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In-service mathematics teachers' perceptions of GeoGebra integrative training materials: The case of geometry teaching

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Abstract

The further education and training phase curriculum and assessment policy statement of South Africa expects mathematics teachers to integrate educational technologies into their teaching. However, the importance of technology integration and adoption has not been fully implemented in schools. In-service mathematics teachers' perceptions of GeoGebra integrative training materials and their impact on the artefacts of teachers' professional development were explored in this study. The study adopted two adult learning theories, namely andragogy and transformational learning. These theories were integrated into Ahmed et al.'s (2021) in-service training framework. A mixed-methods methodology was employed by purposively sampling 29 mathematics secondary teachers from twelve randomly selected schools in the OR Tambo Inland District of Eastern Cape Province in South Africa. Data were collected by using a questionnaire with four open-ended and seven closed-ended questions. The questionnaire was administered at the end of professional teacher development training for mathematics teachers. The researchers used descriptive, inferential statistics and thematic approaches to analyze and interpret the results. The findings revealed that in-service mathematics teachers highly rated the GeoGebra integrative training materials. The participants positively felt that the training materials ushered interest in teaching geometry with confidence. They felt highly motivated and showed interest in disseminating information to other colleagues. The study also revealed improved in-service teachers' professional skills. These skills included improved technological, pedagogical, communication, collaboration and content skills.

Keywords: GeoGebra, integrative training material, in-service mathematics teachers, technology integration, technology adaptation

INTRODUCTION

Pre-service teacher training, induction phase and in-service teacher training are three distinct and closely interrelated consecutive stages in teacher education. Pre-service teacher education program is meant to prepare students for the teaching profession. The induction phase of teaching is designed to make newly appointed teachers familiar with the practices and activities of the institution where they are appointed. It is the preparation required to equip a new member of staff for the duties and responsibilities of his/her specific initial assignment. In-service teacher education also known as teacher professional development (TPD) is defined as "a systematic method of improving teachers' beliefs and practices, knowledge, and motivation for better students' learning outcomes" (Ahmed et al., 2021, p. 20). Teacher education significantly impacts in-service teachers' beliefs and practices, educational reforms, and students' learning (Villegas-Reimers, 2003). The in-service TPD program is meant for teachers who are already practicing for their professional growth and development so that they can discharge their duties and responsibilities more effectively. It is meant to improve teachers' professional knowledge, skills and attitudes so that they can educate children more effectively. TPD is

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Contribution to the literature

- In-service mathematics teachers highly rated the GeoGebra integrative training materials.
- The results have proved that the training materials positively changed the way teachers perceive the teaching of geometry.
- The study recommends policy implementation and support of the use of educational technologies in mathematics teaching and learning. The development of technology-integrative training materials in other mathematics topics is recommended for practice.

the key to the success and improvement of the education system (Dreer et al., 2017). Thus, it is necessary to study the impact of in-service teacher training on teachers' competency and classroom transactions.

There are major changes that the education fraternity has gone through, wherein the use of knowledge by in-service teachers gained many years ago may not be relevant in recent conditions. These changes include but are not limited to curriculum changes, pedagogical and content knowledge. It is important to renew teachers' in-service teachers' knowledge by proving them opportunities, through TPD, to learn, re-learn and un-learn. Lack of in-service TPD causes insufficient professional development of teachers. In fact, inadequate in-service teacher training reduces the gap between demand and actual success levels. For instance, the Congress of the United States (1995, p. 3) stated that the "majority of teachers report feeling inadequately trained to use technology resources, particularly computer-based technologies". In this context, Saleem and Zamir (2016) stated that in-service teachers' training is one of the basic elements for the professional development of teachers. Also, in-service teacher training brings about teacher quality, which is in line with current developments and meets the needs of the current generation. This is because teachers keep themselves up to date with the demands of their field or subject matter. Therefore, such new educational development necessitates the need for in-service teacher education. In-service teachers are introduced to modern and advanced teaching strategies to improve the quality of teaching approaches. This allows them to incorporate innovative teaching methods into the classroom and encourages them to embrace new methods. In-service teacher training can vary from conference formats, staff meetings, or workshop formats. In this study, in-service mathematics teachers were introduced and trained to integrate GeoGebra into geometry teaching through workshops at the school level. Workshops that embed demonstration lessons can allow teachers to learn new skills and showcase instructional approaches. Different strategies to integrate GeoGebra into teaching geometry processes were incorporated. These strategies included preparing teaching materials, presenting and assessing geometry content. This study sought to assess in-service mathematics teachers' perceptions of GeoGebra training materials used during teachers' professional development of geometry teaching.

Problem Statement

In-service mathematics teachers were found to experience difficulties in geometry teaching. The first author realized that in-service teachers do not have good content, pedagogical and technological knowledge in geometry. A lack of pedagogical technological content knowledge might cause teachers to skip content or dwell on conventional teaching approaches. The reasons for poor performance in geometry include teachers' poor to inadequate teaching methods (Chiwiye, 2013). Furthermore, poor teaching approaches in geometry emanate from inadequate teacher vocational training. For instance, Uztosun (2017) highlighted problems related to in-service teacher training. These problems range from deficiencies in teaching training practice, teaching environment and teaching activities (Şahin & Akıncı, 2020; Uztosun, 2017). Observations by the first author included how in-service mathematics teachers failed to adapt to the needs of the time in classroom teaching. Teachers ought to remain relevant in modern-day geometry teaching by adopting educational technologies because these tools enhance engagement, improve understanding and prepare students for a technology-driven world. In order to supplement the traditional instruction in geometry and to bring motivation on the part of learners, the use of technology is encouraged (Adelabu et al., 2019). Educational technologies, like GeoGebra, help students visualize these geometry concepts interactively. GeoGebra allows students to manipulate shapes dynamically, providing real-time feedback as they change parameters. Research indicates that adaptive systems improve learning outcomes by allowing learners to progress based on mastery rather than one-size-fits-all instruction (Robinson & Sebba, 2010).

Generally, in-service teachers appreciate the benefits of educational technologies. However, they find integration of educational technologies challenging. In fact, many in-service teachers grew up without access to technologies like the personal computer and the internet, but learners today are raised in an environment saturated by computer technology. Hence, Moursund and Bielefeldt (1999) assert that in-service teachers grapple with poor to no professional development on

technology integration into their pedagogical practice. Agyei and Benning (2015, p. 15) highlight reasons such as "lack of knowledge about ways to integrate information and communication technologies (ICT) in lesson, lack of training opportunities for ICT integration knowledge acquisition and lack of application software that they can use in mathematics lessons." The need to adapt to changing times includes the fact that the current generation of learners are digital natives. They learn and understand better if concepts are presented using technology. Technology use can intimidate teachers, especially when teachers have little or no technological experience. Some observed teachers show no knowledge or necessary competencies in using technology.

