MATHEMATICS TEACHERS' PERCEPTIONS OF THE VALUE OF GEOGEBRA INTEGRATION IN SOUTH AFRICAN HIGH SCHOOLS

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ABSTRACT

The South African Government has made concerted efforts to introduce GeoGebra and similar open-source dynamic graphics mathematics software to schools. This study appreciates that teachers are crucial in the integration 3of technology that assists in teaching, including GeoGebra, and hence focuses on exploring teachers' perceptions about the value of using GeoGebra. This article presents four qualitative case studies that illustrate the views and experiences of selected teachers in the integration of GeoGebra within a South African curriculum context. Located in the interpretivism paradigm, the researchers listened to the views, opinions and understandings of teachers concerning the integration of GeoGebra. Data were generated by conducting semi-structured interviews with four purposively sampled teachers from four high schools in the Bojanala District in the North-West Province of South Africa. The key finding of this study revealed the need to strengthen the professional development of teachers concerning the integration of GeoGebra into the mathematics curriculum. The study concluded that teachers are enthusiastic in applying GeoGebra as they believed that it was valuable in teaching mathematics to South African high school student. The study recommends the enhancement of professional development with a focus on GeoGebra because of its strong link to the South African curriculum.

Keywords: Information, communication, technology, integration, GeoGebra software, mathematics

INTRODUCTION

In order to master mathematics, it is essential to develop specific skills of understanding in applying problem-solving strategies. These include the solving of equations and their logical application which require an attentive approach to ensure accurate solutions (Iji, Abah, & Uka, 2013). The use of mathematics software facilitates such processes (Zilinskiene, 2014). As most learners perceive mathematics as being abstract and difficult to understand, teachers have become increasingly key in the integration of ICT and mathematics (Bayaga, Mthethwa, Bosse & Williams, 2019). Teachers' perceptions of their ability to use ICT effectively influence their quality of teaching mathematics. There are various ICT tools that are available to use in the education environment such as *Mathematica*, *Matlab,* and *Maple*. These tools have been used to teach, reinforce and enhance the teaching-learning of mathematics of those who use them regularly and effectively (Kilicman, Hassan, & Husain, 2010). GeoGebra has been explored in various studies, and results show that it enhances learners' conceptual understanding and instils positive attitudes towards mathematics learning (Adegoke, 2016). In addition, it promotes the professional development of teachers, specifically in the teaching of mathematics (Jelatu, Sariyasa, & Ardana, 2018). It is also known to improve the understanding of mathematical concepts in geometry (Singh, 2018), trigonometry (Kepceoglu, 2016), and linear algebra (Mudaly & Fletcher, 2019). This study explores teachers' perceptions of what they regard as significant concerning integrating GeoGebra into the teaching of mathematics.

GeoGebra is widely used in South African high schools especially in the provinces of KwaZulu-Natal, Limpopo, and Gauteng (Bayaga et al, 2019; Chimuka, 2017). Mushipe and Ogbonnaya (2019) postulate that the impact of integrating GeoGebra and mathematics teaching-learning was remarkably positive. Since GeoGebra is a free mathematics software programme, it can also be used for teaching statistics and probability, geometry and functions, and can be applied at different school levels. It has received numerous awards since 2002 (Hohenwarter & Lavicza, 2009; Majerek, 2014; Zilinskiene, 2014). *GeoGebra,* as the name suggests, is a combination of "geometry" and "algebra", is known to be an innovative, open-code mathematics software (GNU General Public Licence) that can be downloaded free of charge from the www.GeoGebra.org website which works within a wide spectrum of operating system platforms that have the Java virtual machine installed (Dikovic, 2017).

Most South African schools have access to ICT tools and various mathematics software programmes (Ford & Botha, 2014; Van Wyk, 2014). GeoGebra is widely used in South African high schools with most research showing its use in KwaZulu-Natal, Limpopo, Gauteng and Limpopo (Bayaga et al., 2019; Chimuka, 2017). It is therefore imperative to explore teachers' views in the value of GeoGebra in their teaching of mathematics in South African high schools.

PROBLEM STATEMENT

The South African Department of Education has made strides in providing ICT resources in schools and upskilling teaching in using the provided the ICT resources (Van Wyk, 2014). However, according to Banas (2010) and Tella et al. (2007), teachers struggle with the actual integration of technology into their mathematics lessons. Hence, it is important to establish teachers' perceptions of the value of GeoGebra in teaching mathematics within the South African high school curriculum.

