



**A Case Study: The use of GeoGebra to alleviate learner
difficulty in learning the similarity of triangles in a
South African Grade 9 classroom**

by

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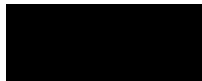
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December 2022

DECLARATION

I, Nompumelelo Mpanza, declare that this report entitled, *A Case Study: The use of GeoGebra to alleviate learner difficulty in learning the similarity of triangles in a South African Grade 9 classroom* is my own original work except where I have explicitly indicated otherwise. I also declare that this research report has not been submitted before, in part or in full, for any degree or examination to any other university.



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Date

DEDICATION

I dedicate this research to my late father Mduduzi Michael Myeni and my mother Nomusa Cetrice Myeni, my husband Sibusiso Mpanza and my three daughters Gugulethu Mpanza, Luyanda Olwethu Mpanza andENZOKUHLE STHANDWA Mpanza.

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I would also like to extend my sincere appreciation to all the learners who participated in this study, Mr. S.P Dlamini, the mathematics teacher for assisting me in conducting the first phase of the data collection, Mr. Z.P Dlaba the teacher responsible for ICT at the school for his support, as well as the SMT members of the school.

My sincere gratitude also goes to my mother, my support structure, who has been an unyielding pillar of strength and support to me during the pursuit of this investigation. Finally, a special gracious thanks to my husband and to all of my family unit.

ABSTRACT

The mixed methods study investigated the use of GeoGebra as a dynamic geometry software (DGS) to alleviate the learning similarity of triangles. A mixed methods philosophical framework in the form of an exploratory case study was used to conveniently and purposively select a sample of 60 Grade 9 learners enrolled at Sondelani Full-Service School (pseudonym), a township school in the Pinetown district in KwaZulu–Natal province, South Africa.

During this research, GeoGebra and the concept of similarity of triangles were introduced to the participants. Then, participants answered several (Euclidean geometry) Similarity Achievement Test (SAT) questions prescribed by the National Mathematics pacesetter for Grade 9 and 10. A 10-item Likert scale questionnaire intended to elicit participants' attitudes about GeoGebra and its impact on Euclidean geometry and mathematics was administered to these participants. The questionnaire also included four open-ended items, asking participants to reflect on the application of GeoGebra. The analysis of SAT data revealed that performance was higher after GeoGebra instruction ($M = 22.50$) than during traditional instruction, which did not feature GeoGebra ($M = 11.65$). Thus, it was found that the use of GeoGebra is an appropriate tool to increase achievement in learning geometry concepts; to promote accuracy, visualization; learner participation; and to create enjoyment and learner interest towards learning mathematics. It is recommended that mathematics teachers need to use GeoGebra for effective teaching and learning of similarity of triangles.

KEYWORDS: GeoGebra, Similarity of triangles, Euclidean geometry.

List of Abbreviations and Acronyms

ANA	Annual National Assessments
CAS	Computer – algebra systems
DGS	Dynamic geometry software
DoC	Department of Communication
DoBE	Department of Basic Education
GDC	Graphing display calculators
GET phase	General Education and Training
FET phase	Further Education and Training
ICT	Information and Communication Technologies
4IR	4 th Industrial Revolution
NCTM	National Council of Teachers of Mathematics
NDoE	National Department of Education
SAS	Side, Angle, Side
AAS	Angle, Angle, Side
SSS	Side, Side, Side
RHS	Right hand side
ZPD	Zone of Proximal Development

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Chapter 1

Introduction to the study

1.0 Introduction

The present study sought to explore learners' understanding in similarity of triangles, experiences and perceptions, when they are exposed to a GeoGebra educational setting. The major focus of this chapter is to formulate the problem of the study by providing a description of the study background, motivation, and a focus of the study. Furthermore, the research questions that were administered to the participants, the significance of this study, and the basic elements of the dissertation are outlined.

1.1 Rationale for the study

The rationale of the study originates from the importance of understanding Euclidean geometry concepts within the senior phase (Grades 7- 9), to learn and teach the basic fundamental knowledge required of the GET (General Education and Training) phase/ (Grade 7 to 9) within the FET (Further Education and Training) phase/ (Grades 10 to 12) effectively. According to Vygotsky (1978), learning takes place when a learner's prior knowledge is raised to a higher level, which he alluded to as the zone of proximal development (ZPD). The ZPD is the contrast between what learners can do using their past knowledge without assistance and what they can do with the assistance from teachers or well-informed learners. The theory of scaffolding is relatively associated to ZPD (Vygotsky, 1978).

The researcher is investigating whether South African teachers need to incorporate GeoGebra in a mathematics classroom to ascertain its efficacy to alleviate learner difficulty encountered in learning similarity of triangles. Based on the researcher's teaching experience, many learners struggle when learning similarity of triangles within the senior phase. Most probably, this could be the reason for the poor performance of learners in Euclidean geometry in the FET phase. According to Steyn (2016), the NSC mathematics diagnostic reports identified poor learners' results in the geometry questions, and Euclidean geometry is a topic that creates a third of the mathematics paper 2 examination.

Euclidean geometry (EG) has been a topic mentioned as difficult for most learners, and teachers are blamed for poor performance in mathematics (Novak & Tassell, 2017). Similarity is

a topic from Euclidean geometry. The previous South African mathematics curriculums all included geometry in all GET (7- 9) and FET (10 – 12) Grades, but from 2008 to 2011, geometry was made optional in Grades 10-12 in other words it was not compulsory. The implementation of the new Curriculum and Assessment Policy Statement (CAPS) in 2012 returned Euclidean geometry as a compulsory section of mathematics after it had previously been transferred to an optional Paper Three (DoBE, 2011). Most learners that opted for Paper Three between 2009 and 2013 did not achieve good results in the examination, and as a result, most schools did not encourage their learners to choose Paper Three (Ugorji & Alfred, 2017). This is an implication that Euclidean geometry troubles learners, if similarity is a topic from Euclidean geometry, then it is also contributing to troubling learners, hence if the foundation is administered properly then, less troubles will be encountered.

1.2 Problem statement

In South Africa the majority of the learners do not perform at a level that would allow them to progress to the next Grades for mathematics, and that significantly impacts negatively on the Grade 12 results (Mabena, Mokgosi, & Ramapela, 2021). In South Africa the Grade 12 mathematics pass rate is currently 30%, which is a very low percentage to allow learners to pass mathematics. Secondary school learners in South Africa write an exit examination called the National Senior Certificate (NSC) examination at the end of their Grade 12 year. The NSC exit examination is regarded as an imperative one since learners who perform well in the examination will be permitted to enroll in higher education to pursue a higher certificate, diploma or bachelor's degree (Grussendorff, Booysse & Burroughs, 2010). The mathematics examination consists of two papers. Paper 1 focuses on algebra and equations; patterns and sequences; finance, growth and decay; functions and graphs; differential calculus and probability. Paper 2 focuses on statistics; analytical geometry; trigonometry and Euclidean geometry and measurement. Geometry is regarded as a problematic subject at secondary school level (Luneta, 2014), and in recent years learners have established Euclidean geometry to be challenging (Siyepu & Mtonjeni, 2014). Correspondingly, research conducted by Van Putten, Howie and Stols (2010) asserts that learners in South Africa who want to become mathematics teachers are not well equipped in terms of a comprehensive understanding of geometric concepts.

It must be pointed out that only a small percentage of learners who choose to study mathematics in the FET phase achieve university entrance requirements in mathematics at the end

of their Grade 12 year (Alexander, Lotriet & Pieterse, 2014). Furthermore, Barry (2000) affirms that learners fear learning mathematics due to the statistics published in relation to the poor performance of learners in the national examinations. Considering the current economic realities of South Africa, it is crucial for mathematics teachers and researchers to take steps to ensure that more learners choose to study mathematics and pass mathematics in the FET phase.

One can deduce that South African learners are underperforming in Grade 12 in mathematics. If learners depart Grade 9 without proper understanding of Euclidean geometry concepts, it will be difficult to understand Grade 10 to 12 concepts of the same content, hence it is vital to ensure learners grasp the concepts to formulate a strong foundation, since the baseline for Grades 10 – 12 is Grade 9. Many mathematics teachers and researchers introduce GeoGebra at Grades 10 – 12, however introducing GeoGebra in Grade 9 has the potential to enrich the understanding of Euclidean geometry. The justification for introducing GeoGebra into Grade 9 will contribute significantly to prevent difficulty in learning triangle similarity.

1.3 Motivation for the study

Many researchers have examined the impact of GeoGebra within the FET phase, (Grade 10 - 12), (e.g., Kekana, 2016; Mthethwa, 2015; Vasquez, 2015). However, this study reinforces the perception that if most learners begin learning Euclidean geometry within the senior phase using GeoGebra, perhaps learner's performance in the FET phase would be more effective, because learners experience and understanding would be enhanced.

Technology provides teachers and learners an opportunity to grow and enhance tuition; this is the cause of the increase in policy makers and implementers adopting information and communications technologies (Howie & Blignaut, 2009). This growing trend of merging learning management systems (LMS) is particularly fruitful in a developing economy such as that of South Africa. According to World Economic Forum (2016), this is due to the high demand for mathematics, science and technology skills for advancing its economy and competing in the Fourth Industrial Revolution (World Economic Forum, 2016). The use of ICT – the 'Fourth Industrial Revolution' in education is a significant medium for complementing the delivery of curriculum in most countries that are trying to develop, including South Africa (WCED, 2018: 2). Teaching needs to be innovative to facilitate a learning environment that is friendly to learners.

As a result, learners use a device that is friendly since it is a piece of technology. Yet at the same time learning takes place.

1.4 Focus of the study

The exposure of learners to a learner-centered environment, employing GeoGebra to create opportunities for learners to view and analyse the similarity of triangle concepts rather than employing the traditional manner of instruction is a teacher-centered approach. The importance of visual learning can be summed up in five skills: observation, recognition, interpretation, perception and self-expression (Vasque, 2015). In Grade 9, learners struggle to learn how triangles are similar. This is based on the researcher's experience. Identifying and exposing learners to a method of understanding the similarity of figures that involves the learner more often in the learning process can assist to overcome the difficulties learners encounter. The aim of the present study is to explore the capability of the GeoGebra program towards alleviating learner difficulty in learning the similarity of triangles. In this study, we explore learners' perceptions of learning similar triangles using GeoGebra.

