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Analysis of TPMDK Abilities of Prospective Mathematics Teachers Based on Semester Level and Gender

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ABSTRACT

This research aims to (1) describe the level of mastery of TPMK of prospective mathematics teachers; (2) examine the aspects of TPMK that prospective mathematics teachers dominate. (3) Analyze the differences in the ability of TPMK of prospective mathematics teachers based on semester and gender. This research uses a quantitative approach, with a survey method. The survey was conducted to collect data from respondents regarding the TPMDK (Technological-Pedagogical Mathematics Dimension Knowledge). The population is all prospective math teachers in Region III, Cirebon. The sample was a proportional random sample of prospective math teachers. The results showed that (1) TPMDK ability obtained an average of 2.983, which is included in the high category. Students of prospective mathematics teachers in Region III Cirebon have the knowledge and skills needed by mathematics teachers to integrate technology effectively into pedagogy and high mathematics content. (2) The ability of TPMDK when viewed from the knowledge dimension, in order from the highest is the Factual Dimension (3.09), Metacognitive dimension (3.00), Conceptual dimension (2.96), and procedural dimension (2.94). The tendency toward mastery of technological knowledge and its relation to other knowledge drives high ability in other areas. This is evident in the ability of Technological Factual Knowledge and Technological Conceptual Knowledge.

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1. INTRODUCTION

Technology in the 21st century has become a necessity for everyone, from preschool to high school. It plays a vital role in all aspects of life, including searching for information, interacting with others, conducting buying and selling transactions, working, attending school, and accessing a variety of public services. The integration of technology can significantly enhance effectiveness and efficiency, helping organizations to achieve their goals and improve their management processes.

The utilization of technology in education has become increasingly widespread, particularly following the onset of the COVID-19 outbreak. Formal and informal educational institutions have begun developing online learning platforms. E-learning is now at the forefront of education, with online courses, training sessions, and seminars growing rapidly. Research supports this shift, indicating that Information and Communication Technology (ICT) serves as a medium to enhance the complex learning process, effectively preparing students for ICT integration[8].

Teachers and learners in the future must possess strong IT skills, which should be developed through learning experiences that effectively integrate technology. This integration can only take place if teachers themselves are IT literate and adept at incorporating technology into their teaching [9]. Supporting this view, it has been stated that the educational process's ability to promote digital literacy among individuals is unattainable without enhancing educators' digital literacy [10]. A crucial skill required in this context is proficiency in TPACK (Technological Pedagogical Content Knowledge). This competency has also been recognized as one of the essential indicators for passing the Teacher Professional Education (PPG) in the past three years.

In addition, prospective teachers must possess four key competencies to become professional educators: social competence, personal competence, pedagogical competence, and professional competence. Professional competence refers to teachers' ability to master the subject matter, particularly in mathematics, and their capacity for ongoing development in this area. Pedagogical competence involves a deep understanding of learning methodologies and instructional skills. These two competencies are closely linked to Content Knowledge and Pedagogical Knowledge.

The widespread use of technology in education since the COVID-19 pandemic has created a need for teachers to integrate it effectively into mathematics instruction. This integration aims to enhance students' understanding of mathematics and improve overall learning quality by exploring mathematical concepts. Technology can serve both as a medium for learning and as an innovative form of learning itself.

However, one barrier to the effective use of TPACK is teachers' limited understanding of technology, which can be attributed to age [11]. This is consistent with findings from [12], which indicate that technological knowledge is the weakest aspect of TPACK among mathematics teachers in Jambi. Additionally, a study by [13] reveals that secondary school teachers often lack confidence in their technological proficiency.

Research also shows that students exhibit moderate TPACK abilities [14]. This is further supported by findings from [15], which suggest that students do not use technology effectively and efficiently during microteaching and early PPL learning experiences. The study by [16] emphasizes the importance of identifying key areas to support prospective mathematics teachers' technological knowledge. Furthermore, a study by Herizal et al. (2022) among mathematics education students found that five of seven TPACK components were at a low level. Notably, some of these studies have not differentiated TPACK profiles by semester level.

The results of the study [18] indicate that research on TPACK often focuses broadly on technology, with less emphasis on the content dimension. The study [19] found that while women require more technological knowledge, men tend to exhibit greater confidence, and women generally possess better subject matter knowledge. In contrast, [11] claimed that gender does not significantly affect teachers' TPACK abilities. However, none of these studies have clearly outlined the significance of differences in TPACK skills between male and female educators.

The discussion highlights that the development of Technological-Pedagogical-Mathematical Knowledge (TPMK) requires prospective teachers to master content, technology, and pedagogy, and to be skilled in using technology for effective learning. These skills should be cultivated during their time in college to ensure they develop strong TPMK capabilities. In light of this, there is a need for further research to examine the profile of TPMK abilities among prospective mathematics teachers in Region III Cirebon.

2. METHOD

This research uses a quantitative approach, with a survey method. The survey was conducted to collect data from respondents regarding the TPMDK (Technological-Pedagogical Mathematics Dimensional Knowledge).

The population consists of all prospective mathematics teachers in the Cirebon Region III. The sample, using the proportional random sampling method of both prospective mathematics teachers, can be seen in the following Table 2:

Table 1. Sample and population

No	College Town of Origin	Total		
		Population	Sampel	Persen
1	Majalengka	43	20	46.51%
2	Kuningan	87	47	54.02%
3	Kota Cirebon	562	74	13.17%
4	Kabupaten Cirebon	139	55	39.57%
5	Indramayu	64	18	28.13%
Total		895	214	23,9%

The data collection techniques used for the study include the following:

a. Literature Review:
This method involves utilizing written sources as a foundation for data collection, analysis, and synthesis. Conducting a literature review is vital as it provides a theoretical framework and research background for the study. It also enhances the researcher's understanding of the topic being investigated.

b. Questionnaires:
Although the terms "research questionnaires" and "questionnaires" are often used interchangeably, they have different meanings. Generally, a questionnaire is a list of written questions designed to gather information or data directly from sources. A survey, while similar, typically refers to a questionnaire used in a research context. In this study, the questionnaire will be employed to collect data related to Technological Pedagogical Mathematics Knowledge (TPMK).

The instrument uses a questionnaire with a Likert scale using a self-assessment instrument that was adopted from the development results [20] and [21]. This instrument includes the following sub-variables TK/PT (technology knowledge). TPACK (Pedagogical Content Technology Knowledge). PK (pedagogical knowledge), TPK (pedagogical technology knowledge), PCK (pedagogical content knowledge). TCK (Content Technology Knowledge). Modifications will be made in each aspect that has been developed, in particular, those related to the content knowledge will be adapted to the mathematical knowledge. Mathematical knowledge will refer to Kratwohl's knowledge dimensions.