Furthermore, Macias (2017) indicates that a positive learning environment is possible when teachers take on a leadership role in applying innovative processes of teaching. The bottom-up structured professional development approach is deemed to provide flexibility for teachers to collaborate and construct knowledge. Hence, this study seeks to establish teachers' perceptions of the value of integrating GeoGebra software with the teaching of mathematics in South African high schools.

CONCEPTUAL FRAMEWORK

This research is underpinned by technology pedagogy and content knowledge (TPACK) as a conceptual framework. Technological pedagogical content knowledge (TPCK) is the concept that encapsulates the integration of technology into the teaching and learning environment (Chai, Koh & Tsai, 2013). TPACK is described as an amalgamation form of knowledge that aims to integrate ICT into teaching and learning in any classroom. This interaction results in seven components included within the TPACK framework: technology knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), PCK, technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPACK) (Chai et al., 2013; Schmidt et al., 2009). TPACK is known to be "the basis of effective teaching with technology which requires an understanding of concepts representation using technology; pedagogical techniques that use technologies in constructive ways to teach content, knowledge concepts difficult or easy to learn and how technology can help redress some of the problems" (Koehler, Mishra & Cain 2013, p. 16).

This study seeks to engage teachers in their views and opinions of the value of GeoGebra in the integration of GeoGebra in the mathematics teaching. In reaching this objective, the study seeks answers relating to the teachers' knowledge of mathematics and how what they consider to be valuable in teaching with GeoGebra. TPACK is relevant as a framework in giving the guideline of measure of the value that teachers place in GeoGebra as a technological tool of choice. In order to answer the research question, what are teachers perceived value of GeoGebra in the integration of GeoGebra in South African high school. TPACK offers the measurement and assessment instrument with which to engage the knowledge and practices of teachers in the integration of technology into the teaching environment which informs what they consider valuable about GeoGebra.

LITERATURE REVIEW

High School Mathematics Curriculum in South Africa

The administrative structure of South African schools is divided into primary schools (Grade 1-7) and high or secondary schools (Grade 8-12). The high school band is divided into the Senior Phase (Grade 8-9) and the FET Phase (Grade 10-12). Mathematics is compulsory from primary school level until the last phase of GET, which is Grade 9. Mutodi and Ngirande (2014) state that mathematics performance in South Africa is one of the worst globally. For this reason, it is necessary to analyse what other researchers have observed to be a challenge concerning poor mathematics results.

Spaull (2013) argues that the challenge emanates from primary school where all teachers are expected to teach mathematics, regardless of whether they have qualifications in mathematics or not. Furthermore, Prew (2013) mentions that in the year 2012, 84 secondary schools did not offer mathematics at matric level. Less than 50% of matric learners from the two best performing provinces in South Africa – Western Cape and Gauteng – sat for mathematics in their final examination. This is a reflection of a poor situation concerning mathematics education in South Africa. It is, therefore, important to consider the content aspects of mathematics covered in the South African curriculum, and how this content relates to the mathematical knowledge and skills that GeoGebra has to offer.

Researchers such as, Kumar & Kumaresan, 2008; Okafor & Anaduaka, 2013 point out that part of the challenge in understanding mathematics lies in its abstract nature making it difficult to grasp mathematical concepts and its applications.

Learners fail to develop the crucial visualisation and exploration skills required for mathematics. Hence, GeoGebra is a tool to assist mathematics teachers and learners, as it is regarded as one of the best mathematics software packages that illustrate mathematics ideas with its visualisation technique (Majerek, 2014). This simplifies the understanding of difficult and abstract mathematics concepts. With the introduction of GeoGebra into South African high schools, the study seeks to establish its value in mathematics teaching-learning.

Integration of ICT in Mathematics Teaching and Learning in SA

The DoE (2012, p. 5), as articulated in its National Curriculum Statement (NCS), aims to produce learners who have the ability to "identify and solve problems and make decisions using critical and creative thinking". Learners also need to be able to use technology effectively, with an understanding that problem-solving does not happen in isolation (DoE, 2012).