Training in-service teachers in geometry teaching by adopting educational technologies is a key step in equipping them with methods and modern tools geared to improve learner engagement and understanding. By training in-service teachers to integrate educational technologies, they can enhance learner interaction with dynamic and visual tools (Mishra & Koehler, 2006). Teachers can learn to incorporate these tools through targeted training (Cheong et al., 2013). Dynamic geometry software, such as GeoGebra, allows teachers to create interactive lessons. Therefore, this study aimed to explore how in-service mathematics teachers perceived GeoGebra integrative training materials designed to teach geometry in secondary schools. It is hoped that the technology-integrative training materials may positively impact in-service mathematics teachers' professional growth and prepare them to teach geometry effectively. The following research question guided this study: What are in-service mathematics teachers' perceptions of the influence of GeoGebra integrative training materials towards the teacher's professional development and geometry teaching?

LITERATURE REVIEW

In-service teacher training has become necessary as a result of various needs. The necessity of TPD is mainly due to difficulties experienced by in-service teachers in meeting the needs of the rapidly changing society. These difficulties include inadequate pre-service training (Sönmez, 2008), innovations brought by time (Şahin & Akıncı, 2020), motivation obligation (Murano et al., 2019). For instance, the reasons for poor performance in mathematics are "a lack of learning support, principal teachers' dissatisfaction with the in-career training of teachers in mathematics; and learners taught by teachers who have not participated in career professional development" (Mabena et al., 2021, p. 453). Inadequate pre-service training results from vocational education provided before starting a profession. It may have been inadequate due to poor student selection and mistakes in teaching activities carried out afterwards (Sönmez, 2008). Motivation is a force that controls or directs people's behavior (Weiner, 2012). In this study, teacher motivation is anything that attracts an individual to teach, stay in teaching profession, and find new and interesting ways to teach the students (Taylor & Cranton, 2012). It also refers to social and emotional competences pre-service teachers gained during vocational education (Murano et al., 2019). Effective pre-service teacher training yields positive acquisition of social and emotional competencies (Murano et al., 2019). Otherwise, in-service training has positive effects on attitudes and participants' practices (Nawab, 2017). It is an issue that the education spectrum needs to address how in-service teachers will keep up with the developments in the context of education (Şahin & Akıncı, 2020).

In-service teacher training is a series of activities arranged to engage teachers to enhance their knowledge, raise their skills, and broaden their professional approaches (Ahmed et al., 2021, p. 18). These training courses focus on developing changes in teachers' pedagogical knowledge, content knowledge and technological knowledge. Satisfaction, motivation, professional growth and improved knowledge domain of in-service teachers become the indicators for a good teacher education. For instance, teacher's satisfaction and motivation can directly influence the process of learning (Ahmed et al., 2021). According to Gorozidis and Papaioannou (2014), in-service teacher training programs that focuses on subject and/or technology mattery results in teacher motivation and improved teacher practice. In-service teacher training is rare at university level, for instance in Pakistan, it is common at either school level or district level or provincial level (Ahmed et al., 2021). During in-service teacher training programs, teachers upgrade their knowledge and interest of the subject (Osamwonyi, 2016). The experience teachers acquire during in-service training contributes towards an individual being more competent and satisfied in their roles as teachers (Omar, 2014). Hence, Junejo et al. (2017) pointed out that teacher education be provided to the in-service teachers on a regular basis which accumulates an ongoing investment on teachers to develop their skills. Also, in-service teachers are introduced to modern and advanced teaching strategies to improve the quality of teaching approaches. This allows them to incorporate innovative teaching methods into the classroom and encourages them to embrace new methods.

Ahmed et al. (2021) cited Fisher (2013) argues that it is important that in-service teachers learn to teach new skills because they will not be able to deal with 21st generation that is learning more outside the classroom. In-service teachers should be exposed to ongoing teacher education to learn the new pedagogic ways, innovations and emerging trends in teaching (Ahmed et al., 2021). In-service teachers should implement new skills in their own classrooms (Ahmed et al. 2021; Ramatlapana, 2009). Borg (2011) indicated that improved teachers'

competencies, positive beliefs, positive perceptions and good attitudes towards teacher profession are considered indicators of effective in-service teacher training. These indicators proves that in-service training is an important element of teacher education system (Borg, 2011). For instance. in-service teacher training in Turkey shows that the teachers' perspectives towards in-service training are positive in Turkey (Babacan & Özey, 2019). A study conducted in Pakistan by Nawab (2017) concluded that in-service teacher training has a positive impact on the attitude of the trainee teacher. In Uganda, Nzarirwehi and Atuhumuze (2019) carried out a study on teacher education. The study revealed that in-service teacher training has a positive influence on teacher knowledge, performance, motivation and professionalism (Nzarirwehi & Atuhumuze, 2019). In the South African context, teachers play a significant role in learners' school performance (Cascio, 2013). In the same study, Cascio (2013) attests that learners might not be able to develop a comprehensive understanding of the subject material if in-service teachers lack adequate training and are not passionate about learning about teaching. Furthermore, Omar (2014) claims that in-service teacher training impact positively on teachers' classroom performance. However, other related such as Babacan and Özey (2019), Öztürk and Öztürk (2019), and Katman and Tutkun (2015) pointed out that some of in-service training needs were not adequately met.

One the other hand, Jelatu et al. (2018) note that the use GeoGebra in geometry teaching afford teachers the opportunity to develop professionally. Geometry can be supported by technology, and use of dynamic tools like GeoGebra is useful. Zakaria and Lee (2012) observe that teachers reported that GeoGebra software can generate dynamic geometric objects or figures. Teachers also commented on the ability of GeoGebra to allow learners to visualize mathematical concepts being taught. Mokotjo and Mokhele-Makgalwa (2021, p. 79) concluded that "teachers are enthusiastic in applying GeoGebra as they believed that it was valuable in teaching mathematics to South African high school learners". Mokotjo and Mokhele-Makgalwa's (2021) observation enjoyed the support of Ekpoh et al. (2013) who revealed that there is a difference in teachers who get in-service teacher training and those who do not. These differences are found in teaching methodology, subject knowledge, and evaluation techniques (Ekpoh et al., 2013).

