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Gender dynamics in GeoGebra integration: In-service mathematics teachers' development

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Abstract
Teachers' perceptions of integrating educational technologies such as GeoGebra in teaching varied according to gender and these disparities were explored. The pre- and post-technological pedagogical and content knowledge (TPACK) Likert questionnaires were used as data collection instruments. TPACK was also used as the framework underpinning the study. The researchers purposively sampled 22 mathematics secondary teachers from twelve randomly selected schools in one district. Of the 22 selected teachers, 13 were male and nine were female. The researchers adopted a quasi-experimental research design within a quantitative approach and used the descriptive and inferential statistics to analyze and interpret the results. The findings revealed that males ranked their familiarity and experience with several novel technologies higher than did females. There exist gender differences with more male than female teachers showing a greater benefit to most of TPACK components.

Keywords: GeoGebra, in-service mathematics teachers, technology integration, gender dynamics, TPACK

INTRODUCTION

Integration of educational technologies in classrooms requires teachers who are knowledgeable of it. This means that their readiness and skills in integrating technologies play essential roles in the use of technologies in mathematics teaching. To implement technology inside or outside classroom settings, in-service teachers need to have high confidence levels coupled with a positive attitude. Through computer-based methods like simulations, teaching with information and communication technology (ICT) engages and motivates learners. Several international, national and local initiatives such as professional teacher development have been implemented to encourage teachers to integrate ICT in schools. According to White (2018, p. 35), "teachers decide when, what and how technology is used in the classroom, and in doing so they decide how learners reap the benefits of technology". Teachers' intent to integrate technologies such as GeoGebra into mathematics lessons is strongly influenced by perceived usefulness of GeoGebra, perceived ease of use, attitude towards use, and behavioral intention towards use (Ghavifekr & Rosdy, 2015). Perceived usefulness describes "the degree to which a person believes on the benefit from the use of a particular technology by improving the job performance, while perceived ease of use refers to the importance of a technology in being user friendly for the users" (Ghavifekr & Rosdy, 2015, p. 179).

When teachers know that using technology can improve their performance, they are eager to use it. Even though teachers are the driving force behind the usage of technologies in classrooms, its access and attraction can depend on gender, ethnics, and locations (Manyilizu & Gilbert, 2015). Gender dynamics refers to the culturally specific behavioral expression of a person's internalized identity, which includes notions of masculine and feminine (Ferreira, 2017). Gender dynamics forms the foundation for upcoming identity alterations and is influenced by the dynamics of physical, social, and emotional experiences (Fausto-Sterling, 2012). Gender identification in this situation is a chronological pattern in the employment of GeoGebra by male and female mathematics teachers. Therefore, gender was an important dimension to understand in-service teachers' experiences, teacher change,

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Contribution to the literature

- This study reveals a greater need for gender-sensitive teacher professional development (TPD), which incorporates educational technologies in the teaching and learning of selected topics in mathematics.
- The findings reveal that males ranked their familiarity and experience with several novel technologies higher than did females.
- There exist gender differences with more male than female teachers showing a greater benefit to most of technological pedagogical and content knowledge (TPACK) components.

professional learning, and support. Examining gender differences in teachers' technology-related knowledge domains that is, their technology knowledge (TK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK) has been the interest at the center of this study. According to Saikkonen and Kaarakainen (2021), the digital gender divide is because of the significant gender differences in technology- related self-beliefs. The current study of gender differences largely focused on the levels of readiness of in-service teachers to integrate technology in classrooms. It was also intended to contribute to the existing body of knowledge of gender dynamics. It adds novel evidence on gender differences in teachers' readiness for technology usage and adoption. The researchers believed that understanding gender dynamics in the usage of GeoGebra by in-service teachers could promote technology integration and reduce the digital gender gap in schools. This study was important to understand whether there was an influence of male and female teachers' TPACK mastery of teaching of mathematics. This study intended to determine the digital gender gap by measuring in-service mathematics teachers' opinions of their technology expertise and how it can be incorporated into pedagogy and curriculum through TPD.

Problem Statement

The use of technology in teaching changes the way learners learn mathematics. The integration of technology by teachers in classroom is therefore important. Related studies in elementary and basic education have reported mainly focused on barriers and/or benefits of using educational technologies in classrooms. A little has been reported on teachers' gender differences in the process of integrating technology in teaching and learning of geometry. In elementary schools, primary schools, secondary schools, and tertiary institutions, there is a gender gap in students' attitudes toward, perceptions of, and use of ICT (Manyilizu & Gilbert, 2015). In basic education studies, boys seem to be more positive on ICT attitude than girls (Volman, 2005). Male students in tertiary studies reported to have more confidence on using information communication and technology than females (Mahmood, 2012). Hence, gender dynamics could exist among teachers. Teachers are a product of tertiary education in either universities or colleges of education.

Individual differences related to the skills and use of technology exist (Atika et al., 2022). The first author believed that a better understanding of teachers' gender differences will benefit researchers' effect in promoting technology integration in classroom teaching. In order to determine gender difference in teachers' TPACK, the first author engages in the process of developing secondary mathematics teachers to integrate GeoGebra in the teaching of geometry. This study sought to answer the following research question: How does gender matter in mathematics teachers' TK, TCK, TPK, and TPACK in mathematics teaching using GeoGebra? The purpose of this study was to assess gender dynamics in teachers' TK, TCK, TPK, and TPACK in the process of developing in-service teachers to use GeoGebra in mathematics teaching.

Study Hypothesis

The following hypotheses were generated for study:

H_0. There is no difference between male and female in-service teachers' TK, TCK, TPK, and TPACK after they have been developed to integrate GeoGebra in geometry teaching.