The Mathematics teaching and learning framework proposes teachers need to aim to develop critical awareness skills and the aptitude to handle mathematics problems in all learning environments, even in real-life situations (DBE, 2018). Therefore, when the curriculum is being designed, it is supposed to cater for this aim. It is a known fact that integrating technology in teaching and learning will enhance and develop learners' problem-solving and critical-thinking skills. This study explores teachers' views regarding the integration of ICT software and the teaching of mathematics in the SA high school curriculum, focusing on the FET Phase. The mathematics curriculum in the FET Phase under the Curriculum Assessment Policy Statements (CAPS), is divided into several topics (DBE, 2011): functions, number patterns, sequence series, finance growth and decay, algebra, differential calculus, probability, Euclidean geometry and measurement, analytical geometry, trigonometry, and statistics.

GeoGebra Integration in Mathematics Teaching and Learning in SA classrooms

This section explores relevant literature that links the effectiveness and relevance of GeoGebra to the South African high school mathematics curriculum. GeoGebra is known as an open-source dynamic graphics mathematics software that offers geometry, algebra, statistics and calculus in a connected, user-friendly software environment. It has a variety of features that makes mathematics relatable (Dikovic, 2017; Kovacs, 2014; Majerek, 2014). Marejek (2014, p. 52) describes the main features of GeoGebra software as follows:

> … free for non-commercial use, multi-platform; clear and easy understanding graphical user interface; rich database of ready-made examples; technical documentation in many languages; marking objects follow the mathematical syntax; ability to save a project in multiple formats; works with LaTeX; all objects in GeoGebra are dynamic; possibility to publish the work on the website through JavaScript.

Below, the effectiveness of the integration of GeoGebra in mathematics topics that are part of the South African high school curriculum is explored.

Effectiveness of GeoGebra in Algebra

Functions refer to mathematics work that relates to the relationship between variables in terms of numerical, graphical, verbal and symbolic representations of functions (Van de Walle et al., 2015). The functions may be represented as tables, graphs, words and formulas. The algebra section of the curriculum also encompasses the investigation of algebraic expressions and the simplification of exponents. Learners have to understand the mathematical rules and language necessary for effective learning (DBE, 2011). For example, when dealing with algebraic concepts, one needs to multiply the binomials – a binomial has two terms; for instance, 2x – 2.

Mushipe and Ogbonnaya (2019) found that learners who were taught linear functions using GeoGebra outperformed learners who were taught the same topic using "chalk and talk". Mudaly and Fletcher (2019) attest that GeoGebra is effective in teaching linear algebra where the gradient and the *y* intercept of a line may be investigated. Moreover, Brzezinski (2017) designed various GeoGebra applications where teachers and learners can experiment and learn about solving quadratic equations.

Effectiveness of GeoGebra in Euclidean Geometry and Measurement

According to the DBE (2011), the Euclidean geometry and measurement section in the FET South African curriculum includes the investigation of the properties of special triangles, quadrilaterals and polygons (isosceles, equilateral and the right-angle triangles, e.g. the kite). Choong and Hale (2017) designed a GeoGebra application that illustrates the teaching of geometry concepts which involved noting various properties of triangles using GeoGebra. GeoGebra simplified the drawing of sides and measuring of angles. For example, for a scalene triangle, it was clear that all its sides and interior angles were not equal.

Various studies have been conducted on the effectiveness of GeoGebra in teaching Geometry. Venkataraman (2012) found that learners assisted by the GeoGebra application made better progress towards mathematical understandings, which provides a foundation for further deductive reasoning in mathematics. Several studies highlighted the impact of GeoGebra in the understanding of Euclidian Geometry with a special focus on lines, angles, triangles, and problem-solving skills (Jelatu, Sariyasa, & Ardana, 2018; Singh, 2018; Khalil, Sultana, & Khalil, 2017). Additionally, Yildiz and Baltaci (2016) and Shadaan and Eu (2013) illustrated the positive impact of understanding circles, and cylindrical and spherical coordinates through the integration of GeoGebra.

Effectiveness of GeoGebra in Teaching Trigonometry

Using GeoGebra software for high school mathematical functions (Trigonometry), helps to perform the following classroom task: Evaluate trigonometric functions of an angle given on its terminal ray (Brzezinski, 2017). As illustrated in Figure 1 below, for demonstrational and experimental purposes, Point P may be dragged wherever a teacher or learner chooses for [Min, Max] both coordinates equal to [10, 10]. The same image may be copied and pasted on Microsoft Word as part of the assignment and used as part of the learning process.

