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Mathematics teachers' TPACK in online learning during the COVID-19 pandemic based on demographic factors

The problem and the aim of the study. TPACK is a framework that can provide instructions for teachers to solve problems related to integrating technology into teaching and learning activities. This research was carried out during the COVID-19 pandemic when learning was online. This condition is something new for some teachers in Indonesia, so this study aims to analyze the TPACK perceptions of mathematics teachers in online learning based on demographic factors (gender, age, and teaching experience) and to determine the effect of demographic factors on TPACK perceptions.

Research methods. This research is a survey research with a cross-sectional survey approach. Data were collected using a questionnaire from 74 mathematics teachers in Yogyakarta Province in the odd semester of the 2021-2022 academic year and analyzed using the Mann-Whitney U and Kruskal-Wallis tests.

Results. To determine whether there is a difference between groups on the dependent variable, it is seen from the value (sig) obtained compared to the significance level (α = 0.05). Teacher gender affects TK (sig. 0.010), TCK (sig. 0.003), TPK (sig. 0.004), and TPACK (sig. 0.042). Male mathematics teachers have better perceptions than female teachers in all aspects of technology. Based on age, teachers aged 21-30 years have better perceptions than teachers aged more than 40 years in TK (sig. 0.042), teachers aged more than 40 years have better perceptions than teachers aged 31-40 years in CK (sig. 0.003), teachers over 40 years of age have better perceptions than teachers aged 21-30 years on PK (sig. 0.000) and PCK (sig. 0.013). Based on teaching experience, teachers with more than 20 years of teaching experience have better perceptions of CK (sig. 0.003), PK (sig. 0.001) and PCK (sig. 0.003) than other teachers.

In conclusion, gender and age affect aspects of technology, and age and teaching experience also affect aspects of pedagogy and content. From these findings, policymakers can formulate a training program to accommodate female teachers and senior teachers related to increasing mastery of technology and young teachers related to increasing pedagogical abilities and content.

Keywords: TPACK, online learning, gender, age, teaching experience

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Introduction

Education is a fundamental right for every human being around the world, children, youth and adults, men and women, to improve people's quality of life and ensure that the world is safer, healthier, more prosperous, and contributes to social, economic and cultural progress [1]. Education is a key element in the global education framework for sustainable development goals. Education is at the core of efforts to adapt to change and to transform the world in which we live. Quality basic education is the essential foundation needed for lifelong learning in a complex and rapidly changing world [2].

The coronavirus outbreak in early 2020 caused extensive damage to the educational system, affecting 1.6 billion students in over 200 countries [3; 4]. This has resulted in significant changes in all aspects of one's life, including interacting, working, learning, and teaching [5]. Because face-to-face learning is impossible, policymakers must implement educational policies as soon as possible during the pandemic. As a result, Indonesia's Ministry of Education and Culture issued a circular letter regarding the prevention of COVID-19 in online education and learning units. Educational institutions and educators must quickly adapt to this situation to carry out previously unimagined learning and teaching activities [6], which must be considered both a challenge and an opportunity [7; 8].

Online learning and teaching rely heavily on various factors, including infrastructures such as devices, internet connection coverage [9], human resources [10] such as educators, education staff, and student readiness, and digital-based learning content [11]. The implementation of online learning in Indonesia, which has been currently underway for nearly two years, must have encountered several challenges, including students lacking mobile phones or gadgets, a large number of students living in areas without internet access [12], teachers' limited ability to use technology in teaching [13], and the content of the learning materials presented [14]. Even online learning materials are difficult for students to fully comprehend [12]. The Indonesian government has been working quickly to construct infrastructure in various regions and to improve teachers' competencies through various workshops. The quality of learning is greatly influenced by the teacher's mastery of science and technology [15; 16]. It is crucial to use appropriate technology, materials, and strategies to facilitate and support students' learning [17], necessitating the creation of a framework for developing technology, pedagogy, and teaching materials [18].