H_1. There is a difference between male and female in-service teachers' TK, TCK, TPK, and TPACK after they have been developed to integrate GeoGebra in geometry teaching.

LITERATURE REVIEW

The attainment arising from using educational technologies in classroom teaching has seen an improved level of positive influence on learners (Ivanović et al., 2018). Educational technologies provide enabling tools for the learning environment (Atika et al., 2022). Integrating technology results in teachers being able to maintain learners' attention in class and arouse learners' motivation and concentration (Ayite et al., 2022). Gender plays a pivotal role in the achievement of technology use in classroom teaching (Ayite et al., 2022). Gender disparities in ICT use across settings have been highlighted by studies. This gender disparities starts as early as in elementary education and is more evident in tertiary colleges and university stage (Palomares-Ruiz et al., 2021). Despite countries and governments' effort around the world to promote equity in use of ICT (Palomares-Ruiz et al., 2021), many studies have reported gender imbalance in ICT usage and skill development (Atika et al., 2022). Confidence in using educational technologies varies in terms of gender (Jones, 2012).

Ong and Lai (2006) conducted a study in Taiwan in which they found that men had stronger technology self-efficacy than women in categories like perceived utility, perceived simplicity, and behavioral desire to use technologies. Most of this disparity has been about gender differences in the use of ICT. Studies such as Palomares-Ruiz et al. (2020) and Tam et al. (2020) reported on a significant number of females having negative view of ICT. More females than male counterparts are unable to use technology to improve their learning (Palomares-Ruiz et al., 2020; Tam et al., 2020). Males dominate when it comes to technology use around the globe (Ayite et al., 2022). Mahmood (2012) found that males are more confident with the use of technology than female. Females have limited access to ICT than their male counterparts (Mumporeze & Prieler, 2017).

Despite international attempts to address gender inequality, women still face major disadvantages compared to males in many nations, particularly in the areas of education and employment discrimination. Digital skills acquisition by men is higher than that of women (Palomares-Ruiz et al., 2021). Specifically in the education fraternity, Gómez-Trigueros and Yáñez de Aldecoa (2021) referred to this gender inequality as the digital gender gap. They identified two categories of digital gender gap. According to Booth et al. (2010), the initial ICT gender gap is the disparity in the number of ICT users among males and females. The disparity in technological aptitude between males and females is the second ICT gender gap (Palomares-Ruiz et al., 2020). The initial ICT gender gap is gradually declining with the equal access to ICT that both sexes enjoy in the 21st century (Booth et al., 2010). Despite this, gender difference in technological skills is a most prevailing problem in modern society and it is still to be overcome (Palomares-Ruiz et al., 2020).

In the teaching fraternity, male and female teachers may vary in several ways including their perceptions towards technologies and how they behave afterwards. So, gender influences the acceptance of ICT in teaching processes. As opposed to females, males are viewed more favorably in research relating to technology (Orji, 2010). For instance, Jimoyiannis and Komis (2007) found that mathematics teachers' perceptions post-training about role of educational technology were influenced by their age, gender, confidence, and teaching experience. They further revealed that teachers' attitude towards educational technologies were gender based. For instance, more males recorded a positive attitude on ICT use in teaching and learning than their female counterparts. Thus, male teachers are more experienced with ICT. According to Manyilizu and Gilbert's (2015) study, technology integration in teaching is unevenly distributed by gender. They attest that more male teachers use educational technologies more often than female teachers.

Women faced more challenges in technological issues than men. Another barrier that still exists today and contributes to inequity is female teachers' predisposition to think of themselves as less capable than male teachers (Pritchard, 2010). It would be more accurate to characterize the importance of ICT use in teaching as masculine than feminine. This has caused technological inequality between male and female teachers. The development of in-service teachers in technology integration across the board, regardless of gender, would aid in addressing gender disparities in the uptake of new technologies (Orji, 2010). In a technological driven learning environment, teachers can teach, and learners can learn in a practical, active, and self-directed style (Qazi et al., 2021). Mastering TPACK is one of the strategies teachers can use to improve their technological skills and be able to integrate technologies in classrooms (Astuti et al., 2019). TPACK model advocates the inclusion and use of educational technologies in teaching and learning. It states that teachers must have adequate CK of the subject they teach, PK and TK (Mishra & Koehler, 2007).

Mishra and Koehler (2007) refer to TPACK as deep teaching knowledge. TPACK provides mastery indicators on how well teachers are utilizing technology in the classroom (Gómez-Trigueros & Yáñez de Aldecoa, 2021). In fact, mastering TPACK gives teachers potential to confidently use educational technologies in teaching and learning (Astuti et al., 2019). Regardless of open-door policy to access and use of ICT tools, most in-service mathematics teachers have not mastered TPACK. One of the factors that could possibly affect mastering of TPACK by teachers is gender. Related studies on technological skills gender gap have identified significant gender differences associated with TPACK mastery (Astuti et al., 2019; Gil-Juárez et al., 2011; Gómez-Trigueros & Yáñez de Aldecoa, 2021; Martín & González, 2018). These studies found that female teachers have lower TPACK than male teachers. Knowledge domains that include TK, TCK, and TPK differ between male and female teachers. This affects the mastery of their TPACK. Astuti et al. (2019), Gebhardt et al. (2019), and Gómez-Trigueros and Yáñez de Aldecoa (2021) reported significant differences in both sexes' TPACK. The report was opposite in that they found no gender differences in teachers' TPACK (Espinar & González, 2009; Ortega Sánchez & Gómez Trigueros, 2019; Sáinz & López-Sáez, 2010; Scherer & Siddiq, 2015). For instance, according to a study by Scherer and Siddiq (2015), there were no gender disparities in how teachers utilized instructional technology.