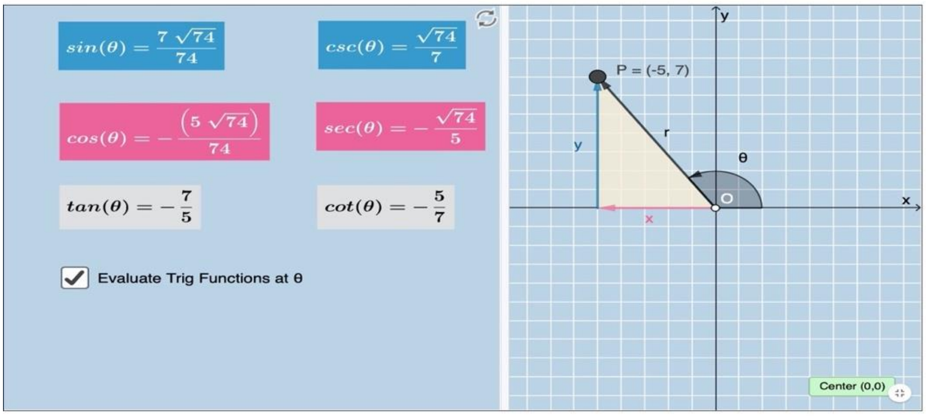

Figure 1: Illustration of integration of trigonometric GeoGebra functions in teaching trigonometry

According to Zengin, Furkan and Kutluca (2012) and Kepceoglu (2016), GeoGebra is effective in teaching trigonometric concepts with a special focus in periodicity of trigonometric functions. Hence, it can be concluded that the integration of GeoGebra helps in creating a learning environment in which learners can discover, explore, estimate and visualise. It has the characteristic of promoting the conceptual understanding of abstract mathematics concepts that are included in the South African high school mathematics curriculum.

RESEARCH METHODOLOGY

This study is part of a larger research project that qualitatively explored how teachers integrate GeoGebra in their teaching of mathematics in South African high schools. This particular study used interpretivism as a paradigm to explore such teachers' views. Interpretivism is a paradigm where individuals seek to understand their world by providing participants with opportunities to share their experiences, views and opinions (Thanh & Thanh, 2015). The qualitative approach has been particularly suitable for this study, as the meaning of the phenomenon was made clear by using the views, perceptions and experiences of the participants (Maree, 2012; McMillan & Schumacher, 2010). According to Okeke and Van Wyk (2016), qualitative research methods are concerned with understanding human thoughts and behaviour with an emphasis on the meaning they attach to their actions. We therefore considered in detail the cases of four teachers, each as a separate case, and proceeded with an intra-case analysis. Punch (2013) maintains that the case study is an empirical research method that investigates the phenomenon within its real-life setting and relies on multiple sources of evidence. We, therefore, considered the narratives of the four participating teachers as separate entities and cross-examined their responses in search of commonalities and differences.

In order to gather the necessary data, the researchers used semi-structured interviews, which facilitated a subjective relationship with the participants to understand the integration of GeoGebra from their perspective. Four teachers from four different high schools in the Bojanala District of North-West Province were selected using purposive sampling. The data generated was transcribed, coded and categorised into meaningful themes that emanated from the data. The use of both the semi-structured interview and observation methods ensured the credibility and trustworthiness of the data. All the participants signed the consent forms to illustrate their willingness to participate voluntarily in the study.

DISCUSSION OF RESEARCH FINDINGS

In order to fully understand teachers' perceptions of how they value GeoGebra in mathematics teaching in South African high schools, the responses of four sampled teachers were considered. The sampled teachers received training in the integration of GeoGebra, and also use GeoGebra in their mathematics teaching. They shared their stories through the unstructured interviews. The sampled teachers in this study are referred to using their pseudonyms as follows: Mr Magwe, Mr Sebaya, Mr Golenyane and Mr Maziya (all pseudonyms) – are provided. Below is the biographical information of the participants, outlining their qualifications and experiences in the teaching of mathematics.