Table 2. Instrument
(adopted from Mishra and Anderson & Krathwohl)

Variable	Dimension	*Sub Dimension*	Statement	Item number
Technological Pedagogical Mathematics Dimension Knowledge	*Mathematical Dimension Knowledge*	*Mathematical Factual Knowledge*	Saya memahami berbagai jenis simbol, notasi dalam berbagai topik matematika	1
			Saya memahami berbagai jenis simbol, notasi dalam kurikulum matematika sekolah	2
		Mathematical Conceptual Knowledge	Saya dapat mengidentifikasi keterkaitan antar topik dalam matematika	3
			Saya mampu menguraikan teorema, rumus dengan tepat dan lancar	4
		Mathematical Procedural Knowledge	Saya dapat menggunakan cara berpikir matematis	5
			Saya dapat membuktikan teorema, rumus-rumus dengan berbagai teknik	6
	Pedagogical Dimension Knowledge	*Pedagogical Factual Knowledge*	Saya memahami berbagai pendekatan pembelajaran	7
			Saya mengetahui berbagai jenis gaya belajar	8
		Pedagogical Conceptual Knowledge	Saya dapat mengidentifikasi pemahaman dan miskonsepsi dalam matematika	9
			Saya dapat membedakan beberapa metode dan strategi pembelajaran	10
		Pedagogical Procedural Knowledge	Saya dapat memberikan penguatan keterampilan berpikir melalui tugas yang menantang	11
			Saya dapat memandu dan mengelola diskusi kelompok agar lebih efektif	12
	Technological Dimension Knowledge	*Technological Factual Knowledge*	Saya mengetahui berbagai *software* dalam komputer ataupun online	13
			Saya menggunakan berbagai media sosial untuk berbagai kepentingan	14
		Technological Conceptual Knowledge	Saya dapat membedakan berbagai fungsi media sosial	15
			Saya dapat menentukan jenis komunikasi *online* yang paling efektif	16
		Technological Procedural Knowledge	Saya memiliki keterampilan teknis yang memadai untuk menggunakan teknologi	17
			Saya dapat menggunakan *software* untuk visualusasi secara *online*	18
	Pedagogical Mathematical	*Pedagogical Mathematical*	Saya dapat mengidentifikasi miskonsepsi matematika siswa	19

Variable	Dimension	*Sub Dimension*	Statement	Item number
	Dimension Knowledge	*Conceptual Knowledge*	Saya dapat menentukan metode pembelajaran matematika yang bervariasi sesuai dengan karakteristik matematika	20
		Pedagogical Mathematica Procedural Knowledge	Saya dapat memilih pembelajaran yang efektif untuk mengembangkan ketrampilan berpikir matematis	21
			Saya mampu menjelaskan cara menyelesaikan permasalahan matematika dengan menggunakan berbagai metode	22
		Pedagogical Mathematical Metacognitive Knowledge	Saya membaca masalah yang diberikan secara berulang-ulang dan memberi tanda pada kata-kata yang dianggap sebagai kata kunci	23
			Saya memikirkan kembali hubungan antara hal-hal yang diketahui dalam masalah matematis yang akan dijawab	24
			Saya membuat hubungan antara hal-hal yang telah diketahui dengan cara-cara yang digunakan dalam menyelesaikan masalah matematis	25
	Technological Mathematical Dimension Knowledge	*Technological Mathematical Conceptual Knowledge*	Saya mengetahui berbagai jenis *software* matematika	26
			Saya dapat memilih software yang sesuai dengan topik-topik matematika	27
			Saya mampu membedakan kegunaan *software* matematika	28
		Technological Mathematica Procedural Knowledge	Saya mampu menggunakan *software* yang berkaitan matematika	29
			Saya mampu menggunakan alat berkomunikasi secara *online*	30
		Technological Mathematical Metacognitif Knowledge	Saya memahami pokok permasalahan sebelum menyelesaikan masalah matematika dengan menggunakan *software*, sehingga memahami langkah selanjutnya yang akan dilakukan dalam menyelesaikan masalah matematika	31
			Saya berusaha berpikir dua kali, saat terdapat jawaban yang kurang benar ketika dikonfirmasi menggunakan *software*, dan akan membetulkannya dengan menggunakan strategi atau cara yang lain untuk menyelesaikan masalah matematika sampai menemukan jawaban benar.	32
	Technological Pedagogical Dimension Knowledge	*Technological Pedagogical Conceptual Knowledge*	Saya mampu memilih berbagai teknologi untuk memberikan penguatan dalam pembelajaran matematika	33
			Saya dapat memilih teknologi-teknologi yang dapat memberikan penguatan konten matematika	34
		Technological Pedagogical Procedural Knowledge	Saya dapat merancang dan menggunakan teknologi apa yang dapat meningkatkan kualitas pengajaran	35
			Saya dapat memilih teknologi yang sesuai untuk mengasses kemampuan matematika	36

Variable	Dimension	*Sub Dimension*	Statement	Item number
		Technological Pedagogical Metacognitif Knowledge	Saya menyakini pengunaan teknologi, fasilitas internet, software dapat meningkatkan efektivitas pembelajaran matematika	37
			Saya dapat menerapkan strategi pembelajaran yang berbeda dengan menggunakan teknologi dan informasi yang bervariasi	38
	Technological Pedagogical Mathematics Dimension Knowledge	*Technological Pedagogical Mathematics Procedural Knowledge*	Saya mampu menggunakan strategi pembelajaran matematika yang menggabungkan isi materi, teknologi dan pendekatan pembelajaran di kelas	39
			Saya mampu menggunakan *software* matematika untuk pembelajaran dan sekaligus menilai hasil belajar siswa	40
		Technological Pedagogical Mathematics Metacognitif Knowledge	Saya mengetahui kemampuan yang saya miliki dalam menyelesaikan soal dengan menggunakan *software* matematika	41
			Saya dapat memadukan pengetahuan teknologi yang dimiliki untuk mewujudkan pembelajaran matematika yang efektif	42

The instrument was structured with a Likert scale ranging from 1 to 4. The results of the reliability test show that the level of reliability is in the high category with a coefficient of 0.961. This is shown by the SPSS results as follows:

Table 3. Reliability Test

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.961	.961	42

Based on the above table, it can be concluded that the reliability of the instrument is in the very high category with a value of 0.961.