Mishra and Koehler's Technological Pedagogical Content Knowledge (TPACK) is a comprehensive integration of knowledge and skills into materials, pedagogy, and technological developments [19]. TPACK is more than just adding technology to learning and content [20]. Teachers must learn the right technology, how and why to use it, and practice it in the classroom [21; 22]. Teachers' confidence and experience in designing learning can be greatly enhanced by incorporating TPACK into the classroom [23; 24].

Online learning has been operating effectively in Indonesia for almost two years, but it has impacted teachers who are more familiar with the use of technology [25]. This must confirm whether teachers can select the appropriate technology and how and why to use it in the classroom. Although much research has been conducted, there is a lack of knowledge about the demographic factors that influence the TPACK of mathematics teachers in online learning. Therefore, this study aimed to determine the TPACK of mathematics teachers based on demographic factors. Demographic factors studied in this study include gender, age, and teaching experience. Research on demographic factors can determine the strength of the impact of differences on people from various backgrounds [26]. TPACK's relationship with demographic factors can provide information for planning teacher development programs [27]. The results of this study are expected to be used as information for developing training programs to increase the TPACK of mathematics teachers.

Materials and methods

This research is a survey research with a cross-sectional survey approach [28]. Data were obtained through a survey using a questionnaire on Google Forms. The link was shared with the coordinators of the high school Mathematics teacher community (junior high school and senior high school) in each district/city in the Yogyakarta Province area via social media WhatsApp. A sample of 74 mathematics teachers was obtained by filling out the questionnaire. Considering the demographic aspects of the participants based on internal (gender [29] and age [30]) and external (teaching experience [31]) factors which, these factors affect TPACK. The TPACK instrument contains 28 items with a scale of 1 – 5, which was developed from [32; 33]. There are six items for TK, three for CK, seven for PK, three for PCK, two for TCK, three for TPK, and four for TPACK.

Before data collection, proving the validity and reliability of the instrument were carried out. Instrument validity was measured by content validity which was determined using expert agreement. The validity index proposed by Aiken [34; 35] is used to determine this agreement. An instrument item can be categorized based on its index. If the index (V) is less or equal to 0.4, it is said to have less validity, 0.4-0.8 is said to have moderate validity, and if it is greater than 0.8, it is said to have high validity [36]. From the calculation of the V index, it was found that 5 items had high validity and 23 items had moderate validity. Proving the reliability of the instrument using Cronbach's alpha (α), Cronbach's alpha was chosen because it is considered the best for calculating item reliability [33]. The questionnaire will be reliable if it has a high level of reliability > 0.70 [37], whereas according to [38], the value of α in the range 0.6 – 0.7 (reliable) and α in the range 0.7 – 0.8 (very reliable). The results of proving the reliability of the instrument are as follows: TK (α=0.94), CK (α=0.79), PK (α=0.88), PCK (α=0.87), TCK (α=0.88), TPK (α=0.89), TPACK (α=0.84) and overall reliability (α=0.95). From the results of the evidence, it was found that the instrument is valid and reliable. The following is the TPACK questionnaire instrument (Table 1).

Table 1

Aiken's index (V) and reliability (α) of the TPACK questionnaire

Item		V	A
TK1	I know how to use technology to solve my problems.	0.80	
TK2	I am a quick learner when it comes to technology.	0.75	
TK3	I stay up to date on significant new technological developments.	0.70	
TK4	I frequently use technology in a variety of activities.	0.85	
TK5	I am familiar with a wide range of technologies.	0.80	
TK6	I can use the technology that I require.	0.80	
	TK		0.94
CK 1	I am proficient in mathematics.	0.85	