THEORETICAL FRAMEWORK

This study adopted two adult learning theories namely andragogy and transformational learning (TL). The adult learning theories provide insight into how adults learn (Teaching Excellence in Adult Literacy [TEAL], 2011). Andragogy is the art and science of helping adults learn as opposed to the concept of pedagogy, the art and science of helping children learn (Knowles, 1980, p. 43). TL is the "learning that changes the way individuals think about themselves and their world, and that involves a shift of consciousness" (TEAL, 2011, p. 2). Andragogy and transformational adult learning theories are founded on the principles that effective in-service teacher training is relevant, engaged, active and learner-centered.

Andragogy and TL theories are unknown to provide a basic theoretical framework for training activities (Ahmed et al., 2021). Furthermore, andragogy and TL theories can help teachers be more effective in their practice and more responsive to the needs of the learners they serve (TEAL, 2011). Hence, in the context of teacher training, a theory of adult learning, such as andragogy, is usually considered instead of pedagogy, which is a theory of child learning (Ahmed et al., 2021). In-service mathematics teachers were selected with the andragogy assumptions in mind. These assumptions include that teachers are adult learners who are self-directed, they bring substantial prior experience to the learning, they became ready to learn when they experience a need, they are adults who are problem-centered and interested in immediate application of knowledge, and self-motivated in their learning specifically when the learning is relevant to their goals and personal needs (Zhang & Zheng, 2014). Furthermore, the conditions that help adults to learn as per Smylie's (1997) prescription were adequately met in this study. These conditions included a thorough process of learning from and with the other colleagues, collaboration during the working and learning and opportunities to learn from teachers who had experience of integrating technology in teaching, freedom to share challenges or good practice experienced during the training. Also, the afore-mentioned conditions acted as a catalysts form andragogy to TL. TL theory has brought changes into in-service teachers.

Really, the teacher has made an intentional effort to get the understanding of integrating GeoGebra from their experience of teaching geometry (Holliday & Brennan, 2021). Considering that in-service teacher training is an independent variable, this study finds its influence on changes (dependent variables) in-service teachers could portal after the training (see **Figure 1**). TL gave in-service teachers the opportunity to develop a sense to create change in themselves (Ahmed et al., 2021). These dependent variables included but were not limited to positive influence on teachers' pedagogical, content and technological knowledge, improved teacher classroom performance, highly motivated and desirable professionalism such as good communication skills (Ahmed et al., 2021; Nzarirwehi & Atuhumuze, 2019).

METHODOLOGY

This study adopted mixed method research with more emphasis on qualitative approach. The mixed

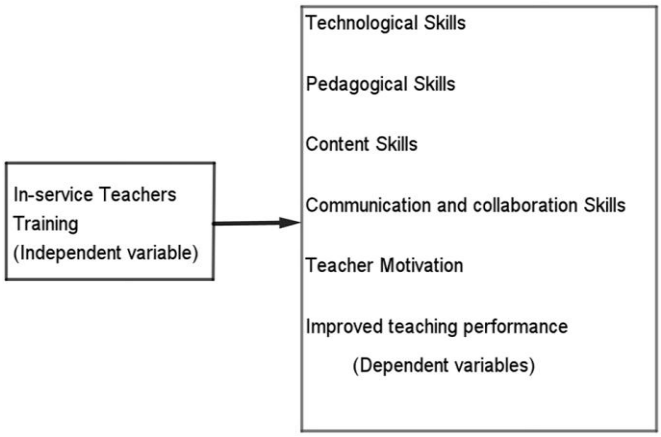

Figure 1. In-service teacher training framework (Ahmed et al., 2021)

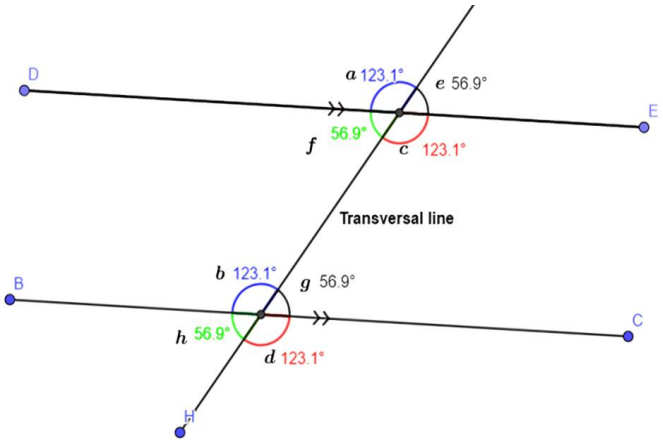

Figure 2. A snapshot of related angles measured on GeoGebra platform (Source: Authors' own elaboration)

method approach intended to describe in-service mathematics teachers' perception of GeoGebra integrative training material after a series of professional development training. The research was conducted by administering a questionnaire to in-service teachers after GeoGebra training. The questionnaire consisted of both open and closed end questions to gather qualitative and quantitative data, respectively. There were 29 in-service mathematics teachers who attended the training on using GeoGebra as dynamic geometry software. There were 11 questions relating to teachers' perception of GeoGebra integrative training materials on geometry teaching. Out of the 11 questions, 7 questions were used to collect quantitative data and 4 questions employed to gather qualitative data.

Nature of GeoGebra Integrative Training Materials

In this study, a significant number of training sessions were carried out on in-service trainings for mathematics teachers. The GeoGebra integrative training materials included geometry concepts such as lines and angles, perpendicular bisector, angle at the center, angles subtended by same chord or arc, angles in cyclic quadrilaterals and tangent-chord theorem.

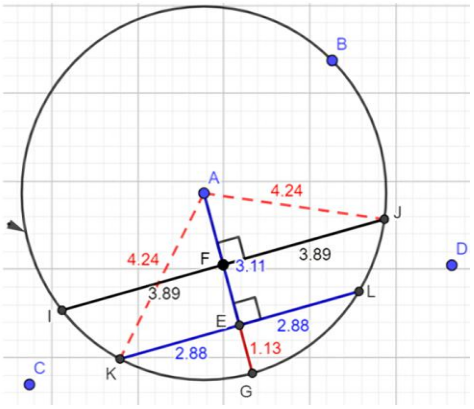

Figure 3. Snapshot of the results of perpendicular bisector theorem application using GeoGebra (Source: Authors' own elaboration)

Briefly explained, the first GeoGebra integrative training materials introduced participants to the use of GeoGebra in the teaching of lines and their related angles. The objectives of this training material were to use GeoGebra to draw and demonstrate the concept of parallel lines, perpendicular lines, intersecting lines and different types of angles that are formed. During this session, participants were equipped with the skills of how lines and angles are constructed and demonstrated on the GeoGebra platform (see **Figure 2**).

