariasi dalam mengintegrasikan TPACK dibandingkan dengan guru perempuan. Implikasinya, penelitian ini memberikan wawasan yang berharga untuk pengembangan program pelatihan guru yang mempertimbangkan faktor gender dalam meningkatkan kompetensi TPACK, yang penting untuk integrasi teknologi yang efektif dalam pendidikan matematika.

1. INTRODUCTION

The era of Society 5.0 faced by society today has had an impact on various sectors, one of which is education. Education is required to integrate technology to facilitate learning activities, and this era hopes that technology will make learning easier for humans. Education is one of the biggest investments, especially in preparing skills for the 21st century, which is intensified today [1], [2]. The role of educators in designing mathematics learning activities is needed to achieve this goal. A mathematics teacher must create active, creative, fun, and meaningful learning activities by paying attention to the scope of the material and its relationship to other materials, learning strategies, media, and the background of students' previous mathematical abilities [3].

The professionalism of teacher performance in realizing active, creative, fun, and meaningful mathematics learning activities is highly emphasized by the government. This opinion is in line with the statement that the main competency that a teacher must possess is that the teacher must effectively master the ability to teach so that students can gain optimum knowledge [4]. It is also explained in the Law of the Republic of Indonesia Number 14 of 2005 concerning teachers and lecturers that a teacher must have four competencies, namely pedagogical, personality, social, and professional competencies.

Teachers must play an important role in efforts to integrate technology in the classroom. Teachers are expected to be more creative [5] and professional with their competencies [6]. In addition, teachers must also have a set of soft skills and hard skills in using new technology [7]. Teachers must be able to deal with and prepare new technologies for use in the classroom in order to create an interesting teaching and learning process [8], [9]. However, Based on the Teacher Competency Test data from the Subject Knowledge and Pedagogical Knowledge aspects, it provides information that mastery of material and pedagogics is still below the Ministry of Education and Culture's average target score of 55 [10]. This has an impact on the learning process, making it less than optimal.

The results of the 2019 Teacher Competency Test are still below the standard of 54.05, while the value set by the government as a passing standard is 90.00 [11]. In addition, the results of the Program for International Student Assessment (PISA) released by the Organization for Economic Cooperation and Development (OECD) in Paris show that the ability of Indonesian students for the average score in mathematics is 379, while the OECD average score is 487 [12]. The characteristics of today's students who are familiar with technology are in the generation also known as Generation Z, which has been accustomed to all digital technology. With generational differences between teachers and students, teachers must be willing and able to adapt to the generation of their students [13], so teachers must improve their competence.

One framework that facilitates these competencies is Technological, Pedagogical and Content Knowledge (TPACK). Technology used in classroom learning can influence the way one teaches or learns and can develop effective technology integration knowledge for teachers [14], [15]. Teachers have basically known that TPACK is needed to integrate technology in learning [16]-[18]. Technology not only facilitates teachers' teaching activities but also supports students' learning [19], [20], so teachers need to learn and improve their skills in designing technology-integrated lessons.

Research on TPACK has been widely conducted, and the results concluded that the perception of TPACK is very important for teachers to prepare for 21st-century education [21]. The problem is that currently, teachers have not learned what material content is representative of the use of technology and what learning strategies will use technology. With the rapid development of technology, teachers should utilize the TPACK approach in

learning by preparing themselves, planning learning and guiding students so that educational goals are achieved.

Based on the results of research on TPACK, gender has a different influence. Gender has an effect, and there are significant differences in TPACK [22], [23]. Male lecturers have higher TPACK compared to female lecturers [24]. Research has shown that there are significant differences in gender variables [25]. Another study also found that male and female lecturers showed significant differences in TPACK competencies [26]. However, another research study showed the opposite results, namely that gender has no influence or significant effect on the TPACK of lecturers [27]. Based on the problem and the importance of TPACK, the focus of this research is to analyze the TPACK ability of mathematics teachers in Sumatra based on gender factors.

Research related to the competence of teachers' TPACK has been extensively conducted: identification of science teachers' perceptions of TPACK [24], enhancement of English teachers' TPACK [26], analysis of elementary school teachers' TPACK [28], competence of social studies teachers' TPACK [29], analysis of elementary school mathematics teachers' TPACK [30]. Yet, there has been no research analyzing mathematics teachers' TPACK in terms of gender. Therefore, this study aims to provide a detailed analysis based on gender.

The purpose of this research is to explore the influence of gender on TPACK competence, an aspect that is relatively underexplored in the literature. Although some studies have highlighted gender differences in TPACK, few have examined this context in mathematics teaching, especially in geographical regions such as Sumatra. Thus, this research offers a new perspective in TPACK studies by investigating how gender variables affect mathematics teachers' TPACK competence, which can provide valuable insights for the professional development of teachers and the design of more inclusive and effective training programs. Therefore, this research is not only academically relevant but also has significant practical implications for the development of education policies and mathematics teaching practices that utilize technology in Indonesia.