CK2	I can think mathematically.	0.75	
CK3	I use various methods and strategies to improve my understanding of mathematics.	0.80	
CK			0.79
PK1	I know how to assess student's performance in class.	0.75	
PK2	I can modify my instruction based on what students understand or do not understand.	0.80	
PK3	I can adapt my teaching style to the student's learning style.	0.85	
PK4	I am capable of assessing student learning in a variety of ways.	0.70	
PK5	I am familiar with various approaches, methods, and learning models.	0.85	
PK6	I understand the common misconceptions that students have.	0.70	
PK7	I am skilled at class organization and management.	0.80	
PK			0.88
PCK 1	I can select effective approaches, methods, and learning models for teaching mathematics and enabling students to think mathematically.	0.75	
PCK2	I can tailor the material's stages to the level of student comprehension based on their prior learning experience.	0.85	
PCK3	I can select appropriate learning methods to help students overcome their difficulties in understanding the materials.	0.75	
PCK			0.87
TCK1	I am familiar with the technology used to learn and comprehend mathematics.	0.80	
TCK2	I can use technology to present mathematical materials.	0.75	
TCK			0.88
TPK1	I can select a technology that will increase the impact of a learning approach, method, or model.	0.70	
TPK2	I am capable of assisting students in their use of technology in the classroom.	0.75	
TPK3	I can apply what I've learned about technology to various learning activities.	0.75	
TPK			0.89
TPACK1	I can plan and deliver math lessons incorporating content, technology, and teaching methods.	0.75	
TPACK2	I can select the appropriate technology to support learning about what I teach, how I teach, and what my students learn.	0.80	
TPACK3	I can use strategies that combine what I've learned in class about content, technology, and learning styles.	0.75	
TPACK4	I can assist others in coordinating the use of the content, technology, and instructional methods at school.	0.70	
TPACK			0.84
Whole instrument			0.95

Data from filling out the questionnaire were analyzed using descriptive and inferential analysis. The descriptive study describes the TPACK values for each component and the demographic data. The Mann-Whitney test determined the mean difference between the two groups (gender). The Kruskal-Wallis test was used to determine differences between more than two groups (age and teaching experience).

Literature review

TPACK is an advancement of PCK, which Shulman introduced in 1986 [39], by incorporating technological knowledge into content and pedagogical knowledge. The TPACK framework is made up of the relationships and complexities that exist between technological knowledge, pedagogy, and content [19; 40]. The TPACK framework is the foundation of the teaching and learning processes. It can help teachers solve problems related to integrating technology into classroom teaching and learning activities [41; 42], as seen in the following figure.

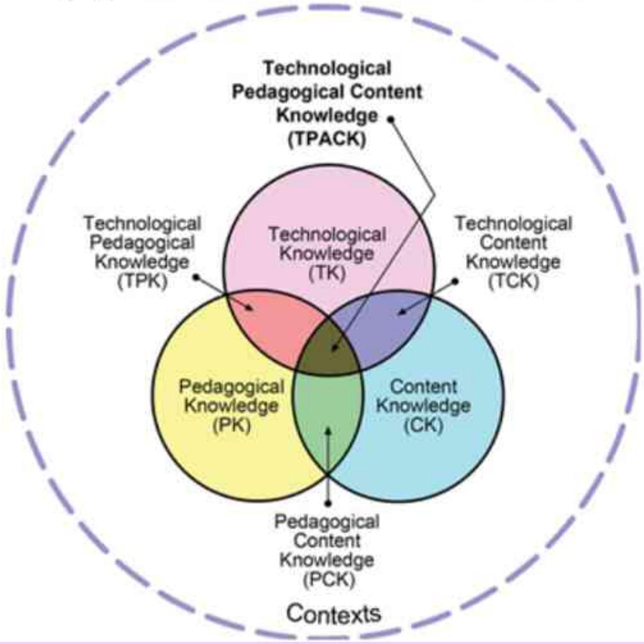

Figure 1 The TPACK framework and its knowledge components [40]