The analysis of the data was carried out using descriptive statistics and the t-test. In order to analyse the TPMK ability of the pre-service teachers for each aspect, descriptive statistics were used. While the t-test was carried out in order to test whether there was a difference in the ability of TPMK between pre-service teachers and mathematics teachers, the differences in the ability of TPMK of pre-service mathematics teachers were based on semester and gender. In this study, the data were analysed in two stages using SPSS 24 software: i) descriptive analysis and ii) t-test.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1 Description of TPMDK

The data are presented in tables. The maximum, minimum, mean, and standard deviation are discussed to illustrate the concentration and dispersion of TMPDK skills. Each aspect of TMPDK, such as mathematical knowledge, pedagogical knowledge, technological knowledge, mathematical-technological knowledge, mathematical-pedagogical knowledge, technological pedagogical knowledge, and technological mathematical-pedagogical knowledge, is described in detail.

Table 4. Average TPMDK with Semester

Semester	Mean	Std. Deviation
III	2.9796	.39786
V	3.0624	.33021
VII	2.9486	.37832
Total	2.9830	.37789

According to the table above, semester V has the highest TPMDK score compared to other semesters. Meanwhile, students in the seventh semester have the lowest TPMDK score compared to other semesters. However, the difference in scores ranges from 0.03 to 0.12. The average score of the TPDMK ability for the students was 3.033, while the students obtained an average score of 2.966. This is shown in the table below;

Table 5. Average TPMDK based on gender

Gender	Mean	Std. Deviation
L	3.0332	.43677
P	2.9664	.35635
Total	2.9830	.37789

On the basis of the table above, the TPMDK ability of the male students has a higher score than that of the female students. However, the mean score differs by 0.067.
The TPMDK ability is also described based on the origin of the student's school. This consists of SMA, MA, and SMK. The average score can be seen in the following table;

Table 6. Average TPMDK based on school origin

School Type	Mean	Std. Deviation
SMA	3.0268	.39144
MA	2.9076	.39519
SMK	2.9917	.29882
Total	2.9830	.37789

On the basis of Table 6 above, it can be seen that students from upper secondary schools have the highest level of TPMDK skills compared to students from MA and SMK. The MA and SMK are followed by the MA and SMK, respectively. TPMDK skills are also described according to the city/district of origin in order to provide a broader picture. These data can be seen in the following table;

Table 7. Average TPMDK based on the place of origin of PT

City of Origin	Mean	Std. Deviation
KOTA CIREBON	3.0463	.34359
KABUPATEN CIREBON	3.0892	.44563
KUNINGAN	2.9154	.32683
MAJALENGKA	2.9214	.29558
INDRAMAYU	2.6429	.26689
Total	2.9830	.37789

The TPMDK skills of students from Cirebon Regency are higher than those of students from other cities, according to Table 7 above. Cirebon Regency, Majalengka Regency, Kuningan Regency, and Indramayu Regency follow this.

What is presented in the tables above is an overview of the TPMDK skills of the prospective mathematics teachers based on their gender, the semester level, the origin of the school, and the location of the college.

In order to provide a more specific picture of the aspects of TPMDK skills acquired, a more detailed description is certainly needed. A more detailed description of which aspects have been mastered well enough to be maintained, and which aspects need to be improved again, can certainly be derived from this picture. In detail, the TPMDK skills based on their aspects can be seen in Table 8 below;

Table 8.Average aspect TPMDK based on the semester

	Semester							
	III		V		VII		Total	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
MFK	3.0060	.54936	3.0952	.43108	3.0056	.46767	3.0234	.49354
MCK	2.6928	.54567	2.9167	.56219	2.7360	.47128	2.7547	.52349
MPK	2.6807	.49125	2.7381	.55478	2.7640	.54922	2.7266	.52745
PFK	3.0181	.49661	3.0714	.61059	3.0449	.61994	3.0397	.57086
PCK	2.8735	.52291	3.0119	.43460	2.8034	.46232	2.8715	.48555
PPK	2.9518	.56100	2.9762	.45468	2.9270	.51429	2.9463	.52017
TFK	3.2651	.57029	3.0833	.68891	3.2079	.57311	3.2056	.59715
TCK	3.3373	.57439	3.4048	.43108	3.3652	.53706	3.3621	.53156
TPK	3.0602	.64106	3.0357	.64763	3.0393	.64941	3.0467	.64288
PMCK	2.7470	.45111	2.8810	.53885	2.7528	.51192	2.7757	.49521
PMPK	2.8795	.53300	2.9643	.53411	2.7978	.52613	2.8621	.53156
PMMK	3.0442	.52774	3.0794	.39516	2.8951	.48356	2.9891	.49027
TMCK	3.0000	.54599	3.0952	.69565	2.8801	.53712	2.9688	.57786
TMPK	3.1566	.58917	3.3690	.59530	3.0618	.52668	3.1589	.57367
TMMK	2.9940	.51498	3.1548	.60976	2.9382	.43836	3.0023	.50930
TPCK	3.0241	.55712	3.0595	.56528	2.9944	.57155	3.0187	.56263
TPPK	2.9337	.56725	2.9762	.51741	2.9101	.53599	2.9322	.54285
TPMK	3.0422	.45669	3.2143	.57534	3.0787	.48792	3.0911	.49634
TPMPK	2.8735	.55679	3.0357	.48631	2.8989	.52321	2.9159	.53068
TPMMK	2.9699	.57567	3.0595	.55439	2.9326	.48378	2.9720	.53441

The data in Table 8 above shows that third-semester students have the highest conceptual knowledge of technology compared to other aspects of TPMDK, with a score of 3.34, while they have the lowest mathematical procedural knowledge. The students in the V semester own the same thing, in contrast to the students in the VII semester, who can conceptualize technology with the lowest conceptual knowledge of mathematics. In Table 9, the description of the results of the TPMDK ability based on gender can be presented.