Contribution to the Literature

This research contributes to:

- Adding a new geographical context to TPACK research by exploring the competencies of mathematics teachers in Sumatra.
- Providing empirical evidence on how gender influences TPACK competencies.
- The findings of this research can be utilized to design professional development programs that consider gender differences in the integration of technology in mathematics teaching.

2. METHOD

The research method employed in this study is sequential explanatory mixed methods. The sequential explanatory mixed method is a mixed method with a strong quantitative background against a qualitative approach. Survey data are collected in the first phase, analyzed, and then followed up with qualitative interviews [7]. The quantitative data used in this study was a TPACK questionnaire. This research questionnaire used a Google Form and then distributed to respondents or the mathematics teachers who were previously contacted and interviewed. Qualitative data was obtained through interviews regarding how teachers integrate TPACK components in learning.

The sampling technique employed was purposive sampling. Purposive sampling or consideration sampling is a technique that is used if there are certain considerations in sampling or determining samples for specific purposes [31]. The population of this study was mathematics teachers in Sumatra consisting of ten provinces, namely Aceh, North Sumatra, West Sumatra, Riau, Riau Islands, Jambi, Bengkulu, South Sumatra, Bangka Belitung, and Lampung. However, the sample of this study was 50% of the number of provinces in Sumatra (five provinces). The provinces were West Sumatra, North Sumatra, Riau, Riau Islands and Jambi. The data obtained from distributing the questionnaire were 106 teachers from 80 schools/madrasahs in the five provinces and 197 students. Of the 106 teachers, two male teachers and four female teachers were interviewed regarding how they integrated TPACK into learning. Table 1 displays the research samples based on gender.

Table 1. Teacher Data by Gender

Gender	Frequency	Percentage (%)
Male	26	24.53
Female	80	75.47
Total	106	100

The instruments used in this study were a questionnaire on the competence of mathematics teachers in Sumatra towards the TPACK component, a questionnaire on students' responses in the TPACK-based learning process, and a teacher interview sheet. The instruments have been tested for validity and reliability. In this study, the questionnaire was uploaded via Google Forms and then distributed to school principals who had been contacted previously, and some had also been interviewed about the implementation of this study. The interview technique was employed because the researchers wanted to know some information in-depth. Interviews in this study aim to find out how teachers integrate technology into learning. Based on the formulation of research problems, the technique used in analyzing data and testing the hypotheses was two-way ANOVA. The normality test and the homogeneity test of the data group variance were first carried out to carry out statistical tests.

3. RESULTS AND DISCUSSION

The results showed that the average TPACK score of mathematics teachers in Sumatra based on gender was quite high. These results can be seen in the following figure.

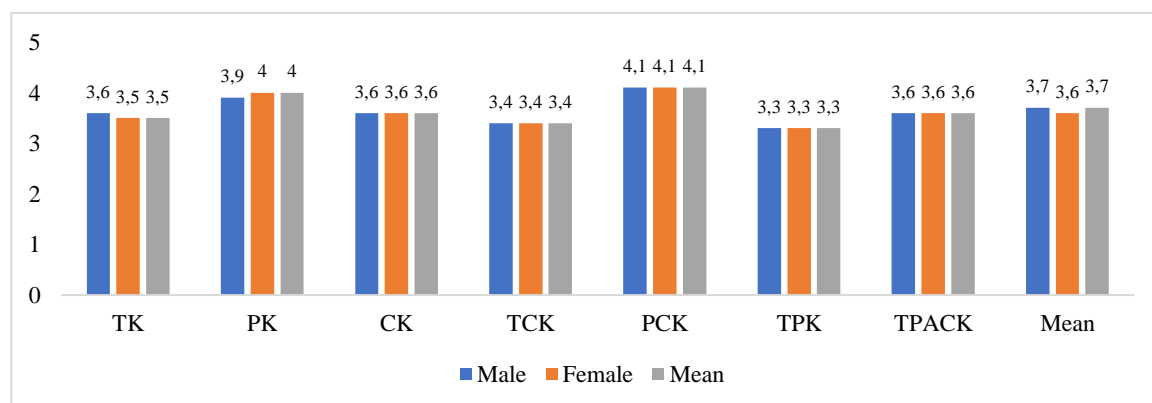


Figure 1. TPACK Abilities Questionnaire Results by Gender

TPACK abilities of mathematics teachers based on gender have the highest competence in pedagogical content knowledge (PCK) aspects. The male teachers' ability to teach using strategies that can make it easier for students to understand learning materials has an

average of 4.12 (high category), while the female teachers' average was 4.1 (high category). The lowest competency based on gender is technological pedagogical knowledge (TPK). The male teachers' abilities to use technology in teaching and learning activities to achieve the learning objectives has an average of 3.38 (slightly above the average), while the female teachers' average was 3.36 (slightly above the average).