1.5 The research questions

The generation of data in this study seeks to respond to the following two research questions:

- Does GeoGebra have the capability to alleviate difficulty towards learners' conceptual understanding of similarity?
- What are learners' perceptions of learning the similarity of triangles with GeoGebra?

1.6 The significance of the study

The findings from this study are intended to contribute to mathematics intervention strategies. This is by investigating the capability of the GeoGebra program towards alleviating learner difficulty in learning the similarity of triangles. In addition, we will explore learners' experiences and perceptions when learning similar triangles using GeoGebra when teaching Grade 9 learners. Learners who intend to choose Mathematics in Grade 10 as one of their subjects from the subject package they choose, will have the advantage of understanding one of the Euclidean geometry concepts particularly Similarity through;

- Acquiring a proper conceptual understanding the similarity of triangles.

- Acquiring knowledge of how to use GeoGebra.
- Acquiring problem solving skills for solving geometry problems with the assistance of GeoGebra.

1.7 The description of key terms

1.7.1 Euclidean geometry

Euclidean geometry is the study of plane and solid shapes and their properties that are based on the theorems and axioms developed by the Greek mathematician Euclid. It entails proving riders utilizing theorems and axioms. A rider is simply a non-routine geometry problem (Machisi, 2021). Euclidean geometry is that significant section in mathematics where we learn about the different shapes and their properties. Specifically, the size of the angles and the lengths of the sides. Definitions, theorems, axioms and proofs establish the basics of Euclidean geometry.

1.7.2 Traditional learning method

According to Broughton, Brumpit, Pincas and Wilde (2002), existing learning methods are reliant on teacher instruction and do not provide sufficient opportunities for learners to participate. The traditional teaching style is known as teacher- centred instruction, which is not learner- centred. According to Ahmed (2013) in a traditional classroom, learners develop into passive learners, or rather just receivers of teachers' knowledge and wisdom. They have no power over their own learning. Teachers make all the decisions regarding the curriculum, teaching methods, and the different forms of assessment. According to Duckworth (2009) teacher-centred learning actually impedes educational growth. According to Cottel and Millis (1993) and Bonner (1999) traditional teaching methods comprise:

- Reading texts and solving problems
- Formulate questions
- Attending lectures
- Monitor the discussions
- Writing and responding to short or extensive questions and objective type questions
- Solving short or complex unstructured problems and cases
- Oral presentation of the topic and reply to short questions from the audience
- Studies

1.7.3 The GeoGebra software

Tamam and Dasari (2021), describe GeoGebra as computer software designed to aid in the teaching and learning of mathematics subjects, mainly geometry, algebra and statistics. As a result of the various features that GeoGebra provides, its users can visualize abstract geometric objects quickly, accurately and efficiently.

1.8 The study outline

The present study is organized into six chapters. Chapter One is an introduction which discusses the background to the study, rationale, focus of the study, significance of the study, and description of key terms. In addition, the introduction also clarifies what is covered in each chapter. Chapter Two outlines the related literature documenting previous research findings about the learning of Euclidean geometry concepts. We examine the notion of similarity of triangles in the literature review, as well as how learners perform in similarity of triangles. This study explores how GeoGebra technology supports discovery learning engagement and achievement using the GeoGebra programme. Moreover, the impact of GeoGebra on learners' mathematics achievement, as well as the additional programs that can be explored during mathematics learning are discussed. In addition, the challenges of using GeoGebra in mathematics classroom are briefly discussed.

Chapter Two also presents the background findings related to Euclidean geometry and the association of similarity of the triangles with Euclidean geometry.

Chapter Three presents the theoretical perspectives that frame the study. These theoretical perspectives include a discussion of constructivist views of learning, meaning making and perspectives of geometry and its learning. Chapter Four outlines the methodology used in this study. It also interrogates the research design, research approach, population and sampling, the researcher's philosophical position in the study, research instruments, data generation procedures, data analysis, research ethics, and trustworthiness of the findings in this study.

Chapter Five looks at the in-depth data analysis of this study. It provides a comprehensive discussion of the techniques used to analyze the data. Furthermore, it discusses the questions that participants were asked and the responses obtained. Final Chapter Six is the discussion

of the results and conclusions made based on the findings of the study. This chapter also discusses how the research questions were answered by the participants. The main findings are also presented. The discussion of results is organised around the research questions.

Chapter 2

Review of the literature

2.0 Introduction

The purpose of this chapter is to discuss the literature related to the use of GeoGebra to alleviate learner difficulty in learning similarity in a Grade 9 mathematics classroom. The literature review covers the following themes: the similarity of triangles; the use of GeoGebra in enhancing learner performance; learners' motivation in using GeoGebra in mathematics lessons; Euclidean geometry; the learning of Euclidean geometry applying GeoGebra; the use of technology for mathematics learning. Lastly, the chapter addresses issues of the impact of GeoGebra on learning mathematics.

As alluded to above, this chapter sought to, among other things, assess the importance of using GeoGebra in teaching Euclidean geometry, especially the similarity of triangles. It also sought to determine whether GeoGebra enhances and increases learners' understanding of geometric theorems and whether their level of interest increases when they utilize GeoGebra. To this end, it was imperative that the researcher first establish the characteristics of triangle similarity, and then set the other goals for this study.

2.1 Similarity of triangles

In a one-to-one mapping between two triangles, triangles whose corresponding angles are the same or whose lengths are proportional to their opposite sides are named "similar triangles" (Biber, 2020). Typically, textbooks explain similarity by stating that the corresponding angles of similar triangles are equal and the ratio between the corresponding sides is equal. The symbol \sim means "is similar to". When ratios between corresponding sides of a triangle are equal, we say the sides of the triangles are in "proportion". Some examples are indicated in Figure 3:1–2, in relation to similar triangles, for a typical mathematics lesson in South African classrooms.

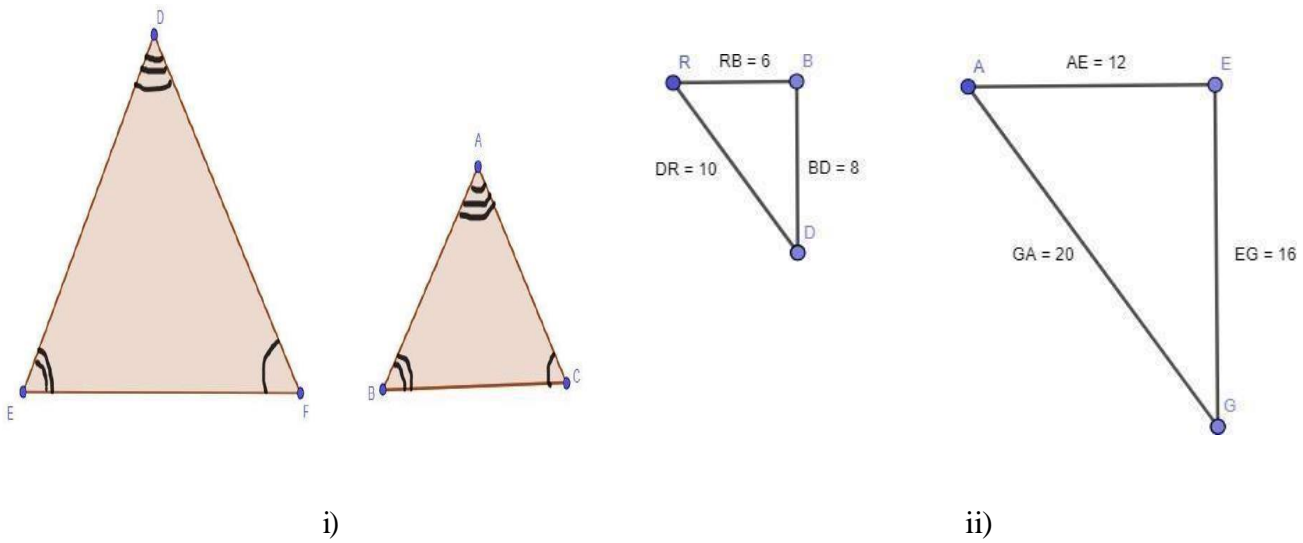


Figure 2:1. Similar triangles: i (sourced from Biber, 2020) ii (sourced from screenshot of participant 420)

According to Figure 2:1 (i), the angles of one triangle are equal to the angles of the other triangle.

Therefore $\triangle DEF \sim \triangle ABC$; $\hat{D} = \hat{A}$; $\hat{E} = \hat{B}$; $\hat{F} = \hat{C}$ three corresponding angles are equal. Figure 2:1 (ii),

illustrates $\triangle RBD \sim \triangle AEG$, there is similarity between these two triangles as ratios of the

corresponding sides of the two triangles are equal: $\frac{AE}{RB} = \frac{AG}{RD} = \frac{EG}{BD}$.

2.1.1 Characteristics of similar triangles

Similarity comprises a basic link between algebra and geometry and in addition has a close relationship to trigonometry (Kallia & Panagiotis, 2009). The theorem which expresses that two similar triangles have their sides proportional and Pythagoras's theorem constitute two basic links between geometry and algebra. The connection of geometry and algebra is particularly relevant to construct, since it permits using the visualization of geometry in algebraic problems and the flexibility of algebraic operations in geometrical problems (Kallia & Panagiotis, 2009). Kallia and Panagiotis (2009) claim that similar triangles and the Pythagoras theorem form the cornerstone of trigonometry. Thus, using similar triangles, we can compute the sides and angles of an object by measuring the lengths of a smaller model.

According to Vollrath (1977) in geometry similarity forms a relationship between shapes/figures. A particular shape F_1 is similar to a shape F_2 if there is a transformation s such as ($F_1 = F_2$, i.e. the square is similar in shape to another one only when the ratio of their sides is the same). Similarity of triangles are used to learn and prove the Theorem of Pythagoras, Circle geometry and Trigonometry in mathematics education. In a study conducted by Mahmud (2020), the Pythagorean Theorem was proven by using 14 original methods.