Table 9. Mean TPMDK based on gender

	Gender					
	L		P		Total	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
MFK	3.0566	.54297	3.0124	.47746	3.0234	.49354
MCK	2.9623	.56201	2.6863	.49314	2.7547	.52349
MPK	2.8208	.51975	2.6957	.52789	2.7266	.52745
PFK	3.0000	.65044	3.0528	.54372	3.0397	.57086
PCK	2.9151	.58619	2.8571	.44871	2.8715	.48555
PPK	2.9528	.58230	2.9441	.49998	2.9463	.52017
TFK	3.1887	.68799	3.2112	.56635	3.2056	.59715
TCK	3.4623	.61119	3.3292	.50033	3.3621	.53156
TPK	3.1604	.68482	3.0093	.62618	3.0467	.64288
PMCK	2.8208	.56411	2.7609	.47132	2.7757	.49521
PMPK	2.8868	.61739	2.8540	.50200	2.8621	.53156
PMMK	3.0189	.49964	2.9793	.48832	2.9891	.49027
TMCK	3.0063	.66824	2.9565	.54662	2.9688	.57786
TMPK	3.2453	.73132	3.1304	.51089	3.1589	.57367
TMMK	3.0189	.60417	2.9969	.47598	3.0023	.50930
TPCK	3.0000	.64301	3.0248	.53561	3.0187	.56263
TPPK	2.9811	.59616	2.9161	.52511	2.9322	.54285
TPMK	3.0849	.58619	3.0932	.46504	3.0911	.49634
TPMPK	3.0189	.62759	2.8820	.49217	2.9159	.53068
TPMMK	3.0849	.67749	2.9348	.47477	2.9720	.53441

According to Table 9 above, male students have a higher average score than female students in MFK, MCK, MPK, PCK, PPK, TCK, TPK, PMCK, PMPK, TMCK, TMPK, TMMK, TPPK, TPMPK, and TPMMK. Meanwhile, female students chose a higher average score for PFK, TFK, TPCK, and TPMK than male students. However, the difference in the scores is not all that great.

3.1.2 Analisis aspek dominan TPMDK

This subsection focuses on analysing which aspects are best and least mastered by prospective mathematics teachers. These findings will, of course, be compared with theory and previous research findings. The purpose of this comparison is to place the research findings in the context of the theory and research. The aspects of the TPMDK that are best mastered show the strengths of prospective teachers and mathematics teachers in the TPMDK, while the aspects that are poorly mastered show the weaknesses of the teachers. Through this discussion, it is hoped that suggestions can be identified to develop the TPMDK skills of teachers and pre-service teachers to face future learning.

Table 10. Average score of each aspect of TPMDK

Report

	Mean	N	Std. Deviation
TCK	3.3621	214	.53156
TFK	3.2056	214	.59715
TMPK	3.1589	214	.57367
TPMK	3.0911	214	.49634
TPK	3.0467	214	.64288
PFK	3.0397	214	.57086
MFK	3.0234	214	.49354
TPCK	3.0187	214	.56263
TMMK	3.0023	214	.50930
PMMK	2.9891	214	.49027
Average	2.9830	214	.37789
TPMMK	2.9720	214	.53441
TMCK	2.9688	214	.57786
PPK	2.9463	214	.52017
TPPK	2.9322	214	.54285
TPMPK	2.9159	214	.53068
PCK	2.8715	214	.48555
PMPK	2.8621	214	.53156
PMCK	2.7757	214	.49521
MCK	2.7547	214	.52349
MPK	2.7266	214	.52745

Overall, with an average score of 3.36, students of Mathematics Education/Tadris have the best ability in the aspect of Technological Conceptual Knowledge (TCK). In order, good skills are Technological Factual Knowledge (TFK), Technological Mathematical Process Knowledge (TMPK), Technological Pedagogical Metacognitive Knowledge (TPMK), Technological Process Knowledge (TPK), Pedagogical Factual Knowledge (PFK), Mathematical Factual Knowledge (MFK), Technological Pedagogical Conceptual Knowledge (TPMK), Technological Mathematical Metacognitive Knowledge (TMMK), and Pedagogical Mathematical Metacognitive Knowledge (TMMK). The nine aspects are above the average score of 2.98 for the TPMDK ability. The other ten aspects are below the average.

In all three areas of factual, conceptual, and procedural knowledge, the technological knowledge of the pre-service mathematics teachers in Region III Cirebon is above the average. The factual knowledge related to pedagogy is also very well understood by the pre-service teachers of mathematics.

The dominant aspects possessed by the students can also be identified through general aspects. With a score of 3.2, the aspect of mastery of technology is the best skill possessed by the students. This can be seen in Figure 1 below;

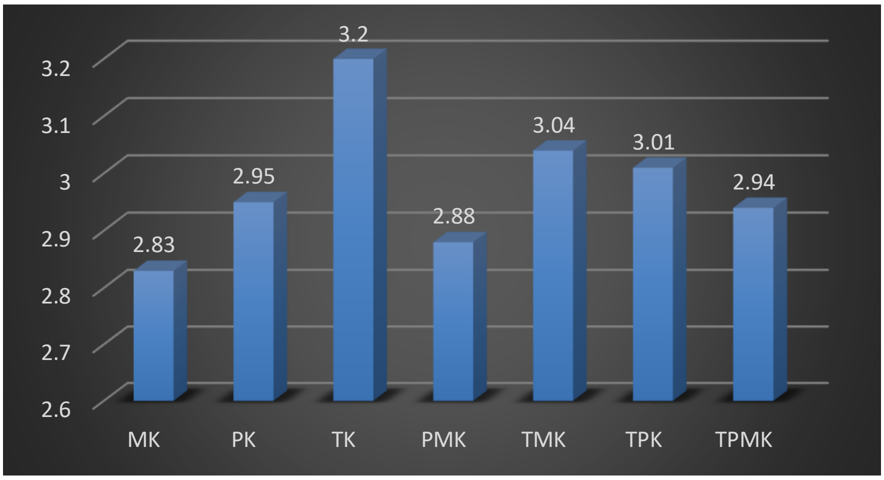

Figure 1. Diagram of the average of every aspect

The above diagram shows that a good technological knowledge ability will also have an impact on the ability of mathematical technological knowledge, pedagogical technological knowledge, and technological knowledge of mathematics education. This shows that a good technological knowledge ability will improve the other abilities that are related to technology.