The second session included GeoGebra integrative training material that focused on the use of GeoGebra to prove and apply perpendicular bisector of circle geometry. The theorem states that the line drawn from the center of a circle perpendicular to a chord bisects the chord. The aim of the theorem was to prove that KE = EL given the circle BJI with center A in **Figure 3**.

The third in-service training session focused on exposing participants to GeoGebra integrative training materials that can assist them in proving and applying the angle at the center theorem of circle geometry. The theorem states that the angle subtended by an arc at the center of a circle is double the size of the angle subtended by the same arc at the circle (on the same side of the chord as the center). The aim of the angle at the center theorem was to make use of the GeoGebra integrative material to prove that DAF = 2DEF, given circle A with DEF and DAF as inscribed and central angles, respectively (see **Figure 4**).

The angles subtended by the same chord (ach) formed part of session four of GeoGebra integrative training materials. The material focused on equipping teachers on how to use GeoGebra to teach angles subtended by a chord theorem of circle geometry. The theorem states that angles subtended by a chord (or arc) of the circle on the same side of the chord (or arc) are equal. The aim of the theorem was to use GeoGebra integrative training materials to prove that $D\hat{C}E = D\hat{F}E$ given circle O with inscribed angles $D\hat{C}E$ and $D\hat{F}E$ on the same side of chord DE (see **Figure 5**).

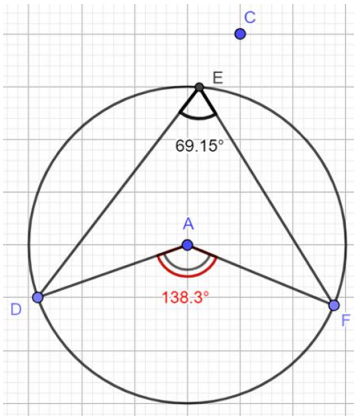

Figure 4. A snapshot of the results of GeoGebra application of angle at center theorem (Source: Authors' own elaboration)

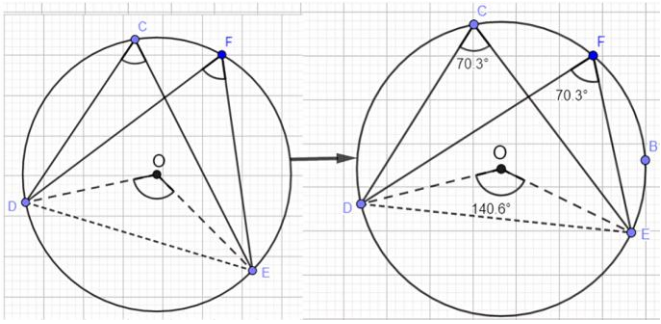

Figure 5. A snapshot of GeoGebra application of angles subtended by a chord theorem (Source: Authors' own elaboration)

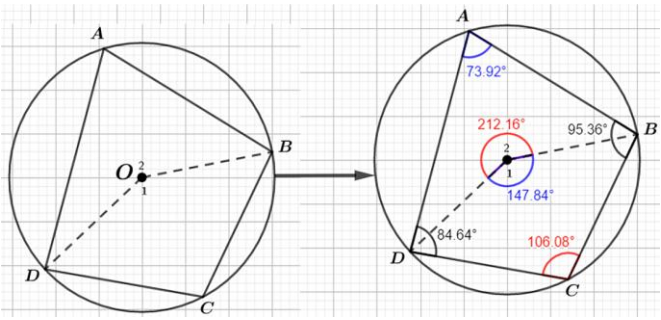

Figure 6. A snapshot proof of opposite angles of cyclic quadrilateral theorem (Source: Authors' own elaboration)

The fifth part of GeoGebra integrative training materials provided teachers with the skills on how to use GeoGebra integrative training materials to teach and apply the cyclic quadrilateral theorem. The theorem states that the opposite angles of a cyclic quadrilateral are supplementary, that is, opposite angles add up to 180°. The theorem aims to prove that $\hat{A} + \hat{C} = 180°$ or $\hat{B} + \hat{D} = 180°$ given any circle with center O and cyclic quadrilateral ABCD (**Figure 6**).

The angle at the center theorem played a crucial role in proving the cyclic quadrilateral theorem. For instance, in proving the theorem, participants were expected to use GeoGebra to construct lines DO and BO and measure angles. The results were such that $\hat{O}_1 = 2\hat{A}$ (central angle = twice inscribed angle), $\hat{O}_2 = 2\hat{C}$ (central angle = twice inscribed angle), $\hat{O}_1 + \hat{O}_2 = 2\hat{A} + 2\hat{C} = 360°$ (angle around a point), then $\hat{A} + \hat{C} = 180°$. But $(\hat{A} + \hat{C}) + (\hat{B} + \hat{D}) = 360°$ (angles of a quadrilateral). In sum, $\hat{B} + \hat{D} = 180°$ ($\hat{A} + \hat{C} = 180°$).

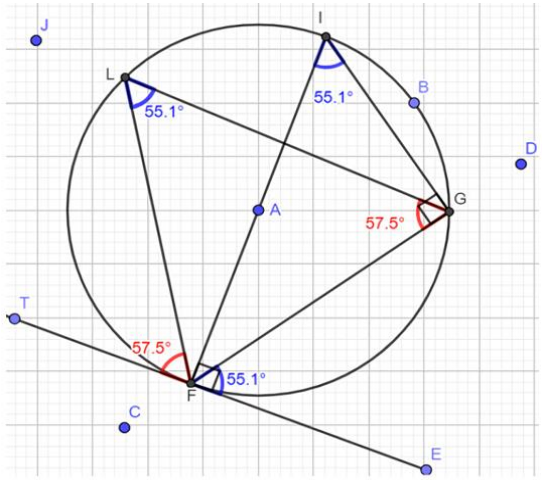

Figure 7. A snapshot of tan-chord theorem application on GeoGebra platform (Source: Authors' own elaboration)

Training session six provided teachers with GeoGebra integrative training materials that equipped them with the use of GeoGebra to demonstrate the theorem, which states that tangents drawn to a circle from the same point outside the circle are equal in length. The last session of GeoGebra integrative training materials focused on the tangent-chord theorem of circle geometry. This theorem states that the angle between the tangent to a circle and the chord drawn from the point of contact is equal to the angle in the alternate segment. The aim of training session was to use GeoGebra integrative training materials to show that $G\hat{F}E = \hat{L}$ and $L\hat{F}T = \hat{G}$ by constructing diameter IF and chord GI (see **Figure 7**).