Biographical background of the participants

The biographical data described below indicates the qualification and level of experience of all four selected participants in terms of teaching mathematics:

- Mr Magwe is a high-school teacher with six years' experience in teaching mathematics, physical science and technology from Grades 8 to 12. He holds a BSc in Computer Science and Electronics, a Postgraduate Diploma in Education, and a Postgraduate Certificate in Education (PGCE). He has been utilising other ICT tools, and recently has been using GeoGebra for 18 months.
- Mr Sebaya is a teacher with six years' experience in teaching mathematics, natural science and technology from Grade 8 to 13. He taught in many provinces in South Africa. He holds a Bachelor of Education (Honours) degree, a PGCE in natural science and mathematics, and a Bachelor of Commerce degree in statistics. He has been using other ICT tools, but currently has been utilising GeoGebra for over a year.
- Mr Golenyane is a teacher with nine years' experience in teaching mathematics, natural science and computer science. He holds a BSc (Computer Science) degree and a PGCE qualification. He has been using GeoGebra and other ICT software tools for a period of six years.
- Mr Maziya is a teacher with five years' experience in teaching mathematics and physical science in Grades 8, 10 and 12. He holds a BEd degree in science and mathematics, a BEd (Honours) degree in physical science, and is currently working on his MEd. He has been using other ICT tools but has utilised GeoGebra for over a year.

Integration of GeoGebra and its Connection to CAPS

The CAPS document outlines the mathematics content areas that need to be taught in South African high schools. It stipulates that the mathematics content should be taught in a manner that develops learners' mathematical reasoning, and creative and reasoning skills (DBE, 2011). As this study focused on teachers' perceptions of the integration of GeoGebra and the teaching of mathematics in South African high schools. Therefore, it was imperative to establish whether they perceived GeoGebra to be relevant in the South African high school mathematics curriculum as outlined in the CAPS document. Participants unanimously agreed that most topics from the CAPS document could be taught by using GeoGebra. Mr Sebaya's responses are mentioned in the following excerpts:

> Yeah, because [for] most of the topics that are there, you can use GeoGebra. For example, the graphs, trigonometry and geometry are there on the CAPS document and you can also teach them using GeoGebra.

Mr Sebaya elaborated:

> Yah, in CAPS, you have functions, geometry … you have trig. All these topics, one can easily teach them using GeoGebra.

He further used the concept of gradient to illustrate how GeoGebra works:

> Calculate the gradient of the first line and the gradient and the coordinates, but there I just … you know, click, and then it gives me the gradient.

However, his interpretation of the two lines on the same Cartesian plane was incorrect because he thought the multiplication of two gradients would give an indication of the length of the line, whereas the multiplication of the two gradients gives an indication of whether the two lines are parallel or perpendicular. The following statement by Mr Sebaya confirmed his misconception:

> And then they would ask, now this is the gradient of this line, this is the gradient of this line and they can now multiply the two gradients to check if the lines are big or not. But if I have to do that on the chalkboard it was going [sic] to take me some time.

Mr Sebaya found GeoGebra valuable to teach functions. He mentioned that GeoGebra was important in comparing different types of graphs as the learners were able to observe the changes. Venkataraman (2012) affirms that GeoGebra makes the teaching and learning of mathematics meaningful and relevant. Mr Sebaya also noticed that the learning environment changed and improved when learners witnessed the advantages of GeoGebra's input. He stated:

> GeoGebra is so good … like in terms of comparison, you need to compare graphs. It's easy to compare different types of graphs and learners are observing. I can see the change in learners; they understand … and that is what I like.

Mr Golenyane also emphasised that he found GeoGebra to be relevant in teaching mathematics as outlined in the CAPS document. He hailed GeoGebra as a useful innovation in the teaching of geometry. He said that theorems, and the elements of circles were some of the topics included in CAPS, which he also taught using GeoGebra. His response follows:

> CAPS covers lots of topics. You know, like geometry, when we are going to be dealing with theorems, for instance, like [the] angle at the centre is twice the angle at the circumference, I teach those concepts using GeoGebra.

He elaborated on how he used GeoGebra in teaching geometry, giving the example that the circle has four spheres and how he used GeoGebra to demonstrate this:

> Why are they saying that? And then, by using the GeoGebra software, then you are just only to go there and pick the sphere and show them why are we saying the sphere has got four circles.