Figure 1 presents three major components: Technology knowledge (TK), knowledge about technology and its application [43; 44]. This knowledge aims to utilize information technology which is growing rapidly. Teachers' understanding related to TK is how teachers use computer software and hardware, projectors, and other technologies related to education. How to apply TK in the learning process is that teachers are able to use and utilize technology as a learning medium, find references, and learning resources. Content knowledge (CK), teacher knowledge about the material to be studied or taught [19; 40]. Teachers must understand the material to be taught including knowledge of facts, concepts, theories and procedures in the subject matter to be taught. Content includes knowledge of concepts, theories, ideas, organizational frameworks, methods of proof and substantiation, as well as established practices and approaches towards developing such knowledge within the discipline. Teachers master and study the material in order to be able to explain and deliver the material clearly, logically and be able to answer questions and provide relevant examples and use learning resources in accordance with the material being taught. Pedagogical knowledge (PK), the knowledge that includes classroom management strategies and principles [45]. The interaction between the three components, which are represented as Pedagogical content knowledge (PCK), pedagogical knowledge to teach specific content [17; 19]. PCK refers to the concept of teachers' pedagogical knowledge in applying learning to specific content, so that learning becomes effective. This combination generates the main ideas to present learning well and correctly but not separated from the curriculum, learning, teaching and assessment. PCK can be applied by teachers by reflecting after teaching, interviewing or dialoguing with students, discussing with other teachers. Technological content knowledge (TCK), knowledge about selecting and using the most appropriate technology for specific content [17]. Teachers in this context must master more than one material and also need to understand the specific and appropriate technology to be applied to teaching materials, so that if the technology is applied it will be easily understood by students. Teachers who have good technological knowledge will have an impact on the ability to deliver material well so that the material presented will be easy to understand. By understanding TCK, teachers will be able and able to determine which technology media is appropriate to convey the material being taught. Technological pedagogical knowledge (TPK), knowledge of how to use technology for different learning [40; 44]. TPK aims to understand what technology is appropriate to achieve pedagogical goals, and allows teachers to choose what equipment is most appropriate based on its feasibility to achieve pedagogical goals. Technology as a medium or learning resource can create new methods and make it easier to apply in the learning process. For example, due to the development of the environment and the needs of society, teachers need to be more creative and innovative in designing learning, one of which is online learning. Technological pedagogical content knowledge (TPACK), knowledge of the application of technology in a variety of subjects and teaching methods [46]. TPACK is the knowledge of using technology in accordance with pedagogics to deliver subject matter well. This knowledge is needed by teachers to integrate technology into teaching materials to produce effective, efficient and maximized learning.

Much literature has examined TPACK about the teaching profession and prospective teachers. This research [47; 48] concluded that TPACK is an important competency for teachers. [29] recommended the need for professional development programs to develop teachers' TPACK. The use of the TPACK model can improve students' ability to use technology in learning and later in their profession. Students become more confident and their understanding is improved [49]. Teachers' confidence in integrating technological knowledge into their teaching can play an important role in influencing how they plan and design web-based learning [50]. Research on teachers' TPACK in the future needs to be conducted frequently especially on issues such as age, gender, and teachers' exposure to technology [47; 48; 51]. From these various studies, it is concluded that TPACK is essential for developing the professional abilities of teachers and prospective teachers. Several studies related to TPACK have been conducted, including looking at the TPACK of teachers and prospective teachers based on gender [27; 29], age [30; 51], and level of education [48; 52]. These studies were carried out from 2010–2019, when the COVID-19 pandemic had not yet hit and had not made extensive changes in the education system. In addition, research that was carried out during the COVID-19 pandemic [53; 54] only examined the readiness of teachers or lecturers in learning in the this era.

Research results

This study analyzed the effect of gender, age, and teaching experience on the perceptions of TPACK of mathematics teachers in Yogyakarta Province in online learning during the COVID-19 pandemic era. Many studies have been conducted related to TPACK. Still, this research is different from existing research, namely the condition of the research sample who have been carrying out online learning for almost 2 years during the COVID-19 pandemic. The following is the average TPACK perception based on the results of completing a questionnaire by 74 mathematics teachers.