Data Collection

The data for the study were collected using a questionnaire. The questionnaire contained questions related to GeoGebra integrative training materials. It was designed to measure and assess in-service teachers' perceptions of GeoGebra integrative training materials. The questionnaire collected both qualitative and quantitative data. There are eleven questions that explore in-service mathematics teachers' perceptions of the GeoGebra integrative training materials. A total of seven questions were used to collect quantitative data while four questions were employed to gather qualitative data (see **Appendix A**). The item description of the eleven questions is shown in **Appendix A**. Likert rating scales were used in the questionnaire to collect quantitative data. Participants registered their extent of agreement or disagreement with participants' responses to questionnaires. A five-point Likert-type rating scale was adopted ranging from strongly agree, agree, neutral,

Table 1. Mean score interpretation table (Nunnary & Berstein, 1994)

Mean scale	Mean 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

disagree, and strongly disagree interpreted numerically as 5, 4, 3, 2, and 1, respectively. The open-ended questions were used to collect qualitative data.

Data Analysis

The study used both quantitative and qualitative data analysis as data was derived from primary data. Analysis of data gathered using a questionnaire assisted in making decisions about the findings of the study. Thus, for closed-ended questions of the questionnaire, descriptive statistics such as mean, standard deviation and graphs will be used. The researchers made use table of mean score interpretation inverted by Nunnary and Berstein (1994) (see **Table 1**). The mean score was then used to make informed decisions about the mean calculated from the quantitative data. For instance, the mean of item 3 (*training material is essential for in-service mathematics teachers teaching geometry*) is 4.75, then it means the participants *at least agreed* on the fact that the training material is essential for in-service mathematics teachers teaching geometry.

The study made use of percentages in some instances to represent the number of participants and/or the number of responses (Setyawan et al., 2018). It is worth noting that, given the smaller sample size for this study, the use of percentages to represent the number of participants and/or the number of responses in no way implies generalizability to the entire population. Furthermore, inferential statistics, the t-test and the z-score test of independence were calculated with SPSS and/or GeoGebra classic 5. Collected qualitative data was categorized into themes to understand the meanings from the perspectives of the participants. The researcher categorized and then generalized themes using a process called thematic analysis. Thematic analysis was used to identify themes and patterns.

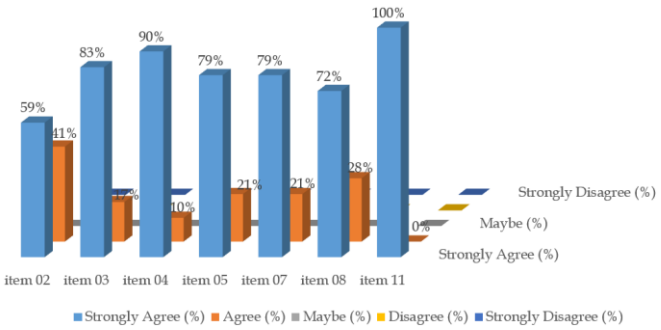

Figure 8. GeoGebra integrative training material evaluation results (Source: Authors' own elaboration)

FINDINGS

Quantitative Results

Out of 29 in-service teachers who attended the professional development training, at least 41% agreed that they now knew how to use GeoGebra integrative training material to teach the theorems they have learnt during the training (see **Figure 8**). None of them disagreed or felt negatively about GeoGebra integrative training materials for geometry teaching (item 02). Further, **Table 2** shows highly statistically significant results t (29) = 50.445; standard error [SE] = 0.091; $p < 0.1$) with mean and standard deviation of 4.59 and 0.49, respectively. The average mean of 4.49 shows that participants generally strongly agreed that engaging GeoGebra integrative training materials will make it easy to integrate GeoGebra when teaching geometry. Item numbered 02 shows that 29 (100%) of in-service teachers at least agree that the training was important as mathematics teachers teaching geometry. In light of that, more than 90% of the participants registered at least an

Table 2. GeoGebra integrative training material evaluation results (N = 29, df= 28, & p= 0.000)

Item description	M	SD	SE	T
Rate your understanding of the training material used to train mathematics in-service teachers	4.59	0.49	0.091	50.445
Training material is essential for in-service mathematics teachers teaching geometry in secondary school	4.83	0.38	0.071	68.448
Based on the quality and relevance of the training material, are you likely to attend the other technology integration training courses?	4.90	0.30	0.056	87.958
After your engagement with the training material, you will disseminate your newly acquired knowledge to other colleagues.	4.79	0.41	0.076	62.915
After your engagement with the training material, are you likely to integrate GeoGebra when teaching geometry.	4.79	0.41	0.076	62.915
After your engagement with the training material, do you feel confident using GeoGebra when teaching geometry.	4.72	0.45	0.084	56.484
Rate the instructor/facilitator's expertise on the use of GeoGebra training material as a tool for geometry teaching.	5.00	0.00	0.000	∞

Note. M: Mean & SD: Standard deviation

agreement (item 03) showing their interest in attending other planned technology integration training.

Table 2 revealed that the items coded item 03 and item 04 were both statistically significant with t-test results t (29) > 60; 4% < SE < 8%; p < 0.1). This means that the t-test of item coded item 03 and item 04 with a sample space of 29 participants is 87.958 and 62.915, respectively. The standard deviation errors of 0.056 and 0.076 are within the acceptable range (between 4% and 8%). The p-values (p less than 0.1) of item 03 and item 04 are highly significant because they fall within the 95% significant level. The mean intelligent quotient score of item 03 and item 04 of the targeted teachers in the district is between 96.656 and 106.422. Statements coded item 03 and item 04 both showed means above 4.50 indicating that participants strongly agreed to statements under study. None (0%) of the in-service teachers disagreed with the call for disseminating knowledge to other mathematics teachers about integrating GeoGebra in teaching geometry after being exposed to GeoGebra integrative training materials (item 07). The aforementioned statement revealed results that are highly statistically significant, with an acceptable margin of standard mean error and t-value of 7.8% and 62.951, respectively. Its mean of 4.79 indicated that in-service teachers at least agreed to share their skills with other mathematics teachers.