TPACK Framework

TPACK model was used in this study as the framework. TPACK framework was developed to serve two purposes. According to Misra and Koehler (2007), the aim of TPACK framework is to assist teachers in organizing their professional development by emphasizing the knowledge that they should possess regarding technology, pedagogy, and content, as well as their interrelationships. TPACK could also be beneficial for teachers creating lesson plans to have a better understanding of how technology interacts with subject matter, pedagogy, and content-specific pedagogy. TPACK framework consists of three knowledge domains PK, CK, and TK.

The actual CK that has to be learned or taught is the subject itself (Koehler & Mishra, 2008). Teachers' understanding of the subject is described by this kind of knowledge. CK is about the subject matter, which the teacher constructs and answers the question of what will be taught. PK is defined as "teachers' knowledge about the processes and practices or methods of teaching and learning" (Koehler & Mishra, 2009, p. 64). It considers the learners' learning requirements as well as the topic's presentational methodologies (Kanuka, 2006). TK is the study of information technology in order to effectively use it at work while continuously adjusting to its changes (Koehler & Mishra, 2008). The connection between CK, PK, and TK is essential for the growth of teachers' knowledge and abilities to incorporate the use of digital resources in their teaching. The intersections of these knowledge domains include PCK, TCK, TPK, and TPACK (see **Figure 1**). The researchers used TPACK framework as a model to determine the degree of in-service teachers' GeoGebra integrative skills based on gender. To achieve this, the study made use of the four technological components of TPACK framework namely: TK, TCK, TPK, and TPACK.

Chai et al. (2016) explain TCK as the knowledge of teachers' strategies to create content and use technology in different ways without regard to the classroom. With this type of knowledge, teachers should know how technology can create new representations for specific content. TCK suggests that, by using a particular technology, teachers can change the way learners practice and understand concepts in a given content area. For example, teachers will know how to use GeoGebra to teach geometry. Koehler et al. (2013) say that TPK, as the knowledge of how various technologies work, can be used in teaching. It involves teachers' understanding of how certain technologies transform both teaching and learning experiences by introducing new pedagogical possibilities and constraints. It is important that teachers realize that using technology in their teaching may change the way they teach. In this study, TPK referred to in-service teachers' ability to choose GeoGebra as an appropriate technology tool for

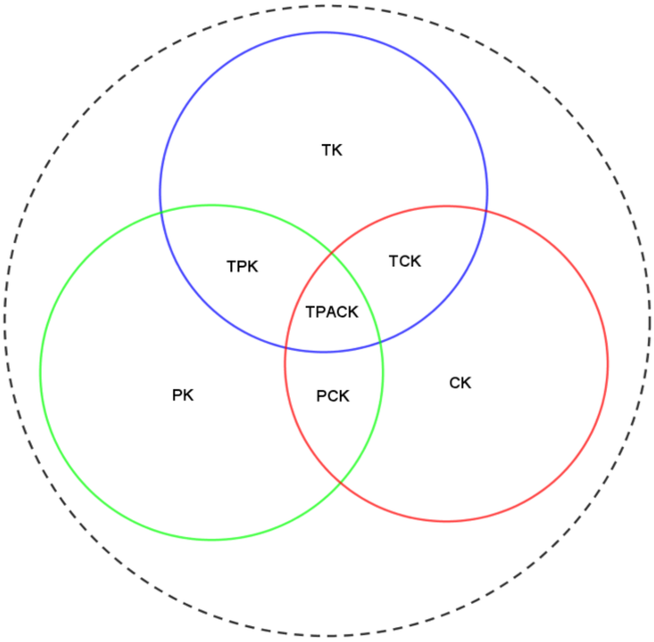

Figure 1. TPACK domains (Source: Koehler & Mishra, 2009, p. 63)

the teaching and learning of geometry. TPACK is knowledge about the use of various technologies for teaching, representing and facilitating knowledge generation of specific subject content (Chai et al., 2016). It is the use of technology in the planning, organization, critique and summarization of a topic, using 21st century technologies to support the teaching and learning of learners. For example, TPACK is the knowledge of how GeoGebra can be used as a manipulative tool to enhance geometry teaching and learning. In this study, TPACK framework focused on the development and assessment of teacher knowledge on the effectiveness of using GeoGebra in geometry teaching. In order for teachers to integrate technology use into their teaching and learning, it is essential that they develop their TPACK skills in a constructivist environment.

Constructivism Theory

Constructivist theory sought to describe how teachers should understand the way people think and process information. Constructivism assumes that knowledge is constructed by the learner and not transferred to the learner (Narayan et al., 2013). A study conducted by Miranda and Russell (2012) found that teachers who believed in learner-centered instruction are more likely to use technology. Constructivist pedagogy and educational technologies have been observed as having a connection that results in significant changes in teaching and learning. Ravitz et al. (2000) indicated that this connection often leads to collaborative learning environments as learners take more responsibility for their own learning. While TPACK has been defined as a teaching framework that guided this study and processes (Koehler & Mishra, 2008), constructivist theory has consistently emerged as the lens through which this study should be viewed.