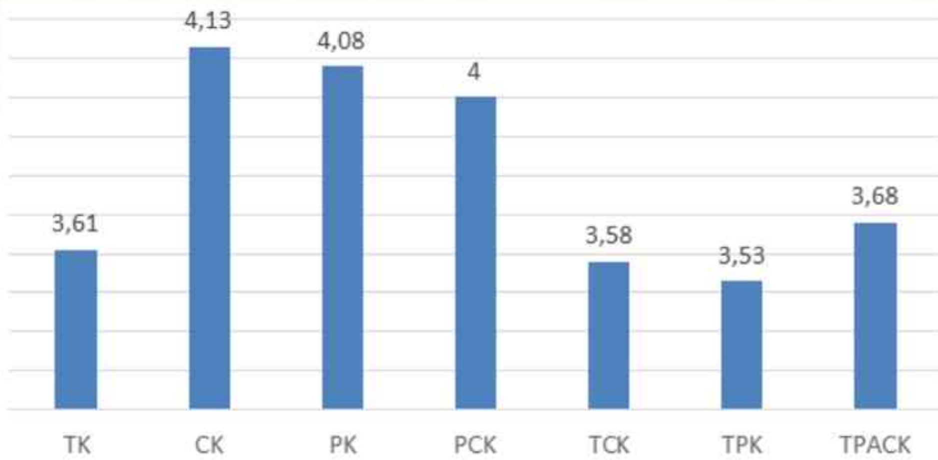

Figure 2 Perceptions of teachers' TPACK based on the TPACK component

The Effect of Gender of Mathematics Teacher on TPACK

From a total sample of 74 people, there were 19 male mathematics teachers and 55 female teachers. The effect of gender on each aspect is shown in Table 2 below.

Table 2

The results of the analysis of the effect of the mathematics teacher's gender on TPACK

Variable	TK		CK		PK		PCK		TCK		TPK		TPACK	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Gender														
Male	3.94	0.57	4.09	0.43	4.06	0.44	3.90	0.32	4.00	0.62	3.89	0.53	3.87	0.46
Female	3.50	0.63	4.15	0.50	4.08	0.32	4.03	0.35	3.44	0.73	3.40	0.65	3.61	0.40
z-score	-2.567		-0.618		-0.508		-1.429		-2.927		-2.884		-2.030	
Sig.	0.010		0.537		0.611		0.153		0.003		0.004		0.042	

The results in Table 2 show that gender influences TPACK perceptions differently. Teacher gender affects TK (sig. 0.010), TCK (sig. 0.003), TPK (sig. 0.004), and TPACK (sig. 0.042). While the teacher's gender did not affect CK (sig. 0.537), PK (sig. 0.611), PCK (sig. 0.153). Judging from the average, male mathematics teachers have better perceptions than female teachers regarding TK, TCK, and TPK.

The Effect of the Age of Mathematics Teacher on TPACK

The age of mathematics teachers was divided into three ranges, namely 11 people aged 21-30 years, 11 people aged 31-40 years, and 52 people over 40 years old. Teachers dominated the research respondents over 40 years old, namely 70%. The effect of the age of the mathematics teacher on each aspect of TPACK is shown in Table 3.

Table 3 shows that age has a different effect on perceptions of TPACK. Teacher age affects TK (sig. 0.042), CK (sig. 0.003), PK (sig. 0.000), and PCK (sig. 0.013). Meanwhile, the teacher's age did not affect TCK (sig. 0.265), TPK (sig. 0.520), TPACK (sig. 0.385). Furthermore, tests were carried out on TK, CK, PK, and PCK to see between categories at significantly different teacher ages.