Maziya also believed GeoGebra was relevant in teaching mathematics in line with the South African curriculum. He gave examples of the correlation between CAPS and GeoGebra and stated that CAPS required graphs being taught to Grade 9 learners, especially how to draw the graphs. Accordingly, GeoGebra is a useful tool in drawing all kinds of graphs. Mr Maziya responded:

> Yeah, they do, they do match, CAPS and GeoGebra because, if for example, I am using GeoGebra to teach geometry at Grade 9 for example, or graphs, or and then CAPS, yes, CAPS would be saying learners have to be taught how to draw graphs. Meaning that automatically, if GeoGebra allows me to draw a graph on the graph slope, then definitely we rely [sic]. Yeah, because it supports what CAPS wants us to do.

Participants unanimously agreed that GeoGebra was a valuable tool to use in teaching mathematics in a South African high school curriculum setting.

Value of GeoGebra in Creating a Vibrant Learning Environment

Bower et al. (2010) hypothesise that the introduction of ICT in a learning environment encourages active engagement between learners and their teachers, as well as among learners themselves. Participants indicated that they found GeoGebra to be valuable in creating an exciting learning atmosphere as it enhances conceptual understanding. Mr Sebaya indicated that learners got excited at the sight of technological tools:

> GeoGebra has the ability to create an interesting learning atmosphere ... So, they were like 'oh you brought your laptop' like … they just like it when you are using technology...

Mr Magwe confirmed that GeoGebra encourages learners to be enthusiastic about learning, and therefore it encouraged independent learning. He noted that learners would be eager to share their learning experiences after they had worked on some mathematics problems independently. This further displayed a sense of enthusiasm for learning mathematics. Magwe responded:

> They would come to you and say, 'are you aware that with that software you gave us yesterday-?' that means when they got home they didn't go anywhere, they just stayed and they were interested in learning more.

Mr Maziya also shared similar sentiments indicating that learners would be thrilled with just the mention of the mathematics lesson being conducted in the mathematics laboratory.

> Learners love to work with technology. They will be so excited when you say, today we are working in the lab. I

> would give them maybe a classwork task to work on. Let's say we did a maths lesson in class. Yah… next time we will go to the lab and continue the maths we did in class.

From the above response, it was evident that learners look forward to a lesson that incorporates technology; and GeoGebra was contributing immensely in creating an interactive and exciting learning environment. Bower, Hedberg and Kuswara (2010) affirm that the introduction of ICT in a learning environment encourages interactive engagement between learners and their teachers, and amongst learners themselves.

The CAPS document (DBE, 2011) outlines the policy concerning the teaching of all school subjects, including mathematics. The value and workings of GeoGebra align to the aims and content areas in the South African curriculum document (DBE, CAPS, 2011). Mathematics learning has to include "an appreciation for the beauty and elegance of mathematics". Zilinskiene (2014) elaborates that GeoGebra is used mainly for demonstration, exploration, modelling, creation, and experimental work. From the participants' perceptions of GeoGebra, it is clear that it added significant value in solving mathematics problems, in addition to creating enjoyable experiences while learning mathematics. Moreover, the appreciation of mathematics as a subject of interest is amply evident; a change from it being previously abstract and boring - this challenge the general stereotype that mathematics is difficult and meaningless.

6.3 GeoGebra for Visualisation and Conceptual Understanding of Mathematics

This appreciation is shared by other researchers (Venkataraman, 2012; Zilinskiene, 2014), who confirm that GeoGebra is a valuable tool in helping learners visualise and conceptually understand mathematics. Azizul and Din (2018) concur that GeoGebra enhances the visualisation and understanding of mathematical concepts for both the teacher and the learner.

Moreover, the aims of teaching mathematics in the South African context include a "deep conceptual understanding in order to make sense of mathematics" (DBE, 2011:8). Similarly, the participants felt that GeoGebra was vital in the visualisation and conceptual understanding of mathematics.

Participants further indicated that GeoGebra was valuable because it helped learners visualise the abstract aspects of mathematics, while it also helped with conceptual understanding. Mr Magwe refers to the teaching of the abstract aspects of geometry when he wanted learners to understand that there is no angle that is 180 degrees because 180 degrees lies on a straight line.

> …when you can relate it stays in their mind that I cannot have an angle that is 180 degrees because it's just a line. When the lines have been connected and triangles drawn, learners see, this is the angle and this is the length….