Figure 8 further shows that 72% of the participants strongly agreed to feel confident using GeoGebra while teaching geometric concepts, with 28% registering agreeing and none indicating otherwise (item 08). Generally, the participants 'strongly agreed', with an average mean and standard deviation of 4.72 and 0.45, respectively. Coupled with this descriptive analysis is the highly statistically significant item that in-service teachers feel confident about the use of GeoGebra when teaching geometry. There is greater evidence that results are significant with t (29) = 56.484; SE = 0.084; p < 0.01. It was interesting to note that 29 (100%) of the participants found the facilitator knowledgeable about the use of GeoGebra as an integrative tool to train teachers to teach geometry (item 11). Furthermore, with the current study's results with a p-value falling within the 95% significant level is evident enough to prove the positive impact of the GeoGebra integrative training materials. The average of 5 and standard deviation of 0 mean that participants strongly agree to the fact that the facilitator was very skilled in integrating GeoGebra in geometry teaching. None of the participants deviated from the mean, hence, the standard mean error indicated 0.

Qualitative Results

The training materials promote learner-centered approaches

In-service teachers' responses on how the GeoGebra integrative training materials promote learner-centered approaches. The following are some of the responses teachers have to say,

> Yes, the GeoGebra integrative training materials allowed us to interact at the individual level (Tr16).

> Yes, because I was given a chance to do it myself and ask questions for clarity (Tr28).

> Yes, because everyone was given a chance to demonstrate, and the facilitator was interacting with us one on one … (Tr 05).

> Through the use of GeoGebra integrated training material, teachers are able to teach learners to be able to practically see and that way they will never forget (Tr20).

> Yes. The training was learner-centered (Tr06).

> Yes, because we were doing everything on our laptop (Tr29).

> Yes, the facilitator gives us a chance to practice (Tr24).

In-service teachers' perceptions of GeoGebra integrative training materials in geometry teaching were also measured based on their opinion of the training sessions they attended. Participants' responses indicated that the training sessions went well. Teachers generally indicated that the training sessions were developmental and hands-on. The results further showed that participants were given a chance to showcase skills learnt during the training sessions. Comments such as

> the training was clear and more practical everyone was given a chance to demonstrate what they learnt (Tr05)

and

> everything that I was trained in was easily understandable (Tr25)

were some of the indications that training sessions went well. Most of the teachers indicated that the GeoGebra integrated training material allowed them to visualize geometric concepts dynamically. For instance, Tr20 stated,

> *the training material make it easier for the teachers to give a visualized understanding because of the integrated nature GeoGebra.*

Some of the teachers commented that training material allowed them to teach learners in such a way that they will not forget geometric concepts because of the visualization aspect of the GeoGebra platform. Respondents such as Tr27 recorded that

> Through the use of GeoGebra integrated training material, teachers are able to teach learners to be able to practically see and that way they will never forget.

There were no major challenges experienced by participants during the training, as pointed out by participants Tr07 and Tr25. However, few participants mentioned technical challenges, which they indicated were further resolved as the training progressed. The recorded responses of participants implicitly show that training sessions were learner-centered, with a significant number of participants indicating "yes". Results show that most of the participants explained that they were given an opportunity to do a presentation while other colleagues were observing. They further stated that they were doing everything on their laptops.

GeoGebra integrative training material for the future of geometry teaching

Participants' opinions on how they perceive the future of geometry teaching are based on their engagement with GeoGebra integrative training materials. Below are some of their responses.

Tr16 said,

> Using GeoGebra integrative training materials allows me to be able to set questions and prepare lesson plans.

Tr06 claim that

> Use of GeoGebra training material to prepare lessons and teach and also to set assessment in geometry.

Tr28 pointed out that

> The training material with GeoGebra integration will make it easy to set and even change your rider quickly to suit your questions.

Tr23 indicated that

> I have learnt to set my own paper without copying old questions, which will help me to be a future examiner.

Tr07 said

> GeoGebra integrative training materials will assist in enhancing my lesson.

Tr20 highlighted that

> The GeoGebra integrative training materials made it easier for the teachers to give a visualized understanding of geometry.

In-service teachers' responses on how the GeoGebra integrative training materials can help them become better teachers revealed that the participants are confident that the knowledge they gain during the training will yield good teaching geometry practice. Comments such as

> the training material with GeoGebra integration will make it easy to set and even change your rider quickly to suit your questions

and

> I have learnt to set my own paper without copying old questions, that will help me to be a future examiner

made by participants Tr23 and Tr28, respectively clearly shows that teachers have future plans with integrating GeoGebra in their teaching. Teachers' responses also shows that the training materials will go a long way in assisting teachers in assessing learners. The results also shows that most of the teachers indicated that the training material of integrating GeoGebra will assist them in future. For instance, respondents indicated that the training material will assist with the setting of new questions, lesson plan preparation, and practical demonstration of geometric concepts and theorems. Further, some teachers indicated that the training would assist them in integrating technology whenever they are teaching mathematics.

Responses such as

> use of GeoGebra training material to prepare lessons and teach and also to set assessment in geometry

and

> using GeoGebra integrative training materials allows me to be able to set questions and prepare lesson plans

made by Tr06 and Tr16, respectively support afore-mentioned statement. Some participants, such as Tr24 and Tr07, assert that the GeoGebra training material will help with technology integration in mathematics content. In sum, according to the in-service teacher training framework (Ahmed et al., 2021) and the results in this study indicate that in-service mathematics teachers are highly motivated to use the training materials in future as a reference for technology integration. The results also reveal that teachers are geared towards future improved geometry teaching and better learner performance in geometry.

Effective use of GeoGebra integrative training materials

The sampled response below indicates some of the areas where in-service mathematics teachers felt that GeoGebra integrative training materials are most effective for teaching and mastering geometry. This portion was concluded with the interpretation of the responses and their analysis.

Tr07 stated that

> GeoGebra integrative training materials will go a long way in assisting with lesson preparations, demonstration in class and also when setting assessments.

Tr17 stresses that

> GeoGebra integrative training materials are most productive because they are more practical than theoretical. Learners will prove or apply theorems practically.

Tr03 claims that

> Drawings or constructions are done easier than to use the old way. Changing one rider to different tasks or easily change the value on the diagram but keep questions and … can boost learners' confidence.

Tr21 clearly stated that

> GeoGebra integrative training materials allows teachers to formulate their own questions. It brings positivity to learners and the love for mathematics.