Table 3

The results of the analysis of the effect of the age of the mathematics teacher on TPACK

Variable	TK		CK		PK		PCK		TCK		TPK		TPACK	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Age														
21-30 years	4.03	0.52	3.91	0.45	3.73	0.22	3.79	0.27	3.55	0.57	3.70	0.48	3.52	0.34
31-40 years	3.68	0.45	3.85	0.23	4.04	0.31	3.91	0.34	3.91	0.58	3.70	0.60	3.70	0.29
> 40 years	3.51	0.66	4.24	0.50	4.16	0.34	4.06	0.35	3.52	0.80	3.45	0.70	3.70	0.46
Kruskal Wallis H	6.336		11.420		17.206		8.684		2.654		1.309		1.912	
Sig.	0.042		0.003		0.000		0.013		0.265		0.520		0.385	

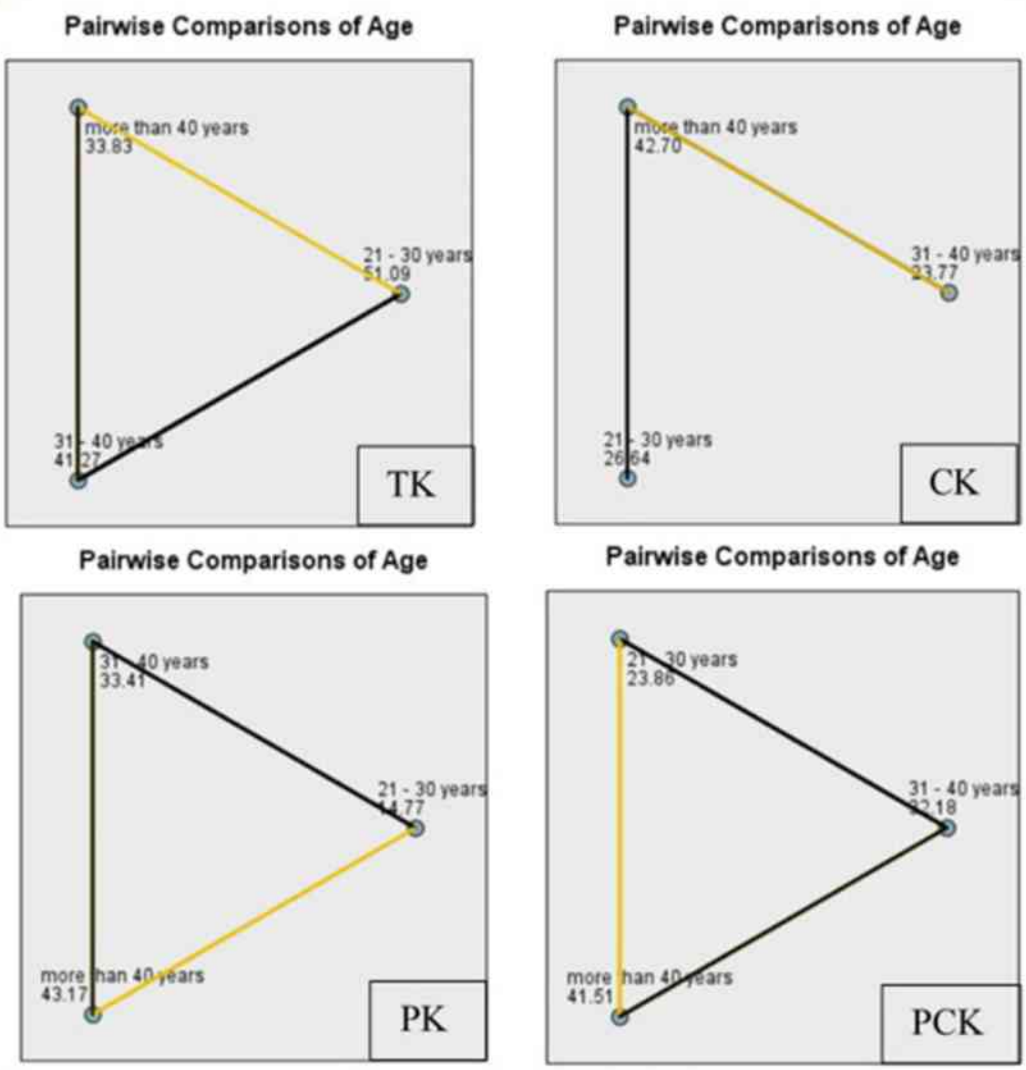

Figure 3 Comparison of teacher age to CK, PK, and PCK

In the TK aspect, teachers aged 21-30 years have better perceptions than teachers who are over 40 years old. In the CK aspect, teachers over 40 years old have better perceptions than teachers who are 31-40 years old. In the PK and PCK aspects, teachers over 40 years old have better perceptions than teachers who are 21-30 years old.

The Effect of Teaching Experience of Mathematics Teachers on TPACK

The teaching experience of mathematics teachers was divided into three ranges, namely 16 people with 1-10 years of teaching experience, 18 people with 11-20 years of teaching experience, and 40 people with more than 20 years of teaching experience. Respondents to the research subjects were dominated by mathematics teachers with more than 20 years of teaching experience, namely 54%. The effect of teaching experience on each aspect of TPACK is shown in Table 4.