Graham et al. (2012) claim that when in-service teachers are good at performing TPACK in the classroom, it means effective teaching and learning will take place. The theory of constructivism can be directly applied to classroom practice and learning. Therefore, constructivism is found consistently and prevalently in this study. At the heart of constructivism is the belief that people learn by building their own understanding and knowledge. It was anticipated that male and female in-service teachers participated in this study would gain understanding and knowledge through their personal experiences and by reflecting on those experiences. It would further appear that in-service teachers who made use of GeoGebra technology in a constructivist environment were likely to improve learners' performance through technology. Embedding TPACK in a constructivist environment can be described as what mathematics in-service teachers must know to effectively integrate and adopt GeoGebra as an ICT tool in the teaching of geometry. Several studies cited by White (2018) claim that teachers who take a constructivist approach to teaching and learning tend to use technology (Becker, 2000; Miranda & Russell, 2011). Learners actively engage in classrooms, where teachers focus on constructivist approaches to learning, as the instructional guide uses more interactive technology (Kimber & Wyatt-Smith, 2006).

RESEARCH METHODOLOGY

The population in this study included teachers from 12 randomly selected schools. A total of 22 teachers were purposely sampled of which 13 (59%) were male teachers and nine (41%) were female teachers. TPACK questionnaire had aspects related to the sociodemographic characteristics of the sample, the highest qualification, as well as gender (see **Table 1**). **Table 1** provides the summary of the characteristics of the participants involved in the study.

Table 1. Demographic profile of male & female secondary school teachers

Variables	Sub-division of variables	Frequency	
		Male	Female
Age (in years)	20-25	0	1
	26-29	7	0
	30-35	1	4
	36-39	4	1
	40+	0	3
Educational level	Diploma	0	2
	Bachelor	12	5
	Honors	1	1
	Master	0	1
Teaching experience (in years)	Less than 1	0	1
	1-5	5	2
	6-10	5	2
	11-15	3	2
	15+	0	2

The study involves majority of male teachers in the age of 26-29. The profile of participants shows that the majority of the respondents had bachelor's university degree. Out of 13 male teachers participated 12 were holders of bachelor's degree. The numbers of female teachers with a bachelor's degree were five out nine teachers. The numbers of teachers with teaching experiences at least one year were eight females and 13 males, respectively. All participants were teaching mathematics in secondary school at the time of the study.

This study employed the quantitative approach. This approach is capable of "describing current conditions, investigate relationships and study cause-effect phenomena" (Gay et al., 2006, p. 10). Quantitative research methods advocate for positivism and undergird with the belief that there is "an objective reality independent of any observations" (Rovai et al., 2014, p. 4). Quantitative research methods provide a structured approach to enquiry (Williams, 2011). Survey research method as a form of quantitative research focuses on people, the dynamic facts about people, and their beliefs, opinions, attitudes, motivations, and behaviors. The pre and post TPACK questionnaires were used to collect quantitative data. Participants were expected to register their knowledge of TPACK components before and after TPD training. The survey used Likert scale and consisted of five parts. These parts include participants' demographic data, TK, TCK, TPK, and TPACK. The constructs and number of items of TPACK questionnaire are shown in **Table 2**.

Participants were asked to indicate their agreement or disagreement with these statements on a Likert scale from (one) strongly disagree to (five) strongly agree. The questionnaire's main goal was to assess gender dynamics among in-service teachers' pedagogical and technological proficiency as well as their attitudes toward teaching of mathematics. A Cronbach's alpha reliability test method was conducted to test TPACK questionnaire. Cronbach's alpha of all items of TPACK component were at least good (see **Table 2**).

TPACK survey and the associated technological components' reliability in Cronbach's alpha (*a*) are presented in **Table 2**. Thus, Cronbach's alpha of TPACK instrument shows that the questionnaire was reliable. The face validity of TPACK questionnaire and training material was completed before the instruments were administered to the participants. They were evaluated by an expert who had knowledge of GeoGebra and its benefit in the teaching of mathematics. The expert checked whether the items in the instruments and training material were relevant; whether items were free from language bias; whether the language used was simple and not ambiguous. This was done to ensure that participants were developed to integrate GeoGebra using the correct content.

Table 2. Male & female TPACK mastery indicator

TPACK component	Exemplary indicator	Items	Alpha
TK	I possess technical know-how required to operate technology.	7	0.86
TCK	Technology has potential to drastically alter how male or female teachers perceive geometrical ideas.	6	0.97
TPK	I can choose appropriate information technologies to improve geometry teaching.	6	0.96
TPACK	I am capable of teaching lessons that effectively integrate GeoGebra technologies, teaching methods, & geometry.	6	0.89

Table 3. Mean score interpretation table

Mean range	Interpretation
4.3 to 5.0	Strongly agree
3.5 to 4.2	Agree
2.7 to 3.4	Neutral
1.9 to 2.6	Disagree
1.0 to 1.8	Strongly disagree

Data collected was typed into Microsoft Excel then all of the raw data has been transferred to SPSS and GeoGebra classic five for data analysis. The data obtained from TRACK questionnaires were analyzed and interpreted by using both inferential and descriptive statistics. Data analysis was conducted for the following variables: participants' TK, TCK, TPK, and TPACK. These variables were compared between males and females using descriptive statistics and t-tests. All the gathered data on TPACK questionnaires was coded by assigning participants codes such as Tr01 or Tr02.

Coding of participants' data collection instruments was done before the data were captured and analyzed in excel and GeoGebra classic five. The analysis was validated by at least one researcher. Mean (M), standard deviation (SD), and t-test are the statistical techniques used in this study. The inferential test such as the *t*-score test (difference of two means) was performed using GeoGebra classic five. The researcher made use of tables, histogram and bar graphs as graphical formats to represent the descriptive data. The researcher interpreted the calculated mean of each component of TPACK using the mean interpretation score interval in **Table 3** (Nunnary & Berstein, 1994). For instance, if TK mean of male teachers is 3.97, then it means the male participants generally agreed on the fact that they improved on TK.