Table 11. Mean ability of TPMDK aspects by gender

	Gender	
	L	**P**
TCK	3.4623	3.3621
TMPK	3.2453	3.1589
TFK	3.1887	3.2056
TPK	3.1604	3.0467
TPMK	3.0849	3.0911
TPMMK	3.0849	2.9720
MFK	3.0566	3.0234
Average	3.0332	2.9830
PMMK	3.0189	2.9891
TMMK	3.0189	3.0023
TPMPK	3.0189	2.9159
TMCK	3.0063	2.9688
PFK	3.0000	3.0397
TPCK	3.0000	3.0187
TPPK	2.9811	2.9322
MCK	2.9623	2.7547
PPK	2.9528	2.9463
PCK	2.9151	2.8715
PMPK	2.8868	2.8621
MPK	2.8208	2.7266
PMCK	2.8208	2.7757

According to the table above, knowing technological concepts is the highest skill mastered by both male and female students. Conversely, the PMCK skill is the lowest skill possessed by both. The students have an average score of 3.0332, and 7 aspects are higher than this, such as TCK, TMPK, TFK, TPK, TPMK, TPMMI, and MFK. Meanwhile, students have an average of 2.9830 with 9 aspects above it. These are: TCK, TMPK, TFK, TPK, TPMK, MFK, TMMK, PFK, TPCK. Female students have a very good ability in relation to aspects of the TPMDK in relation to technology. This ability includes the conceptual knowledge of technology, the factual knowledge of technology, the procedural knowledge of technology, the procedural knowledge of mathematical technology, and the metacognitive knowledge of pedagogical technology.

The origin of the city/regency of the student's college can also be used to identify high levels of conceptual knowledge of technology. This can be seen in Table 12 below;

Table 12. Average ability of TPMDK aspects based on the city of origin

	City of Origin					
	KOTA CIREBON	KABUPATEN CIREBON	KUNINGAN	MAJALENGKA	INDRAMAYU	Total
TCK	3.4257	3.4273	3.2553	3.4500	3.0833	3.3621
TMPK	3.3243	3.1182	3.1702	3.0750	2.6667	3.1589
TFK	3.3108	3.2727	3.1596	3.1750	2.7222	3.2056
TPK	3.2297	3.2000	2.8511	2.9250	2.4722	3.0467
TMMK	3.1284	2.9909	2.8723	2.9750	2.8889	3.0023
MFK	3.1216	3.0818	2.8723	2.8750	3.0000	3.0234
TMCK	3.1081	3.0121	2.9433	2.8833	2.4259	2.9688
TPMK	3.1081	3.2091	3.0319	3.1750	2.7222	3.0911
TPPK	3.0878	2.9818	2.8298	2.8750	2.4722	2.9322
PFK	3.0743	3.2636	2.9468	3.0000	2.5000	3.0397
TPCK	3.0473	3.1182	2.9787	3.0500	2.6667	3.0187
Rata_rata	3.0463	3.0892	2.9154	2.9214	2.6429	2.9830
TPMMK	3.0068	3.1091	2.9362	2.9250	2.5556	2.9720
PPK	2.9527	3.0455	2.9468	2.8500	2.7222	2.9463
PMMK	2.9505	3.1030	3.0142	2.7167	3.0370	2.9891
TPMPK	2.9459	3.0727	2.8191	2.9750	2.5000	2.9159
PMPK	2.9122	3.0636	2.7340	2.8000	2.4444	2.8621
PCK	2.8649	3.0455	2.8191	2.7750	2.6111	2.8715
PMCK	2.7838	2.8818	2.6915	2.8500	2.5556	2.7757
MCK	2.7838	2.9273	2.7021	2.6500	2.3611	2.7547
MPK	2.7770	2.8909	2.6702	2.5500	2.3611	2.7266

Based on Table 12, the conceptual knowledge of technology is the highest level of ability possessed by the students in Region III Cirebon. In order, the highest TCK ability is possessed by students from the regency of Majalengka, the regency of Cirebon, the city of Cirebon, Kuningan, and Indramayu. For the range of TCK skills, Cirebon City is at 2.7770 - 3.4257, Cirebon Regency is at 2.8909 - 3.4273, Kuningan is at 2.6702 - 3.2553, Majalengka

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Regency is at 2.5500 - 3.4500, and Indramayu is at 2.3611 - 3.0833. This shows that, with a range of 0.9000, Majalengka Regency has different capabilities compared to other regencies/cities in Region III Cirebon. Meanwhile, Cirebon City is the city with the most uniform TPMDK capability compared to the other 4 counties/cities. It has a range of 0.5364.

The survey results also have a mapping of the TPMDK capability in terms of the knowledge dimension. The full results are shown in Figure 2 below;

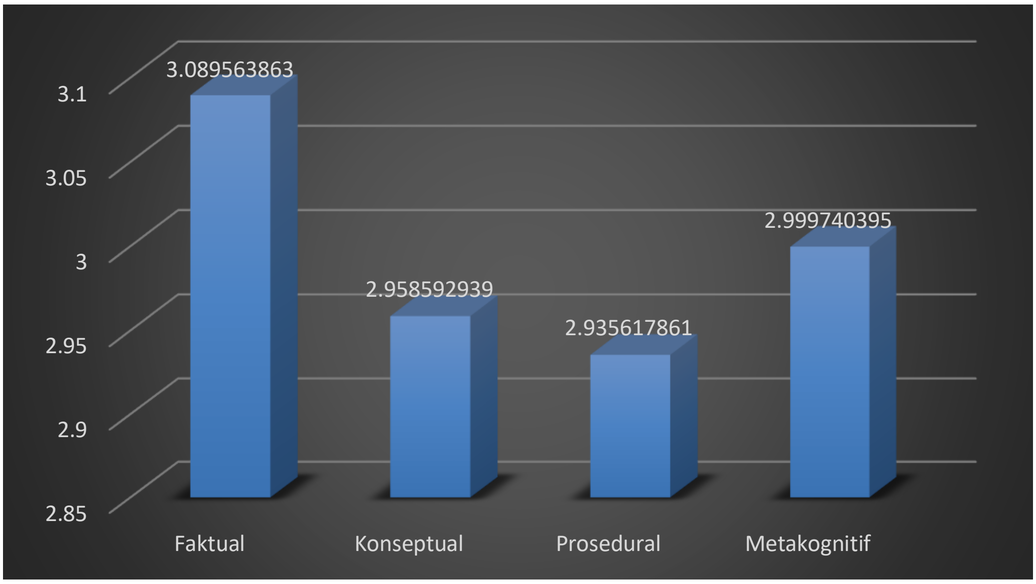

Figure 2. Diagram of TPMDK ability based on dimension

The diagram above shows that the dimension of factual knowledge is the highest knowledge mastered by the students in 5 districts/cities in Region III Cirebon, with an average score of 3.089, followed by the metacognitive dimension of 3.000, the conceptual dimension of 2.96, and the procedural dimension of 2.94.