Table 4

The results of the analysis of the effect of the teacher's teaching experience on TPACK

Variable	TK		CK		PK		PCK		TCK		TPK		TPACK	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Teaching Experience														
1–10 years	3.87	0.56	3.90	0.38	3.81	0.24	3.77	0.26	3.69	0.63	3.73	0.56	3.56	0.30
11 – 20 years	3.70	0.64	3.98	0.55	4.13	0.45	4.09	0.44	3.75	0.79	3.61	0.73	3.78	0.48
> 20 years	3.47	0.64	4.29	0.48	4.15	0.35	4.04	0.35	3.46	0.74	3.41	0.66	3.68	0.43
Kruskal Wallis H	4.743		11.839		14.513		11.599		2.358		2.388		3.074	
Sig.	0.093		0.003		0.001		0.003		0.308		0.303		0.215	

Table 4 shows that teaching experience has different effects on TPACK perceptions. The teacher's teaching experience affects CK (sig. 0.003), PK (sig. 0.001), and PCK (sig. 0.003). While teaching experience did not affect TK (sig. 0.093), TCK (sig. 0.308), TPK (sig. 0.303), and TPACK (0.215). Further tests were carried out on CK, PK, and PCK to assess significantly different categories of teaching experience.

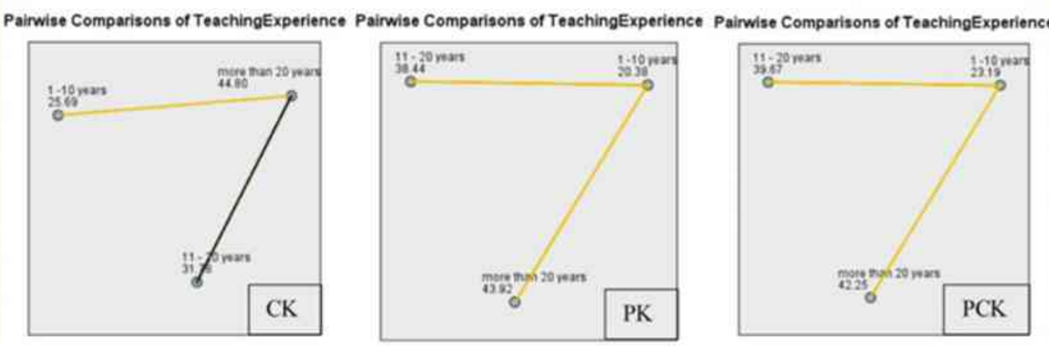

Figure 4 Comparison of average teaching experience with CK, PK, and PCK

Figure 4 shows the CK aspect, teachers who have more than 20 years of teaching experience have better CK perceptions than teachers with 1-10 years of teaching experience. In the PK and PCK aspects, teachers with 11-20 years of teaching experience and more than 20 years have better perceptions than teachers with 1-10 years of teaching experience.