2.1.2 Learners' difficulties with similar triangles

Various studies discuss the relationship of triangles and similarity, as well as the difficulties learners encounter when learning similarity, such as Baykul (2009) and Biber (2005). Biber (2020) conducted a study that indicated that the subject of similarity is one of the concepts that learners have difficulty understanding and learning. Triangle equality and similarity has been one of the most prominent subjects of geometry teaching since the advent of geometry, and we often encounter these examples in our daily lives (Baykul, 2009). According to Mason (1989), learners are not very successful at discovering similarity types.

According to Poon and Wong (2017), learners experience difficulties in in problems where similar triangles are “overlapped”. In some studies, it is stated that learners have difficulties with questions related to the subject of similar triangles (Parastuti, Usodo, & Subanti, 2018; Gül, 2014; Athanasopoulou, 2008; Aydoğan, 2007; Mayberry, 1983). Literature demonstrates that learners encounter difficulties when learning the similarity of triangles. Therefore, it is vital to determine alternative methods of learning that could have the capability of alleviating learner difficulty such as the use of GeoGebra.

2.1.3 The importance of learning the similarity of triangles

In the context of geometry teaching, the equality and similarity of triangles is of the utmost importance since the development of geometry arose everywhere and we often encounter examples of them in daily life (Baykul, 2009). Baykul alluded to the importance of learning the similarity of triangles. Therefore, the similarity of triangles is one of the most critical topics to be learned by learners. This is because a proper understanding of similar triangles is essential to ensure learners perform better results when studying geometry.

2.1.4 Learners performance in similarity of triangles

A study by Ubah and Bansilal (2019) found that the majority of learners struggled with the symbolic specialized similarity notation (\sim). The symbol \sim is a special notation that indicates that two triangles are in a similarity relationship. For example $\triangle ABE \sim \triangle DCE$ shows that two triangles are similar. However, the symbol \sim specifies much more than that. It specifies the order in which the vertices must be arranged when triangles are configured so that the matching of the corresponding angles and sides is evident. Some learners handled this challenge by executing mental transformations on the objects (Gal & Linchevski, 2010). When the cognitive demand of the mental transformation was higher, learners found it harder to identify the similarity relationship.

2.2 The use of GeoGebra in enhancing learner performance

2.2.1 What is GeoGebra software?

GeoGebra is a dynamic mathematical software that was developed in 2001 by Markus Hohenwarter as a master's thesis and allows to operate geometry, algebra and analysis simultaneously (Hohenwarter & Lavicza, 2007; Preiner, 2008). GeoGebra can be defined as a system due to its ability to express mathematical language and visualize it. However, it is also defined as software because it provides dynamic relationships between concepts such as points, line segments, lines and conic sections. GeoGebra is a math software package that presents a combination of 2D and 3D interactive geometry software, CAS, and spreadsheet features (Weinhandl, Lavicza, Hohenwarter & Schallert, 2020).

Hohenwater formulated a GeoGebra programme which integrates geometry, algebra and calculus into a single package. Dynamic geometry software is a computer programme for interactive creation and manipulation of geometric constructions (Ozcakir, 2013). By manipulating some parts of the model, the software will instantly convert the other parts, so that the constraints are preserved (Ozcakir, 2013). The GeoGebra program may be used for learning and is suitable for use by primary school learners, secondary learners and university students. GeoGebra is easy to download from the internet, and once it is installed on your device, you may access it for free. Gaining knowledge of how to operate the programme requires a person to watch many tutorials or access a user manual. This will provide guidance on how to use the GeoGebra programme. The figure below represents a GeoGebra figure after it has been installed on a gadget (pc, tablet and cell phone).

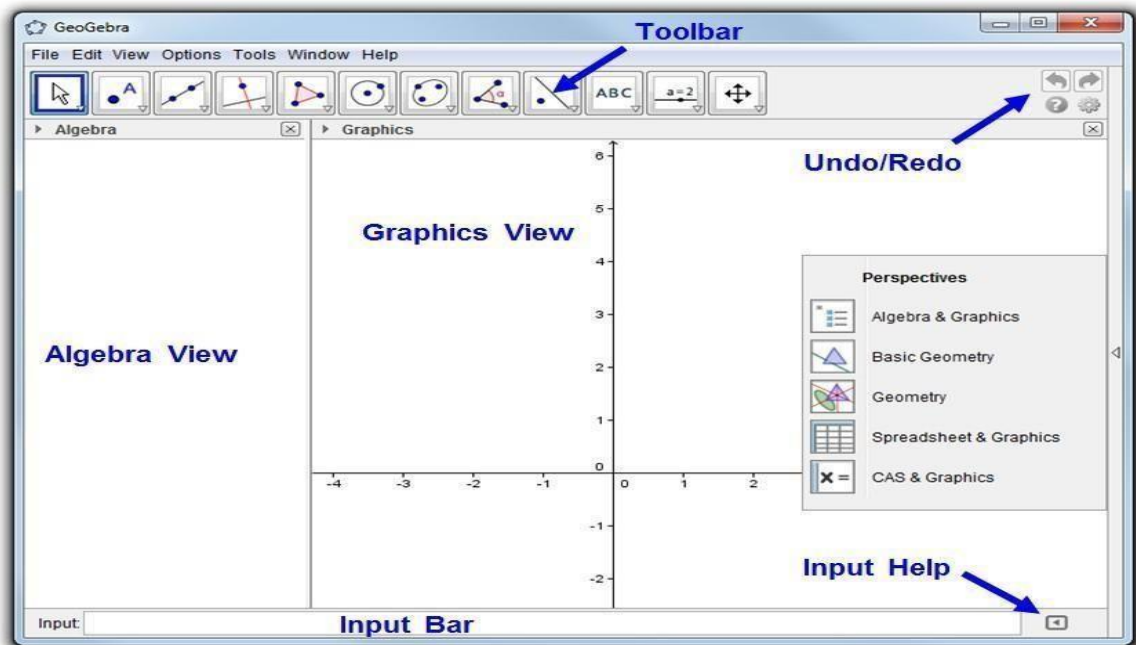
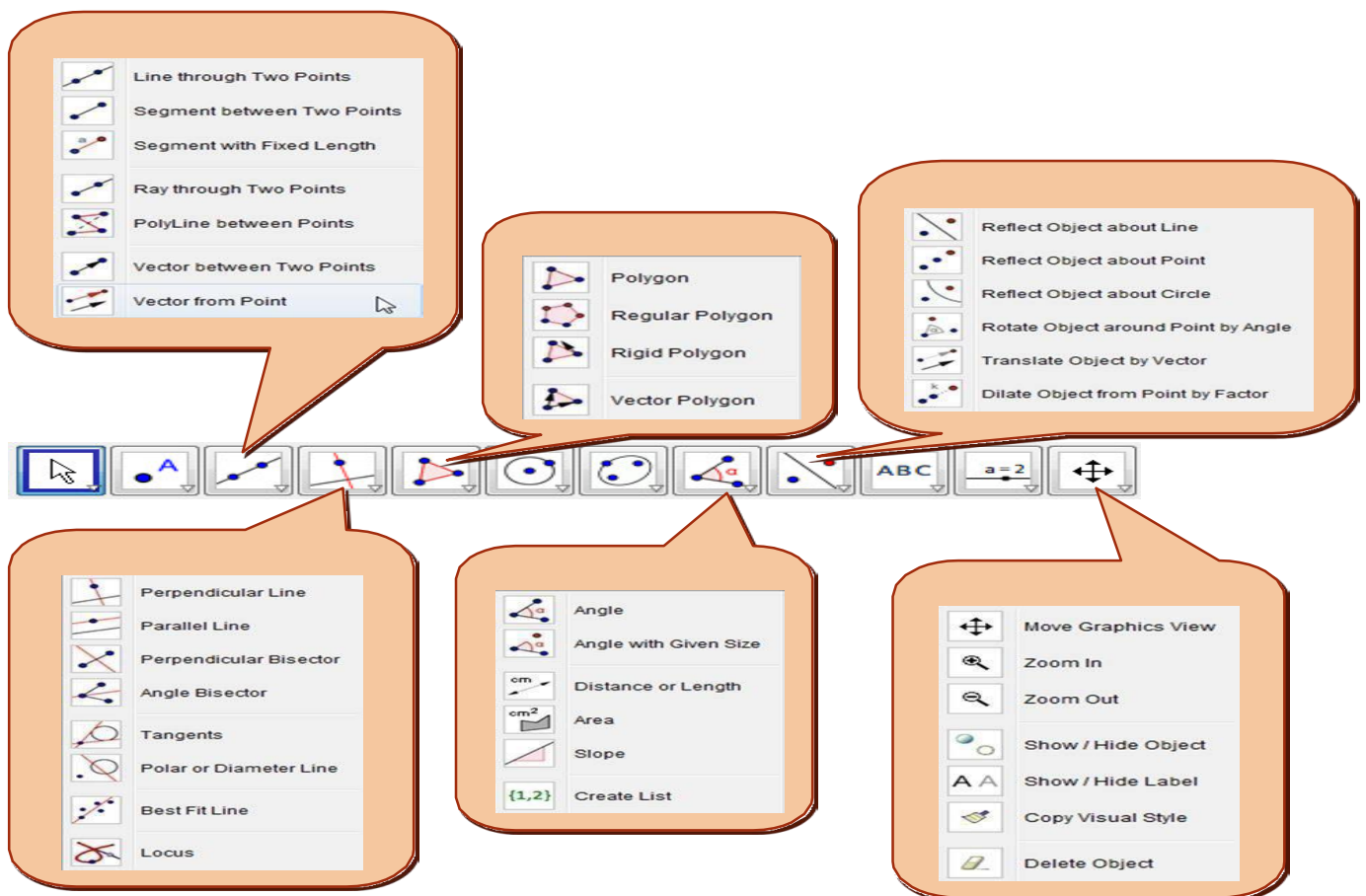


Figure 2:2. GeoGebra screenshot showing window



2.2.2 The benefits of using GeoGebra in teaching and learning of Mathematics lessons

One of the features that differentiate GeoGebra is that it can be used as a system in one aspect and software in the other (Antohe, 2009; Hohenwarter & Jones, 2007). Dikovic (2009) classifies the advantages of GeoGebra software as follows:

- Simple to operate, GeoGebra presents menus, commands and help content translated into multiple languages.
- It enables learners to learn about their activities, studies and projects through experience and discovery.
- It provides learners with the opportunity to customize their work pages.
- GeoGebra is designed to facilitate meaningful math learning. It allows learners the opportunity to solve problems in a dynamic environment.
- The teacher's task is not to convey information directly, but to offer learners with environments that support their mental structures. In this case, GeoGebra provides great opportunities for collaborative learning.
- GeoGebra also offers teachers the opportunity to employ technology in the classroom and bring mathematics to interactive environments.