3.1.3 Different Test

The purpose of this test is to find out in more detail whether there are differences in the TPMK skills and their aspects for future mathematics teachers. This is expected to identify opportunities for improving the curriculum structure to develop the TPMK skills of prospective mathematics teachers, and to identify the potential of each region to develop the TPMK skills of mathematics teachers. It also identified specific opportunities that can be developed according to the abilities and needs of mathematics teachers in terms of TPMK.

A normality test was carried out before the t-test. This test used SPSS with the criteria presented by Kolmogorov-Smirnov, where all aspects had a significance value of 0.00 <0.05. This indicates that all aspects of the TPMDK have an abnormal distribution.

The independent non-parametric test of all aspects of TPMDK based on gender has a significance value > 0.05, except for the aspect Technological-Mathematical-Practical Knowledge (TMPK). This shows that the ability of TPMDK is relatively equal between male and female students. The ability of aspects such as Mathematical Factual Knowledge, Mathematical Procedural Knowledge, Pedagogical Conceptual Knowledge, Pedagogical Procedural Knowledge, Technological Conceptual Knowledge, Technological Procedural

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Knowledge, Pedagogical Mathematical Conceptual Knowledge, Pedagogical Mathematical Procedural Knowledge, Technological Mathematical Content Knowledge, Technological Mathematical Metacognitive Knowledge, Technological Pedagogical Procedural Knowledge, Technological Pedagogical Mathematical Procedural Knowledge, Technological Pedagogical Mathematical Metacognitive Knowledge, Pedagogical Factual Knowledge, Technological Factual Knowledge, Technological Pedagogical Conceptual Knowledge, Technological Pedagogical Metacognitive Knowledge there is no significant difference based on gender.

There are gender differences only in the aspects of mathematical conceptual knowledge (MCK) and technological conceptual knowledge. On average, male students have higher abilities than female students in these aspects. However, overall, the average ability of Technological Pedagogical Mathematical Dimension Knowledge is not significantly different between male and female students.

Another test of TPMDK ability differences is based on the semester level. The semester level is divided into three levels, namely III, V, and VII. All aspects of TPMDK based on the semester level have a significance value > 0.05 except in the aspect of Technological Mathematical Pricedural Knowledge (TMPK). This shows that the ability of TPMDK is relatively the same among the three-semester levels. The ability of aspects such as MFK, MCK, MPK, PCK, PPK, TCK, TPK, PMCK, PMPK, TMCK, TMMK, TPPK, TPMPK, TPMMK, PFK, TFK, TPCK, TPMK, there is no significant difference. Only the Technological Mathematics Procedural Knowledge (TMPK) aspect has a significant difference.

Next, the TPMDK ability based on the city of origin of the HEI differs from the previous two categories; the TPMDK ability based on the city of origin of the HEI has aspects that are mostly not the same. This indicates that for the five cities/regions of origin, the TPMDK skills of male and female students tend to be different. There are only 2 aspects, namely TPCK and PMMK, that tend to be similar to each other.

Based on the school origin of students from the five districts/cities in the Cirebon III region, it can be seen whether there is a difference in the ability in other aspects of TPMDK. The ability of TPMDK, based on its aspects, can be divided into two groups. In the first group, the ability of the aspects such as TPCK, PMPK, PMCK, and MFK does not show any significant differences based on the school origin of the students. Group II, on the other hand, is the group that shows differences in aspects other than the 4 above. In general, there are no significant differences in TPMDK.

3.2. Discussion

Based on the results of describing the TPMDK skills, an average score of 2.983 was obtained, which falls into the high category. Mathematics teacher candidates in the Cirebon III region possess the knowledge and skills required for mathematics teachers to integrate technology into pedagogy and high-level mathematical content effectively. This is in line with the findings of [22], which state that teachers' TPCK knowledge is very good in terms of developing lesson plans and learning assessments, selecting the technology or learning media used, mastering teaching materials, and combining technology, pedagogy, and content

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aspects. This is in line with the findings [23] that TPACK proficiency for mathematics education students in terms of preparing and implementing lesson plans that integrate learning theory/learning strategies, materials, and technology is in the fairly good category. As suggested by [24], the high TPACK proficiency of prospective mathematics teachers in the III Cirebon region is an important asset in extending the TPACK model to DPACK (Digital Pedagogical Content Knowledge). It was further stated that the digital transformation in STEM education requires additional professional knowledge in line with the transformation of communication, mediatisation, and society, which is focused on the needs of students and young people now and in the future.

The TPMDK ability in the fifth semester has the highest score compared to the third and seventh semesters. The ability of TPMDK based on semester levels can be presented in the following diagram;

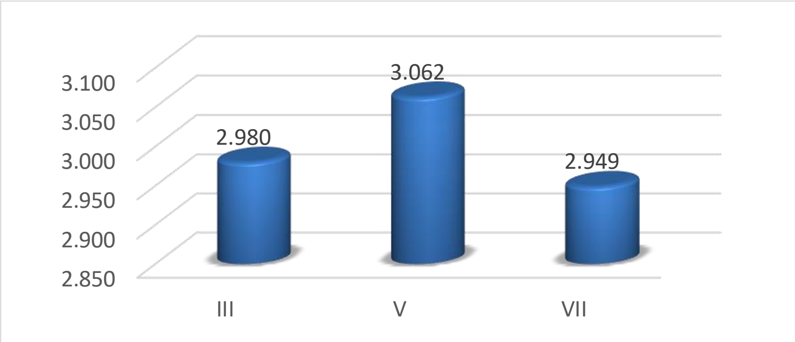

Figure 3. Average TPMDK Ability by Semester

The diagram above shows the difference in average TPMDK ability based on the semester. However, the existing differences are very small, namely 0.08 – 0.12. Several factors contributing to these differences are indicated, including: 1) the level of mastery of the material, mastery of pedagogy, and technology [25], and the learning and teaching environment [23]. The next discussion, the ability of TPMDK is based on gender. The average results of this ability can be presented in the following diagram;

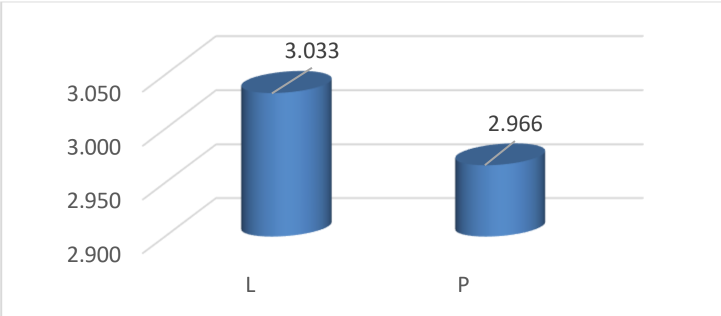

Figure 4. Average TPMDK by Gender

The diagram above shows that the average TPMDK of male students is higher than that of female students, but with a very small difference of 0.067. This indicates a tendency for similar abilities in TPMDK. This is in line with research findings that generally state there is no significant difference between the TPACK of male and female prospective teacher students if they have the same initial abilities, motivation, and interest. Study from

[32] shows that overall, there are differences in TPACK abilities of prospective teachers based on gender, but there are no differences based on grade level.