FINDINGS

This section presents the descriptive and inferential statistical analysis. The following sections discuss the findings, which are broken into categories using the four-technology component of TPACK dimension. These categories include in-service teachers' TK, TCK, TPK, and TPACK.

In-Service Teachers' TK

In-service teachers' pre-TK before the intervention of integrating GeoGebra is shown in **Figure 2**. The findings

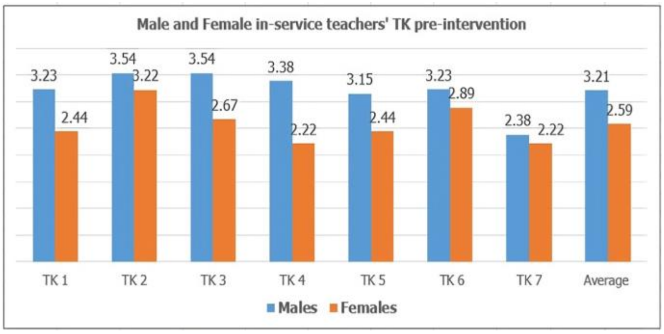

Figure 2. Male & female in-service teachers' TK pre-GeoGebra training (Source: Authors' own elaboration)

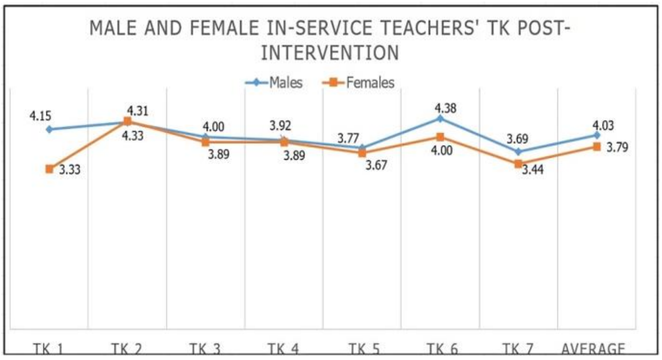

Figure 3. Male & female in-service teachers' TK after GeoGebra training (Source: Authors' own elaboration)

revealed that male teachers were better technologically aligned than their counterparts prior to the training. Male teachers recorded a significant difference in all the listed TK items with the biggest margin of 1.16 in TK4 ('I frequently play around with the GeoGebra'). Averaging all TK items, **Figure 2** show that male teachers' TK was 0.62 higher than their counterparts before training. The mean in **Figure 2** shows that female teachers generally disagree when measured against Likert scale (**Table 3**).

Figure 3 revealed almost the same trend of in-service teachers' TK post the training. Even though, female teachers improved their TK from a general *disagree* (M=2.59) prior to the training to a*n agree* (M=3.79) post the training, male teachers still dominated in all the aspects of TK. **Figure 3** shows TK1 ('I can fix any technical issues on my own') the highest margin of 0.82 in favor of male teachers. Overall, the mean of female teachers was 0.24 lower than of their counterparts. Nevertheless, it was interesting to note that both female and male teachers at least agreed (M for male=4.03; M

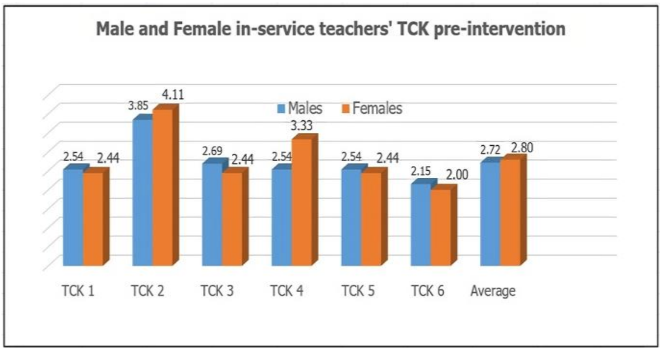

Figure 4. Male & female in-service teachers' TCK pre-GeoGebra training (Source: Authors' own elaboration)

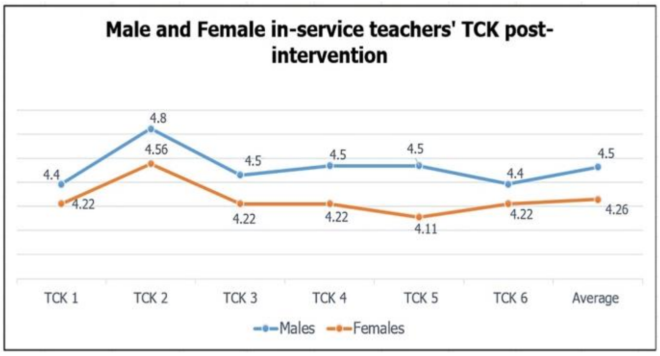

Figure 5. Male & female in-service teachers' TCK post GeoGebra training (Source: Authors' own elaboration)

for female=3.79) that their TK improved after the training of integrating GeoGebra (see **Table 3**).

In-Service Teachers' TCK

The mean of male and female teachers' TCK before the training on integrating GeoGebra in teaching of mathematics, is shown in **Figure 4**. The study measured TCK of teachers on 6 items and the mean was calculated. As seen in **Figure 4**, a significant difference was recorded in TCK2 ('using GeoGebra can significantly change how teachers and learners comprehend geometry ideas') and TCK4 ('I am aware of the technology that can be used to teach mathematics') in favor of females than male teachers. The mean of male and female teachers was 2.72 and 2.80, respectively. This means that female teachers' perception on TCK2, TCK4, and overall TCK were 0.08 higher than their counterparts before the training. According to mean ranges in **Table 3**, the mean results in **Figure 4** generally show that both male and female teachers felt *neutral* (M for male=2.72; M for female=2.80) about their TCK prior to the training. Even though the mean difference of 0.08 was not significant, **Figure 4** revealed that female teachers had a slightly higher TCK than male teachers.