Mr Golenyane added that learners often struggle with understanding graphs. They may confuse the aspect of gradient when the graph is increasing or decreasing. He made an example of how GeoGebra helps learners to visualise this aspect of algebra in learning functions succinctly:

> When we are comparing the graphs, why are we saying this graph is increasing, why are we saying this graph is decreasing. In GeoGebra, you can draw these graphs, then show learners that when the gradient is like this, then there is increasing graph; and when the gradient is like this, then there is decreasing graph.

From the above participants' views, it was evident that teachers perceived GeoGebra to be valuable as a tool that simplifies abstract concepts in mathematics to become relatable and meaningful. In sum, GeoGebra presented learners with opportunities to visualise and understand abstract concepts.

GeoGebra as a Valuable Time-management Tool

GeoGebra was also found valuable by participants in assisting them with their time- management. Participants indicated that they found GeoGebra to be valuable in teaching of mathematics because it allowed them to draw accurate diagrams without spending too much of their teaching time. Mr Magwe appreciated the GeoGebra software because of the feature that provided the accurate angle measurements. It is difficult to draw an angle of correct measurement (degrees) on the board - an inaccurate angle may distort the information. This could ultimately lead to misconceptions in mathematics. Mr Magwe praised GeoGebra, stating that:

> I have once tried Microsoft. But it always limits you. The triangles wouldn't be that perfect; sometimes they don't give you your 90 degrees angles precisely like GeoGebra.

Mr Magwe showed his elation with GeoGebra by illustrating that it saves time in the teaching of functions. He mentioned that he would just insert a few instructions on GeoGebra and the accurate Cartesian plane will be available for learners, and then learning proceeded without delay. He responded:

> Let's say, I'm teaching graphs… instead of re-drawing on the chalkboard you just click and open that page; open and explain whatever you want to explain… previously you had to draw it on the board, if it's a complex model you take plus or minus 5 minutes drawing it and learners would be making noise or something. But now you just jump from 1 diagram to the next, it's as easy as that. But once you are used to it it's very convenient

Participants expressed their appreciation regarding the integration of GeoGebra into mathematics teaching and learning, largely for its ability to provide accurate drawings and save teaching time. In South Africa, teachers are expected to spend about five hours per week teaching mathematics (CAPS, 2011). Therefore, the participants found GeoGebra to be valuable in assisting them with time-management. GeoGebra was also valuable because it allowed them to draw precise diagrams with angles with precise measurements. Also, GeoGebra saved time in teaching functions. GeoGebra has a feature that requires a few instructions on the GeoGebra input tab, and the accurate Cartesian plane will be available for the learners, and then learning could promptly proceed.

CONCLUSION AND RECOMMENDATION

The overall perceptions of the participants about GeoGebra indicated that they got “value for money” concerning the GeoGebra software for it created an exciting learning atmosphere relevant to the South African mathematics curriculum. Further, teachers perceived GeoGebra to be a valuable tool because it could help learners understand functions, geometry and some aspects of trigonometry. However, some examples which teacher-participants articulated showed a lack of understanding in the use of GeoGebra; this meant that with adequate training, practice and exposure, they could soon access, apply and exploit the GeoGebra software to its full capacity to benefit all learners (and teachers). Furthermore, as some of the teacher participants gave examples of an information gap in terms of assessing the effectiveness of the integration of technology in the teaching and learning of mathematics in South African high schools, there is need for further investigation. The teachers demonstrated basic understanding of the functions of the GeoGebra software, but needed more in-depth knowledge of practically applying it as a technological tool in teaching mathematics. As expected, all the participants endorsed GeoGebra in teaching functions and geometry. They believed in the illustrative power of GeoGebra that stimulated conceptual understanding of some of the abstract geometrical and other mathematics concepts without wasting valuable teaching-learning time. From the teachers’ articulations, it was evident that GeoGebra had more to offer; therefore, further training will be beneficial to both teachers and learners in enhancing the integration of ICT into the teaching and learning of mathematics in South African high schools.

Therefore, this study recommends the enhancement of professional development with a focus on GeoGebra because of its strong link to the South African curriculum. Professional development takes strong measure in securing information and communication technology tools for learners to gain practical experience of learning with technology.

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