The benefit of GeoGebra is that it operates on all standard system software and can be accessed through a web browser as well (Iriarte, Aginaga & Ros, 2014).

2.2.3 Learners' motivation for using GeoGebra in mathematics lessons

Many studies on learning geometry have shown an improvement in learners' performance. The learners' perception of GeoGebra in the learning of circles studied by Shadaan and Eu (2013) found that through GeoGebra integration, the learners improved their level of thinking creatively and critically and they were able to construct logical assumptions. According to Vasquez (2015), the application of GeoGebra in learning geometric transformations raised overall learner motivation, engagement and achievement. Learners become more interested in their learning with the use of GeoGebra software because it offers dynamic, hands-on and discovering learning environment. Kekana (2016) found that the use of GeoGebra may stop the negative attitude that some learners are have towards mathematics as many learners perceive mathematics as a problematic subject.

He further alluded that it would be advantageous if mathematics learners had access to GeoGebra. This is because they would use it to practice mathematics and to assist them with their homework. This could even increase learners' enthusiasm for homework. It also provides an opportunity to utilize gadgets at home for educational purposes, whereby instead of using them for games, they utilize them for academic purposes. Dogan (2010) showed that GeoGebra positively affected learners' learning and achievement and improved their motivation. Additionally, the GeoGebra programme increased learners' interest in mathematics (Stols & Kriek, 2012). Study by Kim and Md-ali (2017) and Azizul and Din (2016), revealed that learners were interested in learning mathematics due to their opportunity to use GeoGebra while learning and the opportunity to interact with their peers. Researchers concluded that GeoGebra positively impacts learners' motivation to study mathematics. Learners are highly motivated to learn mathematics with the use of GeoGebra. GeoGebra appears to increase learners' interest in math.

2.3 Euclidean geometry

2.3.1 The background and history of Euclidean geometry

- According to Steyn (2016), Euclidean geometry is a mathematical system associated with Euclid, which he showed in his geometry textbook called "The Elements." Euclidean geometry is the learning of formal axiomatic systems where learners write proofs and solve riders (Yixuan, Lei, Peng, and Jinhong, 2016). As geometric knowledge developed, mathematicians of the time realised there was a need to approach geometry in a more systematic way. This awareness resulted in a breakthrough in Greece around 300 BC with the publication of Euclid's "The Elements" (Fomunyan, 2016), which summarised during the Greece time most of what was known about geometry (Van Manen, 2016).

2.3.2 The key position of this concept, similarity, within the Euclidean geometry

The similarity of triangles is a topic in Euclidean geometry. The previous South African mathematics curriculums all included geometry in all GET (7- 9) and FET (10 – 12) Grades, but from 2008 to 2011, geometry was made optional in Grades 10- 12, hence it was compulsory. The implementation of the revised Curriculum and Assessment Policy Statement (CAPS) in 2012 returned Euclidean geometry as a compulsory section of mathematics after it had been previously been transferred to an optional Paper Three (DoBE, 2011). This implies that Euclidean geometry is difficult to learn. From a Euclidean perspective, the similarity of triangles is one of the topics

that troubles learners, and if administered effectively, this will lead to fewer problems.

The origin of the word geometry is earth measure. Geometry was initially applied to agriculture and construction. Egyptians first used the Pythagorean Theorem to find a square corner for a field or the base of a pyramid. Then empirical and quantitative geometry was transformed by Greek scholars from the sixth through the fourth BC to logically order the body of language. Learning geometry is not just learning the definitions or the attributes of geometric concepts. Also, one should be able to analyze the properties of two and three dimensional (2D and 3D, respectively) geometric shapes as well as develop mathematical arguments about geometric relationships, specify locations and spatial relationships, and apply symmetry, visualization (NCTM, 2000). Therefore, geometry is very appropriate to be included in our mathematics curriculum. Studying geometry is a vital component of learning mathematics. This is because it allows learners to analyze and interpret the world they live in. It also equips them with tools they can apply to other areas of mathematics. Therefore, learners need to develop a proper understanding of geometric concepts and gain adequate geometry related skills.

2.3.3 The learning of Euclidean geometry applying GeoGebra

Godebo (2018) points out that the opportunity to explore Euclidean geometry content which is designed within the GeoGebra program encourages learners to think critically and helps them to develop the ability to recognise mathematical relationships. Godebo also pointed out that teachers must introduce learners to GeoGebra when teaching Euclidean geometry concepts. Mthethwa (2015) found that the application of GeoGebra in the teaching and learning of Euclidean geometry (circle geometry) leads to improved learners' performance, understanding and the justification of proofs and theorems of circle geometry and their application. In Mthethwa's study, learners' perceptions of using GeoGebra to learn Euclidean geometry were examined. This reflected how the learners viewed their performance with GeoGebra while simultaneously learning Euclidean geometry. Only 9% (which was 5 learners) strongly disagreed, with 7 learners disagreeing (13%). The majority of the learners, 78% (46 learners) collectively agreed or strongly agreed that utilizing GeoGebra software in Euclidean geometry has been helpful for them to do well.

According to researchers Mthethwa, Bayaga, Bosse and Williams (2020) participants in GeoGebra investigations were highly motivated, engaged and interactive. They recommended GeoGebra could have far-reaching implications for learning Euclidean geometry. It may further suggest that

multimedia and technological tools should and can be applied to mathematics instruction integration, especially in rural schools, directed to possibly enhance learners' higher-order learning skills (Mthethwa et al., 2020).

2.4 The use of software for math learning

2.4.1 Dynamic Geometry Software

Dynamic Geometry Computer Software (DGCS) includes Cabri geometry, Geometers' Sketchpad, Cinderella, and GeoGebra (Adelabu, Makgato & Ramaligela, 2019). Naidoo and Govender (2014) argue that incorporating DGCS into the learning of geometry improves construction knowledge. In addition, they state that the communication and dissemination of ideas in the geometry classroom tend to improve the learning of geometry. The interactive learning environments of DGCS aid the teaching and learning of abstract geometric concepts in mathematics (Naidoo, 2014). According to Naidoo and Govender (2014), DGCS manipulates learners through influencing them in two ways; learner-centred education and self-regulation. These researchers claim that DGCS make learners think independently. In this sense, teachers act as facilitators, assisting learners when they encountered problems. Therefore, it is through DGCS that learners apply self-regulation. According to Yaacob, Mohamed and Ariffin (2016), DGCS helps learners to acquire complete knowledge of computer technology and improve their skills in geometry. Koparan and Yilmaz (2015) claims that DGCS contributes better to the prospective teachers in the setting of intersection surfaces (3D objects) than the traditional method of using pencil and paper. Therefore, the DGCS has been found to be an effective tool into the teaching and learning of 3D objects in geometry.

2.4.1 Integration of ICT in a geometry lesson

A learning environment equipped with technology usage can enhance the understanding and quality of the education system (NCTM, 2000; Savec et al., 2018; Attard & Holmes, 2020). As research has shown, using technology in mathematics learning creatively and assertively helps individuals develop knowledge and skills needed to meet the demands of 21st-century education and society (Chen, Shih & Law, 2020; Adelabu, Makgato & Ramaligela, 2019; Tamur, Sennen & Men, 2018). Technology integration affords learners with additional practice and the opportunity to look into their problems and to express their findings with different alternative answers (Nurjanah, Latif, Yuliardi & Tamur, 2020; Gonzalez and Birch, 2018; Juandi and Priatna, 2018; Sung, Chang & Liu, 2016).

Teaching and learning with the use of technology has various advantages such as offering

enhanced learning opportunities for learners (Roberts, 2012); as well as improving learner participation (White, 2012) and promoting discovery learning (Bennet, 1999). In the teaching and learning of mathematics, especially geometry, it is imperative for learners to be able to imagine, construct and understand the construction of shapes. This is in order to connect them with related facts. Therefore, a computer will help learners imagine and make observations (Dogan, 2010). Hence, the incorporation of technology into a classroom contributes positively in many different ways.

2.4.2 Learning geometry with ICT as opposed than the traditional method

Geometry textbooks usually present shapes only in pencil and paper form. It may not be easy to understand a textbook-based illustration rather than a visual description of the process necessary for the construction of geometric concepts (Denbel, 2015). The reason for this is that the textbook cannot visualise the dynamic nature of geometrical figures on paper. As a consequence, learners are compelled to mentally look into the possible properties of geometrical objects without an external way to increase understanding of the related concepts (Denbel, 2015). This leads to learners often failing to develop insights into the cognitive concept (Mehdiyev, 2009; Denbel, 2015). This problem persists in the teaching and learning of geometry. This is because it provides no dynamic feature that may facilitate the justification and validation of definitions, axioms and theorems in a perspective manner (Mehdiyev, 2009). Mathematics is taught in a traditional manner, in which learners' imaginations and previous knowledge are not considered (Moloi, 2013).