Male teachers' TCK improved significantly after the training when compared to female teachers, as shown in **Figure 5**. In fact, male teachers felt positive and registered *strongly agree* in all items of TCK. The most positively rated TCK item was TCK2 ('using GeoGebra can significantly alter how teachers and learners comprehend geometry ideas') with a mean of 4.80. It was interesting to note that even though there existed a significant difference in favor of male teachers, **Figure 5** revealed that female teachers generally registered at an a*gree* in all TCK items. These items include 'I can demonstrate geometric subject information using the GeoGebra software tools' (TCK3) with a mean of 4.22, 'I am capable of representing geometry content using the appropriate technology '(TCK5) with a mean of 4.11, 'I am able to carry out geometric-related inquiry tasks using GeoGebra' (TCK6) with a mean of 4.22.

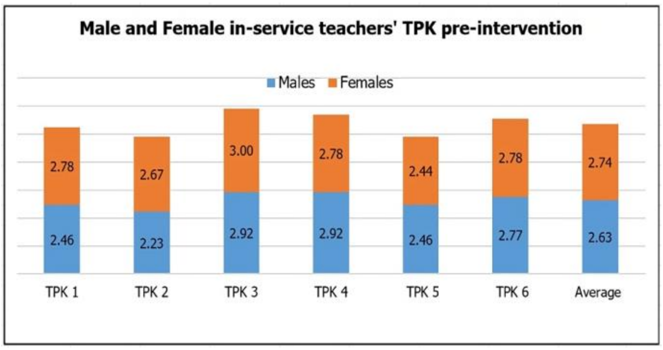

Figure 6. Male & female in-service teachers' TPK pre-GeoGebra training (Source: Authors' own elaboration)

In-Service Teachers' TPK

Male and female in-service teachers' TPK was assessed in six items. **Figure 6** shows the pre-intervention results of teachers' TPK with a significant difference. The differences are more marked in four out of six TPK items in favor of female teachers. These four items stated that 'I can choose appropriate information technologies to improve geometry teaching' (TKP1), 'I can use information technologies to enhance learners' enthusiasm for learning' (TPK2), 'I view the implementation of GeoGebra technology in the classroom critically' (TPK3), and 'I can utilize GeoGebra technology to improve classroom interaction' (TPK6).

Generally, teachers self-rated themselves as *neutral* (M for male=2.63; M for female=2.74) before the training according to mean interpretation (**Table 3**). The mean difference of TPK1, TPK2, TPK3, and TPK6 was 0.32, 0.44, 0.08, and 0.01, respectively. Overall, **Figure 6** revealed that female teachers had positive belief about their TPK before the intervention of integrating GeoGebra in mathematics teaching with a mean of 2.74, which was 0.11 more than their counterparts. The mean of female and male teachers was 2.74 and 2.63, respectively.

Post the intervention, TPK construct contained 6 items and the results are shown in **Figure 7**. The mean and standard deviation were computed on the data from male and female in-service teachers' TPK construct. The results revealed that all six of the issues received at least an *agreement* rating from both male and female teachers after intervention. Female teachers' least rated TPK item

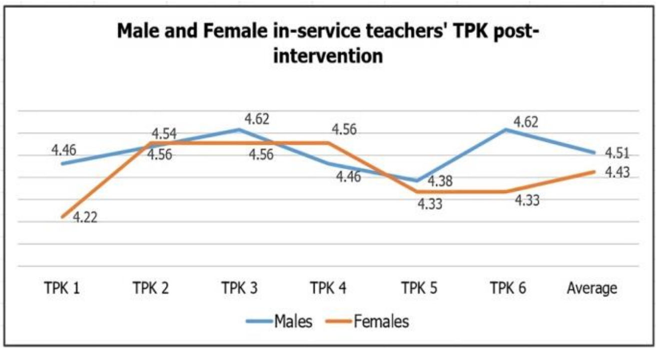

Figure 7. Male & female in-service teachers' TPK post-GeoGebra training (Source: Authors' own elaboration)

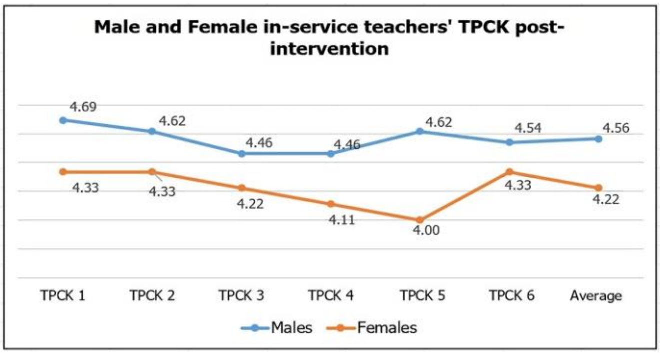

Figure 9. Male & female in-service teachers' TPCK post-GeoGebra training (Source: Authors' own elaboration)

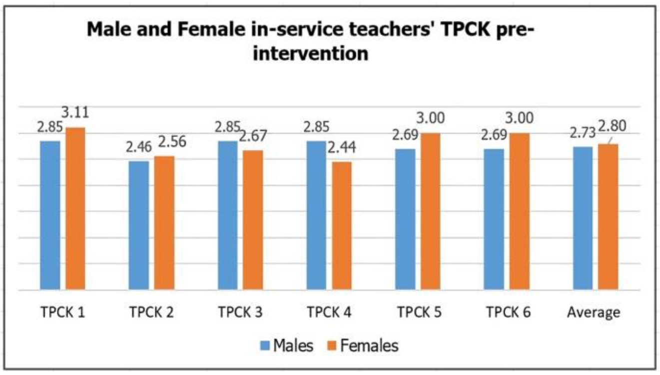

Figure 8. Male & female in-service teachers' TPACK pre-GeoGebra training (Source: Authors' own elaboration)

was TPK1 with a mean of 4.22, which stated, 'I can choose technologies to improve geometry teaching'.