4.2.1 Discussion of Domain TPMDK

This research includes several aspects that can be categorized into dimensions and/or sub-elements, combined with the knowledge dimension used in this study. Sequentially, the aspects of TPACK from highest to lowest are: Technological Knowledge (3.2), Technological Mathematical Knowledge (3.04), Technological Pedagogical Knowledge (3.01), Technological Pedagogical Mathematical Knowledge (2.94), Pedagogical Knowledge (2.95), Mathematical Education Knowledge (2.88), and Mathematical Knowledge (2.83) in line with the findings [20], which show good TPACK abilities, particularly in PCK and TK. In line with the findings [26], the TPACK abilities of certified and non-certified teachers are identical. However, certified teachers have an advantage in TK and TCK abilities, while non-certified teachers excel in PCK. The ability of TPMDK, when viewed from the knowledge dimension, in order from highest to lowest, is the Factual Dimension (3.09), the Metacognitive Dimension (3.00), the Conceptual Dimension (2.96), and the Procedural Dimension (2.94). This indicates that prospective mathematics teacher students in the III Cirebon region possess very adequate factual knowledge in terms of mathematics, pedagogy, and technology.

Students have a good understanding of symbols, mathematical notations included in the curriculum, as well as mathematics in general. Learning approaches and various learning styles are also well understood by prospective teacher students. Students have a good understanding of software and social media. This is in line with the condition of students born in the year 2000 who belong to Generation Z [27]. This generation is also called the iGeneration, net generation, or internet generation. They have similarities with Generation Y, but they are able to perform all activities simultaneously, such as tweeting using a phone, browsing with a PC, and listening to music using headphones. Whatever they do is mostly related to the virtual world. Since childhood, they have been familiar with technology and adept with sophisticated gadgets, which indirectly influence their personalities. However, procedural knowledge still needs to be further improved.

The dominant aspects mastered by prospective teacher students, as presented in Table 9, which are above average, in order are TCK, TFK, TMPK, TPMK, TPK, PFK, MFK, TPCK, TMMK, and PMMK. The tendency to master technological knowledge and its relation to other knowledge becomes a driving force for high proficiency in other aspects. This is evident from the abilities in Technological Factual Knowledge, Technological Conceptual Knowledge, and Technological Procedural Knowledge, which are part of Technological Knowledge that falls into the very high category. Another factor is that the students belong to Generation Z, which has a common sense of technology [27]. The dimension of factual knowledge is the dimension of TPMDK that is most mastered by students, regardless of gender, semester level, city of origin, or school of origin. The other dimension is the cognitive dimension, which ranks second in mastery among students, followed in order by the conceptual and procedural dimensions. These two abilities can be presented in the following table;

Table 13. Dimensions of Factual Knowledge from the TPMDK Aspect

Jenis Kelamin	MFK	PFK	TFK
L	3.0566	3.0000	3.1887
P	3.0124	3.0528	3.2112
Total	3.0234	3.0397	3.2056

Based on Table 13 above. Facts related to technology are the knowledge most mastered by students, both male and female, compared to facts about mathematics and pedagogy.

Table 14. Dimensions of Conceptual Knowledge from the TPMDK Aspect

Jenis Kelamin	MCK	PCK	TCK	PMCK	TMCK	TPCK
L	2.9623	2.9151	3.4623	2.8208	3.0063	3.0000
P	2.6863	2.8571	3.3292	2.7609	2.9565	3.0248
Total	2.7547	2.8715	3.3621	2.7757	2.9688	3.0187

The data in Table 14 shows that conceptual knowledge of technology is the main support for mastering the concept of technology application in mathematics and pedagogy for both men and women. TK, TMK, and TPK are interrelated and influence each other in forming TPACK (Technological Pedagogical Content Knowledge), which is knowledge that integrates technology, pedagogy, and content within a specific learning context [7]

Table 15. Dimensions of Procedural Knowledge from the TPMDK Aspect

Jenis Kelamin	MPK	PPK	TPK	PMPK	TMPK	TPMPK	TPPK
L	2.8208	2.9528	3.1604	2.8868	3.2453	3.0189	2.9811
P	2.6957	2.9441	3.0093	2.8540	3.1304	2.8820	2.9161
Total	2.7266	2.9463	3.0467	2.8621	3.1589	2.9159	2.9322

Table 15 above shows that the ability of Technological Mathematical Procedural Knowledge is the highest aspect mastered in the knowledge dimension of TPMDK. This illustrates that prospective mathematics teacher students in the III Cirebon region are very capable of integrating and using technology related to mathematical processes.

Table 16. Dimensions of Metacognitive Knowledge from the TPMDK Aspect

Gender	TPMMK	TPMK	TMMK	PMMK
L	3.0849	3.0849	3.0189	3.0189
P	2.9348	3.0932	2.9969	2.9793
Total	2.9720	3.0911	3.0023	2.9891

The data in Table 16 above shows that students' metacognitive abilities are very good in terms of utilizing various technologies in mathematics learning, using them effectively in learning, and determining the stages or steps in utilizing technology or mathematical software.

3.2.2 Discussion of the Result Difference Test

The next discussion conducted is related to the difference test. The difference test of TPMDK ability will be based on gender, semester, city of origin, and school of origin. In addition, the discussion will continue on the aspects of TPMDK, as well as based on the dimensions of its knowledge.

The first difference test was conducted using the parametric independent sample test, which yielded a significance value > 0.05, indicating no difference in TPMDK ability based on gender. In line with [28], who obtained results, there is no significant difference between the TPACK of male and female mathematics teachers. The results of the TPACK difference test based on gender indicate that there is no significant difference between male and female teachers in terms of TPACK ability [29].

In line with these findings, no significant differences in TPMDK abilities were found when viewed by semester level. The results of this test show that the TPMDK ability for semesters III, V, and VII is relatively the same. Interestingly, when looking at the highest average score, it is in the fifth semester.