2.4.3 Teachers' perceptions of ICT in the classroom

Bower, Hedberg and Kuswara (2010) declare that the incorporation of ICT in a learning environment encourages interactive engagement between learners and their teachers, and amongst learners themselves. A study conducted by Mokotjo and Makgalwa (2021) on Mathematics Teachers' Perceptions of the Value of GeoGebra Integration in South African High Schools contributed to the perceptions by Mr Golenyane, Mr Maziya and Mr Magwe. Mr Golenyane highlighted that he found GeoGebra to be teaching mathematics as outlined in the CAPS document. He applauded GeoGebra as a useful innovation in the teaching of geometry. Further, 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 was: "CAPS covers lots of topics. You know, like geometry, when we are going to be tackling the 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 utilized GeoGebra in teaching geometry, giving illustrations on how the circle has four spheres and how he used GeoGebra to demonstrate this: Why are they saying that? And then, using the GeoGebra program, you simply need to go there and pick the sphere. Then you can simply show them why we say the sphere has four circles. Maziya regarded GeoGebra relevant to teaching mathematics in line with the South African curriculum. He gave examples of the correlation between CAPS and GeoGebra and declared that CAPS required graphs to be taught to Grade 9 learners, especially how to draw graphs. Mr Magwe confirmed that GeoGebra has the ability to encourage learners to be enthusiastic about learning, and hence it encourages independent learning. He mentioned that learners would be eager to share their learning experiences after they had worked on some mathematics problems independently.

2.4.4 Additional programs to explore during mathematics learning

2.4.4.1 Geometers Sketchpad

Geometers' Sketchpad (GSP) is software that can be used in geometry to advance teaching and learning (Kesan & Caliskan, 2013). Geometer's Sketchpad can be used by learners and teachers as a useful instrument for helping them in learning geometry (Hartono, 2020). The GSP provides the user with the opportunity to explore simple, as well as highly complex, theorems and relations in geometry (Giamatti, 1995).

Geometer's Sketchpad (GSP) can be utilized by learners and teachers as an enhanced tool to help them in learning geometry (Hartono, 2020). In other words, it is a software program to help learners understand geometry. This is done by starting with points, lines, and angles, and progressing to more complex understandings such as arches, turns and transformations (Hartono, 2020). Learners can associate points and lines that are connected with angles in a way that is easy to understand. Kesan and Kaliskan (2013) presented some GSP characteristics, which are narrated below:

- a. Accuracy in terms of digitally painting and measuring
- b. The process of visualization from the beginning with diverse dimensions is easy to understand
- c. Can be used to facilitate learners conducting investigations, exploration and problem solving
- d. Confidence and strong reasons for learners' in making conclusions can even provide motivation for doing proof
- e. Has specific characteristics, animated images, trace images, and provides features to simulate various simulations.
- f. Click on The Geometer 'Sketchpad, so that you get a view like Figure 2:4



Figure 2:4. The view of the Geometer's Sketchpad

2.4.4.2 The use of Geoboard

Geoboards are mathematical manipulatives used to discover basic concepts in plane geometry such as the perimeter, area and the characteristics of triangles and other polygons (Carroll, 1992). Originally, “they were typically made of wood with nails driven half way in and utilized elastic bands to form shapes with the nails. Geoboards were invented by the

Egyptian mathematician, Caleb Gattegno” (Carroll, 1992). Scandrett (2008) elucidates the Geoboard as a flexible tool that can be used at all levels for teaching and learning about different areas of mathematics.

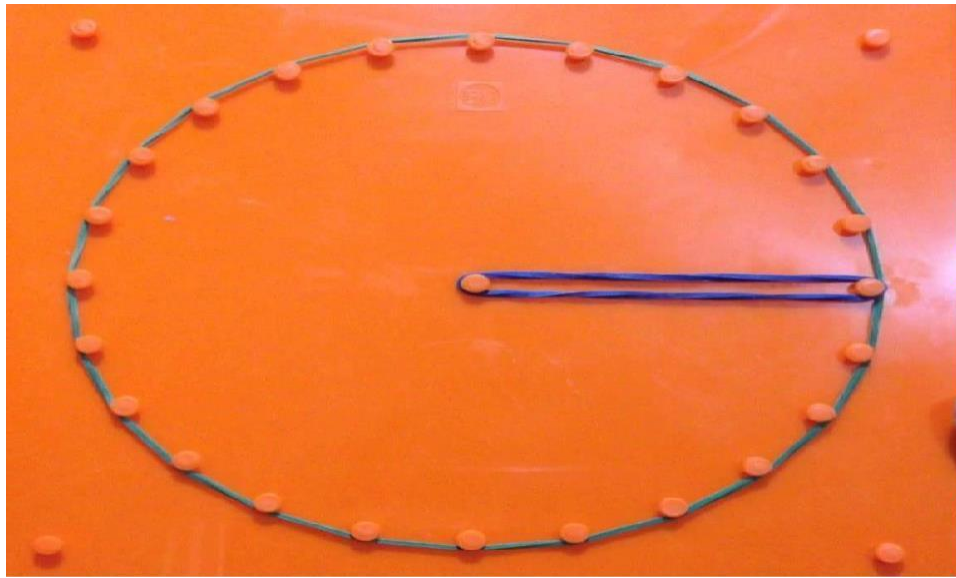


Figure 2:5. Geoboard (Source: Carroll, 1992)

Sibiya (2019) found that most learners had poor fundamental knowledge of geometry theorems, so using a Geoboard in mathematics classes will help to enhance learners’ comprehension of geometry theorems. Geoboards have the potential to develop learners’ motivation levels for learning these theorems.

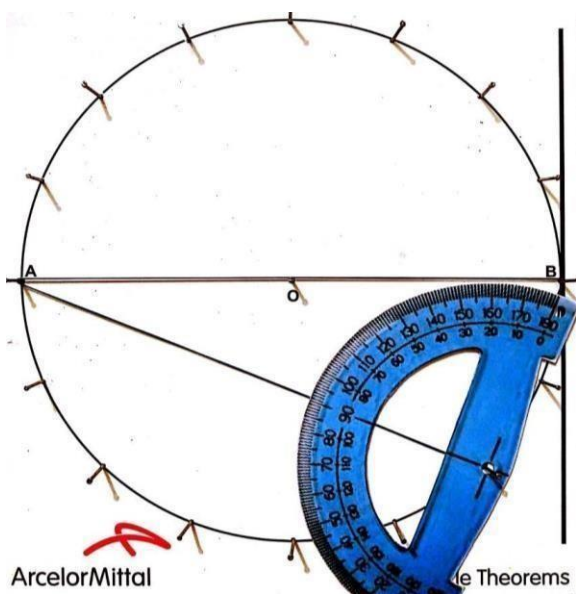


Figure 2:6. Source: Participant 5 (Sibiya, 2018)

2.5 The impact of GeoGebra on learning mathematics

2.5.1 Hindrances to learning mathematics using GeoGebra

One of the challenges of using GeoGebra, according to Mthethwa (2015), is the potential for misplaced or corrupted registry files, outdated drivers and malicious spyware. In addition, GeoGebra files can be corrupted or deleted through improper program installation or removal. These may lead to serious problems of the kind

listed below:

- It takes a long time to start up or shut down the computer, as well as to open a website or launch a program;
- Some programs are unable to be activated and used as normal;
- Contrary malicious programs are downloaded or installed unawares;
- Annoying error messages constantly pop up on the computer;
- Blue ‘screen of death’ occurs occasionally;
- System at times crashes;
- Windows settings can be changed adversely.

During orientation on how to use GeoGebra software, the researcher discovered that teaching learners how to use GeoGebra software takes a very long time.

2.5.1 The GeoGebra programme incorporates self-discovery

The study by Matthews (2017) incorporated a question that asked about the successes Matthews experienced utilizing GeoGebra to integrate MP5 into an Algebra II unit of study. Results indicated that his instruction targeted a deeper level of mathematical understanding. This targeting of a deeper level of understanding also resulted in the use of discovery learning. In particular, his instruction shifted from not utilizing discovery learning to implementing it. This was with the goal of helping learners see the connection between algebra and its graphical representation. This emphasizes the importance of self-discovery.

The study by Tran, Nguyen, Bui and Phan (2014) on discovery learning with the assistance of GeoGebra Dynamic Geometry Software discusses the perspective of discovery learning, the role of discovery learning and the types of learning in mathematics. The researchers noted that the teacher would pose questions so that the learners themselves could gain knowledge of what the teacher intends to teach by completing discovery acts. This is done through GeoGebra, thus aiding the teaching and learning process. Tran et al. (2014) pointed out that as the GeoGebra software is dynamic, it promotes discovery learning to a high extent. Literature demonstrates that the use of GeoGebra in a mathematics lesson and self-discovery are inseparable. Self- discovery deepens mathematical understanding of a learner.

2.5.2 Visual learning through the use of GeoGebra

The use of GeoGebra provides learners with more opportunities to visualize geometric concepts, which usually accommodates below-average learners (Mthethwa et al., 2020). According to Kilic (2010), the process of learning geometry involves visualizing geometric concepts at the same time as constructing images (shapes and patterns) associated with geometric concepts. In addition, Kutluca (2013) and Özçakir (2013) also shared the same view that in studying geometry, learners should be able to develop some of these basic skills: logical thinking abilities, spatial intuition about the universe, comparing and generalising, being careful and patient, reading and comprehending based on the geometrical concept. Hence the intervention with dynamic geometry computer software will help enhance learners' understanding in logical reasoning in mathematical concepts and increases their performance (Adelabu, Makgato & Ramaligela, 2019). GeoGebra developed visualization and understanding of different mathematical topics such as geometry and functions (Akkaya, Tatar & Kagizmanli, 2011; Thambi & Eu, 2013). Vasque (2015) points out that the GeoGebra software, with its features in terms of visualisation, may help in improving learners' understanding of Euclidean geometry concepts in mathematics.

2.6 Conclusion

The literature reviewed reflects a positive outcome when learners are taught Euclidean geometry using GeoGebra. Researchers examined the benefits associated with GeoGebra and the improvements in mathematics learning that occurred when using GeoGebra. Due to this, this study will either support or not support the existing literature regarding the use of GeoGebra. In particular, it will help with the teaching of Euclidean geometry in the senior phase. The next chapter will discuss in detail the theoretical framework used in this study.