Figure 7 further revealed that male teachers' least rated TPK item was TPK5 ('I am able to choose the best tools for teaching mathematics'). Male teachers' least rated item was 0.16 more than female teachers' least mean (M for male=4.38; M for female=4.22). Items such as 'I am capable of utilizing GeoGebra technology in a variety of teaching activities (TPK4)' recorded the mean of 4.56 by female teachers post the training. This record was 0.10 more than their counterparts.

Consequently, the mean for TPK post intervention results showed that male and female in-service teachers self-rated their TPK as *agreed* (see **Table 3**). Male and female mean was 4.51 and 4.43, respectively. Thus, a significant increase in teachers' TPK was observed in all the 6 items of the construct in both male and female teachers. Buttressing on participants' TPK, post-intervention results showed that male in-service teachers strongly (M=4.51) believe that training improved their skills in TPK with a significant gender difference of 0.08.

In-Service Teachers' TPACK

A statistically significant mean difference between in-service male and female teachers' TPACK pre-intervention is shown in **Figure 8**. The results showed that participants self-rated their TPACK as *neutral (maybe)* on all items before the training. The most significant gender difference in favor of female teachers was observed in TPCK1 ('integrating GeoGebra in teaching geometry content will be easy and straightforward for me'), TPCK2 ('I can teach lessons that appropriately combine subject content, GeoGebra technologies and teaching approaches'), TPCK5 ('technology choices I make can improve what I teach, how I teach it, and how students learn') and TPCK6 ('I can select digital tools that improve a lesson's content').

For instance, TPCK1 and TPCK6 had a mean gender difference of 0.26 and 0.31, respectively in favor of females. A significant mean difference in favor of males was recorded on items such as TPCK3 ('I am able to employ techniques that integrate the knowledge I have gained about GeoGebra with the topic') and TPCK4 ('I can serve as a leader in coordinating the utilization of content, GeoGebra, and teaching strategies'). TPCK3 and TPCK4 had a mean of 0.18 and 0.41, respectively registered in favor of male teachers more than female teachers. Pre-intervention results in **Figure 8** show that female teachers felt positive about their TPACK with a slight difference of 0.07 more than their counterparts (M for male=2.73; M for female=2.80). These results changed after the training with participants self-rating their TPACK as *strongly agree*, with a mean above 4.00 in all TPACK constructs in both males and females (see **Figure 9**). Thus, items such as TPCK1, TPCK2, and TPCK5 record the largest mean gender difference of 0.36, 0.29, and 0.62, respectively.

The least mean difference of 0.21 was reported in item TPCK6 ('I can select digital tools that improve a lesson's content'). Further analysis of results in **Figure 9** shows that there were notable changes in teachers' TPACK overall mean between male and female teachers (M for male=4.56; M for female=4.22). The difference was 0.34 in favor of male teachers signifying that they (males) felt highly positive about their TPACK more than their counterparts after the training.

A t-score test, difference of means to compare male and female in-service teachers' TPACK views, after the GeoGebra integration training was high statistically significant for all measuring items. Thus, the collective views (male: M=4.56, SD=0.09; female: M=4.22, SD=0.13,

Table 4. Male & female in-service teachers' TPACK post-GeoGebra training

	Mean	Standard deviation	n	Difference	t	Standard error	p	df
Female post-TPCK	4.22	0.13	6	0.34	5.2673	0.0645	0.0005	8.8976
Male post-TPCK	4.56	0.09	6					

p-value<0.01) also showed reasonable difference with standard error of 0.0645, which is within the acceptable range of between 4% and 8%. Participants' responses on TPACK showed that the intervention assisted in-service teachers with the understanding of technologies in geometry teaching. **Table 4** further showed a significant gender difference of 0.34 that signifies male dominance in TPACK acquisitions skills.

DISCUSSION

Males and females significantly rated the four TPACK dimensions differently, according to the results of the in-service teachers' survey. TPACK mastery of in-service teachers in this study fell above average with male teachers recording a higher mean average than female teachers in all the components of TPACK. Thus, the result in TK shows that male teachers' TK was higher than female teachers before and after the intervention (Ghavifekr & Rosdy, 2015; Ong & Lai, 2006).

Ghavifekr and Rosdy (2015), Palomares-Ruiz et al. (2020), and Tam et al. (2020) found that male teachers compared to their female counterparts have higher technology self-efficacy, perceived usefulness, perceived ease of use, and behavioral intention to use technologies. The findings of in-service teachers' TCK revealed a significant gender difference after the training. In fact, the mean of female teachers after the intervention was 0.34, which was lower than their male counterparts. The same trend was also observed in in-service teachers' TPK. Thus, the post technology integration development gender difference in teachers' TPK was 0.08 in favor of male teachers.

Zooming into TPK items, more male than female teachers had shown interest and confidence in wanting to integrate their teaching approach with GeoGebra. For instance, items such as 'I can select the best informational tools to enhance my teaching of geometry (TPK1), 'I can use information technology to increase learners' motivation to learn (TPK2) and 'I can utilize information technologies to improve classroom interaction (TPK6). The interest and confidence displayed by male teachers, concurred with White's (2018, p. 35) claim that "teachers decide when, what and how technology is used in the classroom, and in doing so they decide how learners reap the benefits of technology".