The ability of TPMDK based on the dimension of factual knowledge in this study also shows no difference, whether based on gender or semester level.

Factual knowledge in mathematics based on gender and semester shows no difference. Similarly, there is no difference in factual knowledge of pedagogy and technology. Mathematics teacher candidates in the III Cirebon region tend to have diverse levels of understanding regarding mathematical symbols and notations, both at the school-level and in general mathematics.

The discussion continues on the conceptual dimension of TPMDK. The conceptual dimension in this study includes 6 aspects, namely: conceptual knowledge of mathematics, conceptual knowledge of pedagogy, conceptual knowledge of technology, conceptual knowledge of mathematics pedagogy, conceptual knowledge of mathematics technology, and conceptual knowledge of pedagogy technology. In general, no differences were found in the six conceptual aspects when viewed from the perspective of semester and gender. Two aspects show differences based on gender, namely, conceptual knowledge of mathematics and conceptual knowledge of technology. The complete results of this difference test can be presented in Table 27. This test uses an independent non-parametric test due to the non-normal data and unequal sample sizes.

The dimension of procedural knowledge in TPMDK includes 7 aspects, namely: MPK, PMK, TPK, PMPK, TMPK, TPPK, and TPMPK. There is no significant difference among these 7 aspects when viewed based on gender. However, based on the semester, there is one difference in the TMPK aspect, while the other six aspects show no difference. The conceptual and procedural dimensions are the two dimensions that need to be improved compared to the factual and metacognitive dimensions. The online learning experience that students had during high school and the early semesters became one of the factors contributing to the lack of conceptual and procedural knowledge. These findings are in line with the study conducted by Farhan, M. S., & Zanthy, L. S. [30], which states that students' difficulties are caused by their inability to master concepts, detailed knowledge of concepts, and students' carelessness in solving problems, as well as their inability to determine causal factors, understand material prerequisites, and identify appropriate strategies and concepts. In line with the research findings that show the average percentage of students' cognitive

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abilities for factual knowledge is 73%, conceptual knowledge is 29%, and procedural knowledge is 10% [31].

The next dimension of knowledge is metacognitive. There are 4 aspects of TPMDK that contain the metacognitive dimension in this study, namely: PMMK, TMMK, TPMK, and TPMMK. All aspects of TPMDK in the dimension of metacognitive knowledge have a significance value > 0.05, indicating that all aspects do not have significant differences based on gender and semester. Based on the previous diagram 2, the average TPMDK ability in the metacognitive dimension is at a score of 3.00, indicating very good. Students read the problems repeatedly, highlight keywords, reconsider the relationship between the mathematical problems and existing concepts, make connections, and determine the methods for solving them. The students also identify the main issues before using the software, compare it with manual methods to check solutions, have confidence in utilizing technology in learning, use various technologies and information, understand their own abilities in using technology for mathematics, and integrate it into their learning. The experience of online learning during the COVID-19 pandemic became a trigger for students to organize and manage themselves in learning mathematics, particularly in relation to the facts concerning aspects of TPMDK.

4. CONCLUSION

Based on the background, results of the study, and discussions carried out, the following conclusions can be drawn;

a. The average TPMDK ability score obtained was 2.983, which falls into the high category. Mathematics teacher candidates in the Cirebon region III possess the knowledge and skills required for mathematics teachers to integrate technology into high-level pedagogy and mathematical content effectively. The ability of TPMDK based on gender, semester, and school origin is relatively the same, while students from PT Indramayu have the lowest TPMK ability. The TPMDK ability of fifth-semester students has the highest score compared to the third and seventh semesters. The TPMDK ability of male students has a higher score compared to female students. Students from high school have the highest TPMDK ability compared to students from madrasah aliyah (MA) and vocational schools (SMK). Followed in succession by MA and SMK.

b. Sequentially, the aspects of TPMDK from the highest are: Technological Knowledge (3.2), Technological Mathematical Knowledge (3.04), Technological Pedagogical Knowledge (3.01), Technological Pedagogical Mathematical Knowledge (2.94), Pedagogical Knowledge (2.95), Mathematical Education Knowledge (2.88), and Mathematical Knowledge (2.83). The ability of TPMDK when viewed from the knowledge dimension, in order from the highest, is the Factual Dimension (3.09), the Metacognitive Dimension (3.00), the Conceptual Dimension (2.96), and the Procedural Dimension (2.94). The tendency to master technological knowledge and its relation to other types of knowledge drives the high proficiency in other aspects. This is evident from the abilities in Technological Factual Knowledge, Technological Conceptual Knowledge, and Technological Procedural Knowledge, which are part of Technological Knowledge that falls into the very high category.

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c. All aspects of TPMDK based on gender have significance values > 0.05 except for the aspect of Technological Mathematics Procedural Knowledge (TMPK). This indicates that the TPMDK abilities are relatively the same between male and female students. The abilities in aspects such as; Mathematical Factual Knowledge, Mathematical Procedural Knowledge, Pedagogical Conceptual Knowledge, Pedagogical Procedural Knowledge, Technological Conceptual Knowledge, Technological Procedural Knowledge, Pedagogical Mathematical Conceptual Knowledge, Pedagogical Mathematical Procedural Knowledge, Technological Mathematical Content Knowledge, Technological Mathematical Metacognitive Knowledge, Technological Pedagogical Procedural Knowledge, Technological Pedagogical Mathematical Procedural Knowledge, Technological Pedagogical Mathematical Metacognitive Knowledge, Pedagogical Factual Knowledge, Technological Factual Knowledge, Technological Pedagogical Conceptual Knowledge, Technological Pedagogical Metacognitive Knowledge show no significant differences based on gender. Only the aspects of Mathematics Conceptual Knowledge (MCK) and Technological Conceptual Knowledge have differences based on gender. The ability of TPMDK is relatively the same among the three semester levels. The abilities of aspects such as MFK, MCK, MPK, PCK, PPK, TCK, TPK, PMCK, PMPK, TMCK, TMMK, TPPK, TPMPK, TPMMK, PFK, TFK, TPCK, TPMK show no significant differences. Only the aspect of Technological Mathematics Procedural Knowledge (TMPK) has differences based on the semester level. The ability of TMPDK based on the origin city of the university has aspects that are mostly different. This indicates that the TPMDK abilities of students tend to differ among the five cities/regencies. There are only 2 aspects, namely TPCK and PMMK, that tend to be similar.

5

8

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