Chapter 3

Theoretical Framework

3.0 Introduction

The previous chapter presented a literature review related to this study. This chapter discusses the theoretical framework that underpins the present study. The chapter begins by explaining the concept of a theoretical framework. The aim of the current study is to explore the capability of the GeoGebra program towards alleviating learner difficulty in learning the similarity of triangles. The study also aims to explore learners' perceptions when learning similar triangles using GeoGebra.

The purpose of this chapter is to outline the theoretical framework on which the current study is based. In this chapter, learners' perceptions of how instructional material should be designed and provided to make sense of their learning experiences are discussed. Constructivism supports learners' attempts to make sense of their perceptions. Therefore, this section highlights constructivist perceptions about modern mathematics learning. As a consequence, constructivism was adopted as a theoretical framework in the present study.

3.1 Constructivism as a theory

In this study, constructivism may be defined as a style of teaching that prioritizes the learner as an agent of knowledge acquisition and understanding (Mohammed & Kinyo, 2020). Dagar and Yadav (2016) define constructivism in education as follows: Learners are required to construct their own knowledge individually and collectively. Each learner has a tool kit of concepts and skills with which he or she must construct knowledge to solve problems presented by the environment. The role of the community, other learners and teacher is to provide the setting, pose the challenges, and provide the support that will encourage mathematical construction. The central principles of this approach are that learners can only make sense of newly encountered situations of their existing understanding. Learning involves constructivism, where learners create meaning by linking newly acquired ideas with their existing knowledge (Dagar & Yadav, 2016).

3.2 The constructivist approach

Constructivism is ‘an approach to learning that promotes that people actively create or make their own knowledge and that reality is determined by the experiences of the learner’ (Elliott, Kratochwill, Littlefield Cook, & Travers, 2000). The constructivist approach is based on the idea that knowledge can never be transferred from one person to another, therefore the only way to acquire knowledge is to create or make it (Vintere, 2018). It is for this reason that this study employed the use of GeoGebra as a learning tool to facilitate the learning of the similarity of triangles. The ability of GeoGebra to visualize diagrams and give learners the opportunity to abstractly construct activities themselves, increases the chances of the learner to construct new knowledge on their own. Considering the fact that as people experience the world and reflect on their own experiences, they build their own representations and incorporate newly acquired information into their pre-existing knowledge. Sultan, Woods and Koo (2011) outline a constructivist approach as one in which learners construct their knowledge based upon their interpretation of events and previous experiences.

3.3 The principles of constructivism

According to the principles of constructivism, learning improves when teachers actively engage with the real world (Vygotsky, 1978). The role of the teacher is to create a conducive learning environment. In a traditional learning classroom, learners are recipients of knowledge while teachers are the only source of knowledge. Constructivism challenges this situation with the concept of viability, which states that all descriptions of events in the world appear identical to whoever observes them (Glaserfeld, 1995). Thus, from the constructivist perspective, knowledge is not passively received from the world but constructed by learners to make sense of the world they experience (Maclellan & Soden, 2004).

3.4 Constructivism approaches to teaching

Tam (2000) mentions the following four basic characteristics of constructivist learning environments that must be considered when implementing constructivist teaching strategies:

- 1) Teachers and learners will exchange knowledge.
- 2) Teachers and learners will share authority, which will be shared between the teacher and learners.
- 3) The teacher's main role is to be a facilitator or guide the lesson.

4) Learning groups will comprise small numbers of heterogeneous learners.

Table 3:1. Traditional classroom as opposed to constructivist classroom (Source: McLeod,2019)

Traditional classroom	Constructivist classroom
Strict adherence to a fixed curriculum is highly valued.	Pursuit of learner questions and interests is valued.
Learning is based on repetition.	Learning is interactive, building on what the learner already knows.
Teacher-centered.	Learner-centered.
Teachers disseminate information to learners; learners are recipients of knowledge (passive learning).	Teachers have a dialogue with learners, helping learners construct their own knowledge (active learning).
Teacher’s role is directive, rooted in authority.	Teacher’s role is interactive rooted in negotiation.
Learners work primarily alone (competitive).	Learners work primarily in groups (cooperative).

Constructivism is a theory of learning and cannot be regarded as a theory of teaching (Fosnot 1996; Richardson 2003). Constructivist teaching theory, based on constructivist learning theory, is a set of prescriptions that challenge the transmission or behaviorist paradigms advocated in many education programs. Experiential learning, self-directed learning, discovery learning, inquiry training, problem-solving learning, and reflective practice are exemplars of constructivist learning models (Gillani 2003; McLeod 2003; Slavin 2000). Constructivism is defined in terms of its relation to teaching. According to Fosnot (1996), teaching based on constructivism discounts the idea that concepts can be taken apart as discrete entities and taught out of context. Rather, constructivist teaching provides learners with concrete experiences in which they can look for patterns, ask their own questions.

In constructivism, the classroom becomes a micro-society in which learners jointly partake in activity. Teachers guide rather than dictate. Empowerment and reciprocity of social relations make up a constructive classroom (Fosnot, 1996). Learners can develop in-depth understandings of the instructional materials and establish complex cognitive maps to correlate bodies of knowledge and understandings (Richardson, 2003).

3.5 Constructivism in mathematics education

Constructivism also changes the role of the teacher in the educational process, as their task is to organize the environment so that the learner can construct their own cognitive forms according to what the teacher wants them to do (Vintere, 2018). According to Cobb (1998), there are two fundamental reasons why constructivism can be an alternative to more traditional methodologies. The first reason is that learners are capable of solving a wide variety of mathematical

problems since they develop more complex and abstract structures. The second reason, through the construction of their own knowledge, looks at learners changing their perspective because they have the potential of creating and controlling mathematics. This increases learners' motivation. Moreover, Bermejo, Ester, and Morales (2021), point out that teaching mathematics and enhancing mathematics competence are unsettled issues within our educational system; thus, a constructivist intervention program for the improvement of math performance empowers various agents involved in math learning, ensuring a significant improvement in learners' performance.

3.6 Constructivism and Technology

In a constructivist and technology-rich classroom, learning is achieved through a learner-centred teaching, which facilitates the learning process (Vinu, Sherimon & Krishnan, 2011). Technology also provides learners with opportunities to discover how to perform tasks that are beyond their habits (Machado, 2012). Additionally, laptops, mobile phones and tablets provides learners with learning opportunities anytime, anywhere (Machado, 2012). The technology associated with game-based learning affords learners the opportunity to experience real-life contexts in online modes (Routledge 2009). Technological skills themselves are regarded as a necessity for progress in current and future societies.

By combining constructive approaches to learning and technology, learners obtain more than one useful skill (Goloi & Osman, 2018). With a constructivist view, this study incorporates technology, allowing learners to perform learning tasks in a mathematics classroom using an ICT method that is supported by the constructivist view. As technology was applied in this study, it facilitated a learner-centred lesson during the conduct of the study.

3.7 Conclusion

The chapter provides an overview of constructivism and the theoretical framework adopted in this study. The teachers' responsibility when preparing for a mathematics lesson must change from a traditional classroom to a constructivist classroom. What follows is the chapter that presents descriptive explanations of the methodology adopted in the present study.

Chapter 4

Research Methodology

4.0 Introduction

This chapter describes the current research site, the target population, the research, approach, research plane and the data collection procedures. The data capture instruments and strategies are discussed in this chapter as are the research approach and data analysis strategies. Appropriate research design has been implemented in order to establish answers for the research questions presented in Chapter One. The study explores Grade 9 learners' use of the GeoGebra programme when learning similarity of triangles in a public school in the Pinetown district, a district in the province of KwaZulu-Natal, South Africa.

4.1 The Research Approach

In line with the pragmatic research philosophy which consists of both the quantitative and qualitative methods, this study adopted a mixed-method design in the form of an exploratory case study. The mixed method research design adopted a triangulation design methodology, which incorporates quantitative and qualitative methods. According to Maxwell (2004) and Maxwell and Loomis (2002), the two methods (quantitative and qualitative) are tools utilized to perform the same goal with different techniques and procedures, despite the fact that they have different strengths and logic. This study was conducted according to the quantitative phase and the qualitative phase in order to find answers to the research questions. To this end, employing the positivism philosophy quantitative data were collected through the Similarity Achievement Test (SAT) and from the close-ended questionnaire. Qualitative data under the interpretivist philosophy will be sourced from the open-ended questions.

4.2 Paradigm

The aim of the present study is to explore the capability of the GeoGebra software towards alleviating difficulty in learning similarity of triangles. The study also aims to explore the learners' perceptions when learning about similar triangles through the GeoGebra application. To address the research aims and questions, this study adopted the mixed method approach, namely:

4.2.1 Positivism

4.2.2 Interpretivism

4.2.1 Pragmatic paradigm

The pragmatism paradigm stems from philosophers who proclaimed that it was impossible to access the ‘truth’ about the real world solely by using a single scientific method as promoted by the positivist paradigm nor possible to determine social reality as constructed under the interpretivist paradigm. In other words, a mono-paradigmatic orientation of research was not sufficient to understand the world. Rather, these philosophers (Alise & Teddlie, 2010; Biesta, 2010; Tashakkori & Teddlie, 2003a, 2003b; Patton, 1990) assert that a worldview which would provide methods of research that are seen to be more appropriate for studying the phenomenon at hand were needed. It is for this reason that, for the purpose of the study, pragmatic paradigm was deemed suitable because it consists of more than one paradigm. Hence, this study adopted the positivist and interpretivist paradigms.

4.2.1 The positivist paradigm

The positivist paradigm defines a worldview to research that is grounded in what is recognized in research methods as the scientific method of investigation (Kivunja & Kuyini, 2017). Comte (1856) postulated that experimentation, observation and rationale based on experience ought to be the basis for understanding human behaviour, and hence, the only legitimate means of extending knowledge and human understanding.

4.2.2 The interpretivist paradigm

Central to the interpretivist paradigm is to possess the knowledge of the subjective world of human experience (Guba & Lincoln, 1989). This approach creates the effort to ‘get into the head of the subjects being studied,’ and to understand and interpret what the participant is thinking or the meaning he or she is making of the context. Every possible attempt is made to understand the point of view of the participant being observed, rather than the viewpoint of the researcher. Much emphasis is placed on understanding the participant and their interpretation of the world around them. The view of the interpretivist paradigm is that reality is socially constructed (Bogdan & Biklen, 1998). Hence, this study has adopted the interpretivist and positivist paradigms to conduct its investigation.