Overall, TPACK results revealed a significant gender difference of 0.34 in favor of male teachers. These findings in TPACK and its technology components are consistent with several related studies such as Ghavifekr and Rosdy (2015), Manyilizu and Gilbert (2015), Martín and González (2018), Ong and Lai (2006) and so on. The findings revealed that there is gender imbalance with TPACK, meaning that male teachers understood the use of educational technologies more than female teachers (Ayite et al., 2022; Manyilizu & Gilbert, 2015). The significant difference in all knowledge domain including TPACK shows that most in-service mathematics female teachers had not mastered TPACK as one of the strategies teachers can improve their technological skills and be able to integrate technologies in classrooms (Astuti et al., 2019). Thus, the current study identified significant gender differences in favor of male associated with TPACK mastery. This finding is corroborated in the studies done by Astuti et al. (2019), Ayite et al. (2022), Gil-Juárez et al. (2011), Gómez-Trigueros and Yáñez de Aldecoa (2021), Jimoyiannis and Komis (2007), Martín and González (2018), Ong and Lai (2006), and Orji (2010).

Regardless of a positive effect noted on female teachers' TPACK development, there exists significant gender difference in favor of male teachers. Female teachers have lower TPACK than male teachers and they have less confidence in using TPACK than males (Mahmood, 2012; Mumporeze & Prieler, 2017).

The male teachers' TPACK mean score of in-service mathematics teachers is 0.3217 more than female with p-value of 0.0005. This gender difference and high significant statistic shows that male in-service mathematics teachers benefited from the training more that female teachers. Male teachers understood TPACK teaching model and are likely to adopt and integrate in their teaching. This finding concurs with the claim made by Palomares-Ruiz et al. (2021).

Palomares-Ruiz et al. (2021) claim that men's ability to acquire digital skills is higher that of women. The current study's findings are contrary to studies done by Espinar and González (2009), Ortega Sánchez and Gómez Trigueros (2019), Sáinz and López-Sáez (2010), and Scherer and Siddiq (2015). These studies found no significant differences in male and female teachers' TPACK.

While most of the results presented in this study are consistent with the literature, it could be argued that this study has also expanded the existing literature on gender dynamics research and TPACK instructional technologies. Despite the positive impact that TPACK integration competencies of male and female teachers have shown through professional development, it could be argued that the researchers could not find much literature on gender differences of in-service geometry teachers on TPACK instructional technologies training. Instead, most studies conducted in South Africa and beyond, seem to focus more on the general impact of ICT improving the performance of the learners and the learning environment (Atika et al., 2022).

Additionally, numerous studies have focused on the performance of prospective teachers and learners using GeoGebra (Chalaune & Subedi, 2020; Stapf & Martin, 2019). Therefore, only limited literature was found on gender differences in terms of TPACK use and skills for the education domain. Therefore, this study makes an important contribution to the existing body of knowledge about the imbalance of male and female mathematics teachers in the field of teaching geometry with technologies. The study also covers the research gap by providing a review of educational technology gender differences with a focus on use and skills for the education fraternity.

CONCLUSIONS

Teachers' level of success of using educational technologies teaching and learning can be seen in TPACK (Gómez-Trigueros & Yáñez de Aldecoa, 2021). The mastering of TK, TCK, TPK, and TPACK gives teachers potential to confidently use educational technologies (Astuti et al., 2019). According to the findings and discussion of this study, the researchers reject the null hypothesis that there is no significant gender difference between male and female in-service teachers' TK, TCK, TPK, and TPACK. The study's finding revealed that there is significant gender difference between male and female in-service mathematics teachers' TK, TCK, TPK, and TPACK. Therefore, the researchers accepted the alternative hypothesis. The findings of the post intervention showed that female in-service teachers have low TK, TCK, TPK, and TPACK in comparison to their male counterparts. This knowledge provides curriculum managers, officials responsible for teacher development and school managers to set guidelines for technology integration training programs for in-service teachers. The study will also assist the department of basic education to promote gender equality in educational technologies usage. Out several mathematics topics in secondary school curriculum, this study considered one topic, which was Euclidean geometry. This is the topic that informed the content (C) in TPACK framework of this study. A significant number of teaching application or software exist in mathematics education. However, the scope of this study was limited to the use of GeoGebra in the teaching and learning of Euclidean geometry, which informed the technology (T). The study considered and adopted the constructivism theory. This is because constructivist approach is learner-centered driven. Therefore, during the training, in-service teachers were expected to be hands-on and experience the use GeoGebra as a tool to teach geometry. The constructivist approach became the pedagogy (P) that the study adopted. The interaction of content topic (C), integration of GeoGebra(T) and the adoption of learner-centered approach (P) made up the content knowledge (CK), technological knowledge (TK) and pedagogical knowledge (PK), respectively. Administering TPACK questionnaires only could have limited participants in expressing themselves fully. Further, standardized wording of TPACK questionnaire items could have constrained and limited participants' naturalness and relevance of questions and answers. The researchers recommend that curriculum planners and subject specialists encourage and motivate female teachers to participate in technology integration workshops to maintain balance in gender equality. The researchers found that the theory of constructivism is consistent and predominant with TPACK framework. At the heart of TPACK framework are therefore the principles of constructivist educational theory. The study focused on only gender dynamics of integrating GeoGebra in in-service mathematics teachers. It will be interesting if future researchers can measure the impact of TPACK framework by researching on learners' perceptions of educational technologies such GeoGebra integration in geometry learning, learner attainment and gender differences. Future researchers can research on the impact of TPACK teaching model on in-service teachers' age and their teaching experiences paying particular attention to gender dynamics.

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Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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