Tr05 explained that

> GeoGebra integrative training materials assist when demonstrating the geometry theorems. This technology makes it possible for learners to observe that mathematics is real through construction and measurement of geometric concepts for learners to visualize.

Similar trends of responses were noted when in-service teachers were asked whether they found the use of GeoGebra integrative training material most productive in their teaching of Euclidean geometry. Many participants maintained that the training materials brought practicality to geometry teaching and learning. Teachers, such as Tr19, stated that

> with the knowledge and skills we obtained from engaging with the training materials, learners will not forget what they have done practically using GeoGebra.

Further, Tr24 emphasized that GeoGebra integrative training materials will make it easy to teach learners because everything is done practically. A significant number of in-service teachers found the use of GeoGebra more productive in demonstrating geometry concepts than mere explanation without illustration. For instance, Tr11 indicated that

> The training material is useful in demonstrating every concept in geometry like the simulation of lines and angles.

Furthermore, the results found in this study show some commonality as most of the in-service teachers maintained that GeoGebra integrative training materials of geometry teaching will assist them with lesson preparations, demonstration in class, and also when setting assessments. In addition, a few teachers pointed out that learners will not forget when GeoGebra is integrated into the teaching of geometry. This is because of the visual nature of the GeoGebra application and that concepts are demonstrated practically, explained to the teachers. A significant number of participants were in favor of GeoGebra's integrative nature to help learners understand geometric ideas visually. According to respondent Tr25, GeoGebra integrative training materials are effective since they allow learners to interact with and see shapes to better comprehend geometry fundamentals. A large percentage of teachers claimed that incorporating the training materials into geometry instruction and learning increases the confidence of both teachers and learners.

Adopting and integration of GeoGebra integrative training materials

The responses below are some of the participants' opinions regarding the adoption and integration of GeoGebra integrative training materials in the teaching of geometry.

> I am interested in adopting GeoGebra. GeoGebra integrative training materials make teaching geometry easy. GeoGebra is used for free, no need to be connected, easy to use (Tr01).

> Yes, am going to adopt and integrate because of the use of GeoGebra integrative training materials, no more learners who can be sleepy during the lesson due to interest of demonstration and theorems are more practical (Tr23).

> Yes, I would absolutely be interested because this will make it interesting to the learners as it was made simple and interesting to me (Tr05).

> Yes, of course it is. It is using technology which they adore very much, so it goes with time. This GeoGebra integrative training materials will also

> help us save time in teaching and setting. One diagram can be moved, and different questions can be asked. Setting becomes easier (Tr28).

> Yes, the GeoGebra integrative training materials will assist me to teach confidently, and learners get to see visuals and interact with the concept (Tr12).

> Yes, it proves so many concepts with not just telling learners but showing them. GeoGebra integrative training materials can also help the teacher to improve the content in geometry and develop some strategies (Tr26).

> I am very willing, and I can't wait to start integrating the skills I learnt from GeoGebra integrative materials in the teaching and preparation of my assessment (Tr06).

Findings from the respondents agreed to adopt GeoGebra integrative training materials and integrate it in the teaching of geometry. Common trends in participants' responses were observed when participants explained the reasons behind the adoption of GeoGebra as a learning object. For instance, 10 participants commended the easy-to-use nature of GeoGebra as revealed during the engagement with the training materials. Considering comments such as

> GeoGebra proves so many concepts,

> GeoGebra integrative training materials makes teaching easy,

> Understanding the training materials makes teachers to improve the content in geometry and develop some strategies,

and so on, justified easy-to-use nature of GeoGebra. Common responses were also observed with at least 8 participants anticipating the positive impact of GeoGebra integrative training materials in the learning processes of geometry. Thus, teachers such as Tr21 believed that

> GeoGebra integrative training materials will develop a love for mathematics from teachers as well as learners

while Tr12 indicated that

> the use of GeoGebra makes learners get to see visuals and interact with the concept.

Further, a significant number of participants felt that GeoGebra brought practicability in geometry teaching and learning with Tr23 commenting that

> no more learners who can be sleepy during the lesson due to interest of demonstration

afforded by GeoGebra software. This means that participants perceive GeoGebra integrative training materials as teaching aids that can help in maintaining learners' attention, boosting their confidence, and alerting them in class. Apparently, participants believed that the use of GeoGebra integrative training materials afforded in-service teachers the opportunity to use a learner-centered instructional approach. One of the respondents highlighted that GeoGebra integrative training materials use will allow learners to discover geometric concepts without the teacher telling them. Moreover, some participants stated that the training materials made the setting of geometry questions easier than before, as one of the reasons behind the adoption of GeoGebra and its integration. Again, the researcher was amazed and delighted to observe that one of the participants stated the free connectiveness of GeoGebra during the training as the reason for GeoGebra integrative adoption. Overall, the responses gave the impression that in-service teachers are interested in adopting and integrating GeoGebra in the teaching of geometry after engaging with the training materials.

DISCUSSION

Most of the findings of this study enjoyed the support of several related literature. For instance, the positive findings of the training materials promoting learner-centered approaches concurred with the findings of Nawab (2017). This study concluded that in-service training of teachers has positive effects on attitudes and participants' practices. A study conducted by Omar (2014) also supports the findings that providing teachers with effective training materials will contribute to training an individual being more competent and satisfied in their roles as teachers. Teacher motivation and pedagogical skills were positive indicators for this study. These indicators are consistent with the study's adopted in-service teachers' framework (Ahmed et al., 2021).

The current study found that engaging with GeoGebra integrative training materials will go a long way in assisting teachers in the future teaching of geometry. These results are consistent with the findings of Junejo et al. (2017), who report that training materials provide in-service teachers with an ongoing investment in developing their skills. Ahmed et al. (2021) stressed that relevant training material and effective professional development training promotes teacher motivation and its likely to improve teacher performance. This recommendation agrees with the findings of this study. Comments such as

> through GeoGebra integrative training materials, I have learnt to set my own paper without copying old questions, that will help me to be future examiner

made by participants Tr28 confirm teacher motivation and envisioned improve teacher performance (Ahmed et al., 2021).

After a series of in-service teacher training arranged by Ahmed et al. (2021) to engage teachers to enhance their professional growth and knowledge development. The study attests that the training materials raise teachers' skills and broaden their professional approaches. These findings are consistent with the current study's results. In-service teachers rated the training materials positively with highly statistically significant results (t [29], $SE > 0.050$, $p < 0.1$) with mean and standard deviation of at least 4.59 and 0.49, respectively. The average mean of 4.59 shows that participants generally strongly agreed that engaging with the training materials highly proved their professional skills in the teaching of geometry using technologies.