4.2.3 Data collection

The study adopted three types of instruments for collecting data, which were the following:

- The Similarity Achievement Test (SAT)
- A close-ended questionnaire
- Open-ended questions

Initially, the Similarity Achievement Test (SAT) were administered for both the pre- intervention and post- intervention assessment which consists of close-ended questions. The test will be based on the Grade 9 and 10 CAPS document, as well as ANA (Annual National Assessment) past papers, to measure learners' understanding on learning the similarity of triangles.

The second instrument will be a researcher designed self-report questionnaire for the participants which was blended in that, it consisted of close- ended questions, to measure the learners' experiences. Furthermore, the close – ended items from the questionnaire were a researcher designed instrument that consisted of a 4-point Likert-scale questionnaire in which participants demonstrate their degree of agreement were used, such as: Strongly Disagree; Disagree; Agree and Strongly Agree. The third instrument comprised of three open – ended questions which were designed by the researcher, to measure learners' perception on learning similarity of triangles using GeoGebra.

4.3 Data generation procedures

The study consisted of two stages during the first stage which was held for one week, the learners were taught by a mathematics teacher who has taught the senior (Grade 7–9) and FET phase (Grade 10–12) for 32 years with the application of the traditional chalk and talk learning approach. Then, a pre-intervention assessment was allocated to the participants. The result of the pre-intervention assessment was recorded and scores were noted.

The second stage, was conducted for three weeks. The researcher, who has an 8- year experience in mathematics teaching and has a degree in mathematics education, will be in charge for conducting stage two that will incorporate the implementation of the GeoGebra software learning and teaching, utilizing tablets. Hence, week one of the second stage was utilized for orientating and introducing the GeoGebra software in order to acquire knowledge and skills of geometric objects and GeoGebra tools/icons. Subsequently, week two of the second stage employed the intervention teaching and learning using GeoGebra software, thereafter week three

was allocated for the post- intervention assessment and for collecting the questionnaire data as well as the open-ended questions. The result of the post-intervention assessment was recorded, and scores were kept aside.

Finally, after the implementation of the post-intervention assessment that entailed the GeoGebra software, learners were administered to contribute their opinion and experience to the close-ended questionnaire as well as on the open-ended questions. Each close-ended questionnaire was recorded, then analyzed. The use of a questionnaire and open-ended questions helped in obtaining insight into learners' experiences of GeoGebra software, especially their perceptions of GeoGebra in the learning of similarity of triangles.

4.4 Sampling

The present study employed non-probability sampling techniques. Convenience sampling was adopted for the study. Sixty learners studying at Sondelani Full Service School that were willing to participate comprised the population of the study. The comprised of learners only willing to participate in the study voluntarily, with the consent from the parents. The participants were 60 Grade 9 learners from Sondelani Full Service School, a school from Ntuzuma Township, Durban, KwaZulu-Natal. A full service school was preferably chosen to conduct the study as a school that offers Inclusive Education. Hence, the application of technology and visual teaching aids is highly recommended to apply in Inclusive Education to accommodate learners with learning difficulties. The socioeconomic background is one resembling majority of disadvantaged learners with some exemption from paying school fees. The researcher identified the need to integrate mathematics teaching and learning utilizing technological devices for the advancement of mathematics results.

4.5 Reliability, validity and rigour

4.5.1 Validity

According to Tomal (2010), there are various types of validity. Firstly, to begin with, content validity refers to the test used to measure subject content. This test was devised by experts in the field who gave professional opinions to ensure that the test was valid. Second is internal validity which focuses on the viability of causal links between independent and dependent variables, and lastly is external validity refers to the generalizability of the results. The pre-intervention assessment and post -intervention assessment scores were submitted to experts for moderation to ensure the validity of these instruments. The validity of the instrument

(Similarity Achievement Test) was assessed by two teachers with more than 30 years of teaching Mathematics geometry and revised in accordance with their feedback.

4.5.1 Reliability

According to Arthur, Waring, Coe and Hedges (2012), reliability has to do with the consistency of the measurements obtained; they further explained that consistency is concerned with the similarity of the scores overtime. The test–retest of employing a pre- intervention and post- intervention test for the Similarity Achievement Test (SAT) measured the reliability of the results.

4.5.2 Ethical considerations

Researchers have a duty to ensure that their research complies with ethical standards to look after the safety of the participants from unfair criticism that may arise from participating in the research (McMillan & Schumacher, 2010). The applications for consent and permission will be sent to all participants willing to participate in the study before the conduction of the study. A permission letter from the school principal was requested for the research (see, Appendix D) and the school principal signed a gate keeper permission letter for the research study.

The letter to obtain permission to conduct the study was submitted to the University of KwaZulu-Natal through my Supervisor’s office and an ethical clearance certificate was received from the University of KwaZulu-Natal research office (Appendix G). The informed consent of each participant was presented in writing (Appendix E). The participant’s parent or guardian signed the informed consent to approve that their children would be involved in this study (Appendix E). A workshop was conducted to inform the participants about the study. The benefits, rights, risks and dangers involved as a result of their involvement in the research were discussed. All participants were informed from the onset of the research that their involvement was voluntary and that they could withdraw at any point, without penalty (Denzin & Lincoln, 2005). The participants were then asked to read and sign the consent form.

Participants were further asked that should any unforeseen circumstances occur; they are free to withdraw from participation. Participants voluntarily agreed to be part of the study. The data obtained during this study was treated with confidentiality and all materials used were kept but will be destroyed immediately after the awarding of research. I used English as medium of communication in order to avoid discrimination due to language barrier. As a researcher, I clarified

the objectives of the research to the principal and school management team of the participating school.

The participants were informed that anything discussed during the study would be kept confidential and would not be used for purposes outside this study. This study used pseudonyms instead of real names of the participants and the names of the schools to protect their identity. The learners' identity was not exposed in the study. I clarified to the participants that there would be no payments due to them after they had participated in this study; however, I committed to discuss with them the results of the study when finalised.

The study employed the ethics rules and codes which are founded on principles of 'respect for persons, beneficence (and non-maleficence) and justice' Brooks, de Riele and Maguire (2014), also the ethics by Brown and Krager (1985) which determined the following five ethical principles, these principles are autonomy (informed choice), non-maleficence (do no harm), beneficence (do positive good), justice (equality and fairness) and fidelity (honesty and faithfulness). Furthermore, the following Creswell's (2014) and Wassenaar and Mamotte's (2012) principles were observed through the following approaches:

- **Beneficence:** this study has provided a valuable contribution towards the community's wellbeing. The results of the study will probably assist the schools of the Pinetown District in the KwaZulu-Natal Province of South Africa. Feedback of the results is expected to be given to the Sondelani Full Service School.
- **Non-maleficence:** in this study there was no anticipated harm that could be caused to the participants.
- **Protecting the participants' anonymity and confidentiality (informed choice)** by ensuring that their identity is pseudonymous, and their information obtained during this study was treated with confidentiality and all materials used were kept but will be destroyed immediately after the study is finished.
- **Employing fidelity,** the study avoided using deceptive practices such as informing them of rewards they will receive, if they participate, hence participants were informed that no gifts shall be rendered to them.
- **Employing justice** where by giving the participants the right to withdraw from the research, when they want to withdraw.

The purpose of the study was explained in the consent form (Appendix E & F). The participants were assured that the information they provided towards this study would not be used for any purpose other than research and they were told that all attempts will be made to keep their names confidential.

4.6 Conclusion

The chapter presented the research methodology used in the study and discusses research methodology, research approach, research paradigm used, data collection, data generation procedures, sampling, reliability and validity considerations as well as the ethical issues covered in this study. The next chapter seeks to present results analysis of the study.

Chapter 5

Results and Discussion

5.0 Introduction

In the previous chapter, the methodology of the present study was discussed. This chapter presents the analysis of data generated from Grade 9 participants who formed part of this study. The data were generated using the pre and post SAT intervention test, the questionnaire and open-ended questions. This chapter is organised into several sections. The first part provides the outline of data generation strategies. The second part focuses on answering research question 1: Does GeoGebra have the capability to alleviate difficulty towards learners' conceptual understanding of similarity? The third part addresses research question 2: What are the learners' perception of learning the similarity of triangles with GeoGebra? The last part addresses the conclusion and summary of this chapter.

5.1 Data generation strategies

Table 5:1 is provided to illustrate the strategies that were used to generate data from the participants to answer the research questions. As indicated in Chapter Four, pseudonyms were used to protect the learners' identity.

Table 5:1 The description of the processes of data generation strategies

The research questions are:	Participants	Data generation methods
1. Does GeoGebra have the capability to alleviate difficulty towards learners' conceptual understanding of similarity?	Pseudonyms: Participant 405 Participant 406	The Similarity Achievement Test (SAT) pre-intervention and post-intervention assessment, Questionnaire.
2. What are the learners' perception of learning the similarity of triangles with GeoGebra?	Pseudonyms: 1. Participant 117 2. Participant 229 3. Participant 329 4. Participant 415 5. Participant 524 6. Participant 816	The Similarity Achievement Test (SAT), Questionnaire and open-ended questions.

The present study focused on exploring Grade 9 learners' use of the GeoGebra software when learning about similar triangles. Data were obtained from Grade 9 Mathematics participants. These participants conducted an experiment using the GeoGebra and their performance on the

instruments is discussed. Two research questions were taken into attention when the questions for the pretest, posttest, questionnaire and open-ended questions were designed.