The hypothesis test was preceded by prerequisite tests, namely normality and homogeneity tests. Table 2 contains the result of the normality test.

Table 2. The Normality Test Result

Gender	Kolmogorov-Smirnov ^a		
	Statistic	Df	Sig.
Male	0.112	26	0.200*
Female	0.059	80	0.200*

Table 2 shows that the data is normally distributed. The next prerequisite test was the data homogeneity test. This test can be carried out directly using the hypothesis test of independent sample t-test assisted by SPSS. The results can be seen in Table 3.

Table 3. TPACK Hypothesis Test Based on Gender

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	Df	Sig.(2-tailed)
Equal variances assumed	1.151	0.698	0.463	104	0.664
Equal variances are not assumed.			0.448	40.298	0.656

Table 3 shows that the value of F is 1.151 and Sig. is 0.698, more than 0.05. It means that the data is homogeneous and can be used for hypothesis testing. The t-value is 0.463, and Sig. Value is 0.664, more than 0.05. Therefore, there is no difference between TPACK between male and female teachers. In detail from each TPACK component, the inferential analysis can be seen in Table 4.

Table 4. Hypothesis Testing of TPACK Components Based on Gender

TPACK Components	Z Value	Sig.
TK	-0.768	0.313
CK	-0.505	0.033
PK	-0.113	0.040
PCK	-0.456	0.813
TCK	-0.595	0.554
TPK	-1.173	0.163
TPACK	-0.448	0.393

Based on Table 4, the seven components were tested partially. There are differences in the TPACK abilities of men and women in the CK (Content Knowledge) and PK (Pedagogical Knowledge) components. Male teachers' CK and PK components are better than female teachers'. However, there is no difference between male and female teachers in the other five TPACK components.

The interview results show that there are differences between male and female teachers in integrating TPACK in learning. Male teachers are more likely to use technology in learning and are more varied in integrating TPACK in learning than female teachers. The following are the results of interviews with male (G1 and G2) and female (G3, G4, G5, G6) teachers, respectively:

Q: *Do you use technology in the mathematics learning process?*

G1: *Yes, I often use technology.*

G2: *Yes, I often use technology.*

G3: *Yes, I rarely use technology.*

G4: *Yes, but not often.*

G5: *Sometimes*

G6: *I rarely use technology.*

Q: *Do you install software related to mathematics learning administration?*

G1: *Yes, for example, Microsoft Word, Microsoft Excel, and Microsoft PowerPoint.*

G2: *Yes, for example, Microsoft Word, Microsoft Excel, and Microsoft PowerPoint.*

G3: *Yes, for example, Microsoft Word and Microsoft Excel*

G4: *Yes, for example, Microsoft Word and Microsoft Excel*

G5: *Yes, for example, I use Microsoft Word, Microsoft Excel, and Microsoft PowerPoint.*

G6: *Yes, for example, Microsoft Word and Microsoft Excel*

Q: *How do you adjust the use of technology according to the mathematics material being taught?*

G1: *I adjusted to the material. If the material taught can be integrated with technology, then I use PowerPoint. If not, I teach manually.*

G2: *I customized the material and used technology.*

G3: *In the field, students do not understand if they use technology to deliver material, making it difficult for educators to customize the right technology for each student's characteristics.*

G4: *Educators have difficulty adjusting the technology to the material due to a lack of knowledge.*

G5: *One way is to show material from YouTube using projectors.*

G6: *I adjusted to the characteristics of students, but I often use the blackboard.*

Q: *How do you match technology with approaches, models, methods, and media for learning mathematics?*

G1: *It depends on the method used. For example, when using scientific methods, I usually use PowerPoint.*

G2: *I usually use a laptop to deliver lessons.*

G3: *I rarely use technology because students will be bored and not focus on learning. So, it is mostly just a lecturing system.*

G4: *I rarely use technology in teaching mathematics.*

G5: *If the method is discussed, then the technology used is usually a laptop and a projector.*

G6: *It depends on the method and approach that is adapted to the technology.*

Based on the results of the data analysis, teachers need to have TPACK competencies. According to Innaha [32], TPACK is the teacher's knowledge in combining technology with learning strategies and methods (pedagogical) to teach the right material (content) in accordance with the indicators that have been made. Suyamto states that a professional teacher must also have adequate TPACK competencies because TPACK is within the four main competencies of a teacher, which include pedagogical competence, personality competence, professional competence, and social competence [13].