Furthermore, based on results shown in **Table 2**, low standard deviations of at most 0.49 in all the 7 items indicates a close relation with the average mean which participants rated at least an agree (see **Table 1**). In fact, the study recorded a low variance deviating from participants' average means which is a good indication of a positive participant perceptions of GeoGebra integrative training materials. These quantitative results show that in-service teachers are enthusiastic after their engagement with the training material (Mokotjo & Mokhele-Makgalwa, 2021). These findings also agree with the studies carried out by Nzarirwehi and Atuhumuze (2019) in Uganda. Their study revealed that in-service teacher training has a positive influence on teacher knowledge, performance, motivation and professionalism. Also, a comment made by participant Tr24 that

> the technology integrative training materials taught me that mathematics can be made easy if it can be taught by integrating technology with teaching methods and content

concurs with the findings of Nzarirwehi and Atuhumuze (2019) and Ahmed et al. (2021).

Studies carried out by Şahin and Akıncı (2020), Sönmez (2008), and Murano et al. (2019) mention several existing gaps in TPD. Most of the gaps highlighted by these studies include but are not limited to inadequate teacher training (Sönmez, 2008), lack of innovations brought by time (Şahin & Akıncı, 2020), motivation obligation (Murano et al., 2019). The findings from this study have shown positive results of closing these gaps. For instance, the issue of inadequate in-service training has yielded positive results. The results indicate that teachers were adequately trained. This finding is further supported by Murano et al. (2019) who pointed out that after TPD training, teachers yield positive acquisition of social and emotional competencies. Ahmed et al. (2021) claim that teachers usually rate the training highly if indicators such as positive teacher motivation, gaining technological skills, pedagogical skills and improved teachers' performance prevail. Indeed, these indicators prevailed in this study. For instance, comments such as

> with the knowledge and skills we obtained from engaging with the technology integrative training materials, learners will not forget what they have done practically using GeoGebra

confirm these indicators.

The positive comments made by teachers and the highly statistically significant results shown in this study also address the concern raised by studies such as Şahin and Akıncı (2020), Babacan and Özey (2019), Öztürk and Öztürk (2019), Katman and Tutkun (2015) that in-service teachers lack innovations brought by time and that some of in-service teachers' training needs were not adequately met. The results of this study indicate that in-service teachers have improved their technological and pedagogical skills to meet with the demands of the digital teaching and learning environment.

Furthermore, the current study revealed positive results on the interest by the teachers to adopt and integrate technologies after the engagement with the technology integrative training materials for geometry teaching. These results include responses highlighted by participants that GeoGebra integrative training materials use allow learners to discover geometric concepts without the teacher telling them. Also, the technological integrative training materials made geometry questions easier than before. These findings, among other reasons, were behind the adoption of GeoGebra and its integration into geometry teaching. These results are consistent with the findings of Osamwonyi (2016). His study claims that in-service teachers upgrade their knowledge and develop interest in the subject during the training programs. Moreover, comments such as

> I am very willing, and I can't wait to start integrating GeoGebra in the teaching and preparation of my assessment

further show that in-service teachers were highly motivated with the technology integrative training materials, and they showed interest in integrating GeoGebra technology. The aforementioned comments are consistent with Gorozidis and Papaioannou (2014), who point out that in-service teacher training programs that focus on subject and/or technology mastery result in teacher motivation, improved content mastery, and improved teacher classroom practice.

In summary, the findings from this study indicate that in-service teachers learn new skills. Learning new skills agrees with the theory of andragogy (Knowles, 1980; TEAL, 2011). Also, the results showed that the

current study was able to transform teachers from their way of thinking (TEAL, 2011). Changing the way individuals think or perceive is consistent with the theory of TL (TEAL, 2011). In fact, the results revealed in this study shows that there are changes that in-service mathematics teachers have undergone. These changes included but not limited to acquisition of new skills (improved technological skills, better pedagogical skills), improved self-esteem, highly confident and motivated, improved interest in collegiality and collaboration, and so on. Knowledge acquisition by adults (andragogy) and the willingness to change (TL) are important in building the principles of effective in-service teacher training that is relevant, engaging, actively participating, and learner-centered.

CONCLUSION

The study draws its conclusions from the in-service teachers' perceptions of GeoGebra integrative training materials and their influence on TPD. In-service teachers' perceptions and professional development artefacts were drawn from teachers' pedagogical technological knowledge, communication and collaboration skills, collegiality, motivation and envisioned teacher and learner performance. In-service teachers rated highly the GeoGebra integrative training materials. This study's results have proved that the training materials positively changed the way teachers perceive geometry teaching. The highly statistically significant results revealed that the training materials positively influenced teachers towards the teaching of geometry using GeoGebra technology. Teachers' willingness to attend more in-service teachers' technology training programs, the interest to integrate and adopt educational technologies, teachers' interest to disseminate newly acquired knowledge to other colleagues and teachers' confidence of using educational technologies were some of the indicators of highly rated GeoGebra integrative training materials. In-service teachers' professional skills were significantly improved. The results also show a significant improvement in teacher motivation. For policy, the study recommends the implementation and support of the use of educational technologies in mathematics teaching and learning. Developing technology integrative training materials in other mathematics topics is recommended for practice.

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APPENDIX A

Table A1. Questions about in-service teachers' utilization of GeoGebra

No	Item description	Research approach	
		Qualitative	Quantitative
1	Was training material promoted learner-centered approaches? Justify your answer	✓	
2	Rate your understanding of the training material used to train mathematics in-service teachers.		✓
3	Training material is essential for in-service mathematics teachers teaching geometry in secondary school		✓
4	Based on the quality and relevance of the training material, are you likely to attend the other technology integration training courses?		✓
5	After your engagement with the training material, will you disseminate your newly acquired knowledge to other colleagues?		✓
6	What did you learn from the prepared training material that will help you in the future.	✓	
7	After your engagement with the training material, are you likely to integrate GeoGebra when teaching geometry.		✓
8	After your engagement with the training material, do you feel confident using GeoGebra when teaching geometry.		✓
9	Where do you find the use of GeoGebra training material most productive in your teaching of geometry? Explain	✓	
10	Will the training material make you interested in adopting and integrating GeoGebra in the teaching of geometry? Explain	✓	
11	Rate the instructor/facilitator's expertise on the use of GeoGebra as a tool for geometry teaching.		✓