Discussion

Based on the components of the TPACK framework, Figure 2 shows a score for each component of TPACK ≥ 3.53 at a moderate level [55]. TPACK is the basis of the teaching and learning process that can provide instructions for teachers to solve problems related to integrating technology into teaching and learning activities in the classroom [41; 42]. Teachers cannot only choose the right technology but also know how and why to use this technology in learning [21; 22]. Based on the survey results, the average TPACK ability of mathematics teachers in Yogyakarta Province is quite good. However, it is necessary to look at the relationship between demographic factors and TPACK perceptions of mathematics teachers so that they can provide information to relevant parties to make appropriate training programs.

The TPACK component, which contains technological aspects, shows that male mathematics teachers have a higher average score than female mathematics teachers. In line with research [51] on prospective teachers and teachers, gender only affected perceptions of aspects of TPACK that involved technology. From the questionnaire results, male mathematics teachers are more likely to follow technological developments and can quickly learn and utilize technology in various activities. In learning mathematics, male teachers can better choose suitable technology and present interesting mathematics material using technology. Several other research results also reveal that there is an influence of gender differences in the use of technology [56-58]. Research [30; 59] shows that men have a positive attitude towards e-learning, whereas women often experience technical problems in online learning [26]. This fact is not related to mathematics training, but it stems from the fact that men are more interested in technology than women. In contrast, women are more interested in language and social science [27].

Mathematics teachers, aged 21-30 years, are more tech-savvy and know many different technologies. Technology learning for older people is relatively slower than for younger people and relatively lower in digital literacy [26; 60]. When the teacher's age increases, the teacher's interest in technology decreases, and tends to be less confident in applying technology [46; 61]. With the current conditions, which are massive in the use of technology in learning, senior teachers must increase their competence in knowledge and use of technology in learning. Mathematics teachers over 40 have better perceptions of CK, PK, and PCK. Teachers can design learning, understand various approaches, methods, and learning models, choose appropriate methods to overcome students' difficulties in understanding mathematical material, and know how to organize and manage classes. Based on research [46], the increasing the teacher's age range, the lower the TK self-efficacy level, while the PCK self-efficacy level is higher. When the teacher's age range increases, the use of technology in learning will be more familiar. The ability to manage the teaching process will also increase with age [62].

The teacher's age is directly proportional to his experience because as he gets older, the teacher becomes experienced and knows where to explore the student's potential and how to make him understand his value [62]. Teachers with more teaching experience have better PCK abilities. Teachers with longer tenure generally have better pedagogical content abilities. The longer they teach, the more content and pedagogical knowledge they develop compared to novice teachers still developing knowledge integration skills [29; 63]. Senior teachers tend to perceive better the capacity of teaching methods and subject matter [47]. Existing research supports that teaching experience positively relates to CK [64].

Conclusion

This study provides an overview of the TPACK profile of mathematics teachers in Yogyakarta Province in online learning during the COVID-19 pandemic era regarding gender, age and teaching experience. The study results showed that male mathematics teachers had better perceptions than female teachers on the aspects of TK, TCK, and TPK. Maths teachers in the 21-30 year age range are more tech-savvy and know a lot of different technologies. Mathematics teachers aged over 40 years have a better perception of CK, PK and PCK. Mathematics teachers with more than 20 years of teaching experience have better perceptions of CK, PK and PCK. These results found that gender and age affect aspects of technology, and age and teaching experience also affect aspects of pedagogy and content. From these findings, policymakers can formulate a training program to accommodate female teachers and senior teachers related to increasing mastery of technology and young teachers related to increasing pedagogical abilities and content. This study has limitations. Namely, the sample is too small, so large sample research is needed in future research to improve the accuracy of the data. In addition, it is also necessary to conduct further research with a qualitative approach to further explore and understand the different effects.

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