Doering [33] revealed that the integration of TPACK can increase self-confidence and improve teachers' content, pedagogy and technology competencies in designing learning. Therefore, the pattern of developing teacher competence with TPACK is in accordance with the demands and changes of the times that continue to advance. The first aspect is technological knowledge (TK) or knowledge of technological diversity from low to digital classes. The research findings show that teachers' TK based on gender is 3.59. This result is similar to research in that the teacher's ability to use technology can be said to be good based on their ability to create PowerPoint slides with attractive designs, well-contrasted colors, and the right order. The second aspect is pedagogical knowledge (PK), which includes knowledge of educational objectives, classroom management, curricular planning, and the development of lesson plans and management [34]. The research findings show that the pedagogical knowledge aspect is in the excellent category, with an average of 4.03. It means that teachers can adapt learning to the characteristics, understanding, and possible misconceptions of students.

The third aspect is content knowledge (CK), which is knowledge of the material to be taught. This content knowledge leads to knowledge or specialization of scientific disciplines [13]. The data shows that CK is in a fairly high category, with an average of 3.66. It can be said that teachers prepare themselves before entering the classroom by understanding the concepts, theories, example problems, and proofs of the material to be taught so that students understand at each meeting. The fourth aspect is technological pedagogical knowledge (TPK), which is knowledge about the use of technology in teaching. This ability states the reciprocal relationship between technological and pedagogical knowledge. The results of teacher TPK in the study showed an average of 3.37. It can be said that teachers can manage learning by using technological aids. TPK is related to the understanding of how technology can affect teaching and learning.

The fifth aspect is Pedagogical Content Knowledge (PCK), or pedagogical knowledge that plays a role in teaching specific material [13]. In this aspect, a learning strategy that is in line with the material to be delivered is needed. The results of teacher PCK in the study showed a gender average of 4.11. It can be said that teachers can adjust learning strategies to the concepts in the material to be taught so that the teaching material can be conveyed appropriately. PCK is the teacher's realization of the need to understand how to use technology in a constructive way to present and deliver learning content. Teachers also need to know how to use technology to help students solve problems during learning, develop new concepts, or help students understand new knowledge [35].

In a study conducted by Hsu [35] concerning teachers' knowledge and competence in Taiwan within the TPACK framework, it was noted that gender significantly influences pedagogical knowledge. This finding supports the findings of the current research, where male teachers' TPACK, particularly in the domains of Pedagogical Knowledge and Content Knowledge, exhibit higher competence. These results underscore the need for gender-tailored interventions to enhance the integration of technology in teaching, especially within the context of mathematics education.

The sixth aspect is technological content knowledge (TCK), which is knowledge about the use of technology in delivering material. The results of the teacher's TCK in the study showed a gender average of 3.45. The teacher can utilize technology as a tool in the process of delivering material. The seventh aspect is TPACK, which is a combination of technological knowledge, pedagogy, and material content. TPACK is not only understanding technology, pedagogy, and content separately but rather as an emergent form and understanding how these knowledge interact with each other [34]. The research findings show that teachers' TPACK based on Gender is 3.66, meaning that teachers can

determine learning strategies that are aligned with existing technology and in line with the material to be delivered.

The analysis of teachers' TPACK abilities in terms of gender did not provide significant differences. However, gender partially affects the CK and PK domains. As revealed [36], the survey results stated that male pre-service teachers had stronger average scores for the TK, CK and knowledge of teaching with technology domains. Male teachers were also more confident in the technology-related aspects of TPACK for science. Male teachers tend to have high self-efficacy (confidence) in understanding and implementing their technological knowledge into learning. Male teachers have more adequate knowledge to manage technology in the teaching process. TPACK is not only understanding technology, pedagogy, and content separately but rather as one emerging form. On the other hand, teachers should integrate technology into their learning and must have the TPACK abilities [37], [38].

4. CONCLUSION

A study on the TPACK competency of mathematics teachers in Sumatra found that, overall, teachers possess a high level of TPACK competency, yet there are significant differences based on gender. Male teachers demonstrate higher competencies in the Pedagogical and Content Knowledge domain and are more frequent and varied in their use of technology in teaching compared to female teachers. These findings underscore the importance of incorporating gender perspectives in the development of teacher training programs to enhance TPACK competencies, which will support effective technology integration in mathematics education and contribute to the improvement of learning quality.

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AUTHOR CONTRIBUTION STATEMENT

NS contributed to conceptualizing, writing original drafts, editing, visualizing, determining methodology, and conducting formal analysis. A contributed to writing, reviewing, editing, and conducting formal analysis. DW contributed to writing and editing.

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