5.2 Analysis of quantitative results

5.2.1 *The perceptions of GeoGebra questionnaire*

A self-report questionnaire instrument was designed by researcher and administered to sixty (60) participants. The questionnaire consisted of close-ended statements designed to measure the learners' experiences with GeoGebra. Furthermore, the close-ended items in the questionnaire consisted of Likert-type statements and a continuum of four possible response items to demonstrate participants' degree of agreement or disagreement, namely: *Strongly Disagree =1; Disagree=2; Agree=3; and Strongly Agree=4*. These bipolar statements provided a broader range of responses and each item was coded as a numerical score so that the data could be analyzed quantitatively. On the whole, the statements measured different aspects of learners' perceptions of GeoGebra as they worked with similar triangles. It is important to point out that the data analysis decision for Likert-type items was made at the questionnaire development stage. This study used Likert-scale data which was treated as interval data because a composite score was obtained from summing up answers to the ten statements. Put another way, the scores from each statement were combined into a single total score for each participant. This approach allowed for the determination of the average score and the standard deviation of the participants' scores.

5.2.2 *The Similarity Achievement Test (SAT) instrument*

The analysis of the data was guided by the first research question, "What is the difference (if any) in understanding similar triangles between learners taught with traditional methods and those taught by integrating GeoGebra into understanding similar triangles?" To answer this question, an SAT was administered for both the pre-intervention assessment and post-intervention assessment which consists of close-ended questions during phase one. The test was based on the Grades 9 and 10 CAPS document, as well as ANA (Annual National Assessment) past papers, to measure learners' understanding on learning the similarity of triangles. The t test was used, with the assistance of SPSS, to analyse the SAT data because the differences between pairs of data were normally distributed the samples were sufficiently large ($n = 60$). This matched pairs test was appropriate not only in that the data were matched but also that

the dependent variable (that is, participants' scores) was continuous and no tied ranks were anticipated for maximum accuracy. The interpretation in this test entails comparing the means between the two groups of participants to determine if there is a difference in performance and if this difference is significant.

5.2.3 Results

In this section, I present statistical results relating to the administration of learners' perceptions of GeoGebra integration into similarity of triangles and the testing of learners' understanding of the similarity of triangles using the SAT.

5.2.3.1 Preliminary analysis of Learners' Perceptions of GeoGebra Questionnaire

Table 5:2. Item statistics of SAT

	Mean	Std. Deviation
I enjoyed learning similarity of triangles using geogebra software	2.90	.817
I like studying similarity of triangles lessons with geogebra software	3.07	.716
I learnt a lot using geogebra more especially i understood the similarity of triangles concepts taught	2.97	.920
I felt confident using the geogebra software during activities since there is accuracy	2.80	.879
I was very engaged in the learning process	2.85	.820
I benefited a lot through interaction with the teacher	3.05	.852
I was able to visualise and answer the questions after each activity	2.93	.861
I was excited to learn similarity of triangles in geometry much using	3.07	.778
I believe i will do well in similarity problems	2.95	.946
Knowing similarity correlation matrix of triangles will help me improve my mathematics results	2.95	.946

Table 5:2 provided the first insight into the appropriateness of the data for factor analysis. Initially, the correlation matrix was examined to gain insight into how each of the 10 items was associated with each of the other 9. In line with Nunnally and Bernstein's (1994) guidelines, correlations were acceptable if they exceeded $\pm .30$. Some of the correlations were not only higher than .60 but were also positive. Whereas relatively high correlations indicate that two items are associated and will probably be grouped together by the factor analysis, items with low correlations indicate that they will not have high loadings on the same factor. In other words, the correlation matrix provides a window into cluster of items that could well be the manifestation of the same underlying factor. Then, the correlation matrix was further examined for multicollinearity in the items.

Although the items had to be inter correlated, the correlations should not be high because multicollinearity makes the determination of the unique contribution of the items to a factor difficult (Field, 2009). In this study, the value of the determinant of the correlation matrix was 5.25×10^{-10} . According to Field's (2009) threshold of 1.00×10^{-5} , this value is very close to zero which suggested that collinearity was high. However, the final decision of whether or not to continue with the analysis of the results was primarily based on the KMO statistic (Mooi, Sarstedt, & Mooi-Reci, 2018).

Table 5:3. The interitem correlational matrix

	1	2	3	4	5	6	7	8	9	10
1 I enjoyed learning similarity of triangles using Geogebra software	–									
2 I like studying similarity of triangles lessons with Geogebra software	.683	–								
3 I learnt a lot using Geogebra more especially i understood the similarity of triangles concepts taught	.660	.626	–							
4 I felt confident using the Geogebra software during activities since there is accuracy	.500	.566	.599	–						
5 I was very engaged in the learning process	.468	.457	.402	.626	–					
6 I benefited a lot through interaction with the teacher	.499	.674	.616	.431	.535	–				
7 I was able to visualise and answer the questions after each activity	.455	.538	.409	.484	.627	.667	–			
8 I was excited to learn similarity of triangles in geometry much using	.664	.676	.654	.605	.591	.623	.526	–		
9 I believe i will do well in similarity problems	.429	.526	.485	.694	.684	.488	.610	.585	–	
10 Knowing similarity of triangles will help me improve my mathematics results	.429	.526	.485	.694	.684	.488	.610	.585	1.000	–

The factorability of the sample was further assessed. The Kaiser-Meyer-Olkin (KMO) measure of sample adequacy supported the appropriateness of the sample size for factor analyses. Specifically, the KMO measure of sampling adequacy was .834 which, according to Mooi et al., (2018) set of distinctively labelled values, was marvelous because it was above the threshold level of .50. Put differently, the KMO measure indicated that there were sufficient items for each factor. The Bartlett's test of sphericity was performed to examine the hypothesis that the correlation matrix is an identity matrix (where all diagonal values were 1's and all off-diagonal values were 0's). Bartlett's test of sphericity was found to be significant, suggesting that the relationship among the variables was strong implying that the correlation matrix was significantly different from an

identity matrix ($\chi^2(327) = 2.277 \times 10^3$), $p < .00001$). This nonsignificant result suggested that the items were unrelated enough to perform meaningful factor analyses.

5.2.3.2 Factor analysis

Having conducted these preliminary analyses, I then proceeded to perform the principal axis factoring (PAF) method, a type of exploratory factor analysis (EFA) and determine the reliability of the scores. Factor loadings were examined to test the hypothesis that a relationship between items and their underlying factors exists. The term “factor loading” refers to the measure of the contribution that each item makes to the factor in question thus illustrating the correlations between items and factors (Cohen, Manion, & Morrison, 2011). As can be seen in Table 4, all factor loadings (h^2) were greater than Stevens’ (1992) threshold of .40, as shown in Table 3. A continuation of factor loadings is the communality of an item which is defined as the measure of the variance in each item accounted for by all other items (Kline, 2011). These five factors accounted for 78.6% of the total variability (in all of the items together), and were accepted as summarising the data. The overall alpha coefficient of the 10-item scale was .83 which, according to Nunnally and Bernstein (1994), indicated that the *Learners’ Perceptions of GeoGebra Questionnaire* instrument had a high reliability.

Table 5:4. The communalities and loadings of SAT

	Communality	(h^2)
I enjoyed learning similarity of triangles using GeoGebra software	.533	.725
I like studying similarity of triangles lessons with GeoGebra software	.634	.754
I learnt a lot using GeoGebra more especially I understood the similarity of triangles concepts taught	.564	.721
I felt confident using the GeoGebra software during activities since there is accuracy	.627	.654
I was very engaged in the learning process	.600	.698
I benefited a lot through interaction with the teacher	.581	.643
I was able to visualise and answer the questions after each activity	.566	.585
I was excited to learn similarity of triangles in geometry much using	.687	.732
I believe I will do well in similarity problems	.696	.915
Knowing similarity of triangles will help me improve my mathematics results	.696	.915

Extraction Method: Principal Axis Factoring.

Note: Loadings <.40 are omitted to assist interpretation

A reliability coefficient of .70 or higher is suggested (Cronbach, Rajaratnam, & Gleser, 2011). However, an alpha greater than .90 would indicate item redundancy wherein some of the items have been rephrased resulting in asking the same question in many different ways (McCrae, Kurtz, & Yamagata, 2011). That said, I posit that the scores on the questionnaire achieved a generally acceptable level of internal consistency judging by the Cronbach alpha value.

Table 5:5. Reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.830	.831	10

The next section results of the SAT before and after instruction which integrated GeoGebra are presented. The SPSS was employed to determine the results.

5.2.3.3 The effect of GeoGebra instruction

5.2.3.3.1 Descriptive statistics

An inspection of Table 2, which shows that the means for the “post” SAT instruction and the “pre” SAT instruction, suggest that the learners’ performance in similarity topic was higher after GeoGebra instruction in general and more than twice in particular (a mean of 22.50) than during traditional instruction, which did not feature GeoGebra (a mean of 11.65).

Table 5:6. The paired samples statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SAT_pre	11.65	60	6.569	.848
	SAT_post	22.50	60	5.953	.769

5.2.3.3.2 The t Test for dependent means

The *t* test for dependent means, which is also called a *paired-samples t test*, involved comparing two SAT scores that were related to each other in a direct way. The *t* test for dependent means was appropriate in this case because each learner had a score in both sets of scores (i.e., a score pre -

GeoGebra instruction and a score post- GeoGebra instruction). Table 3 shows the t score (- 9, 072), the degrees of freedom (59), and the two-tailed significance level (.000) of the t test. The significance level is so small that, even after rounding to three decimal places, it is less than .001. Because the significance level is more extreme than the .05 significance level set for this study, the null hypothesis was rejected. Accordingly, there exists a significant difference between the two groups. More precisely, the results suggested that there is a statistically significant difference between learners who received instruction on similarity of triangles through GeoGebra and through traditional teaching method.

Table 5:7. The paired samples test

	Paired Differences							
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pair 1 SAT_pre SAT_post	-10.850	9.264	1.196	-13.243	-8.457	-9.072	59	.000

5.3 Learners perceptions and experiences regarding the GeoGebra programme

A close examination of participants' perceptions software suggested that the GeoGebra assisted participants' learning of similarity of triangles learning. The study adopted four open ended questions, which constituted of 78% (47 learners) participants willing to share their experiences and perceptions. The data obtained from the open-ended questions after the use of the GeoGebra software revealed that most of the participants showed interest in learning mathematics and that they preferred using GeoGebra during the lesson.

5.3.1 Learners preferring learning similarity of triangles using GeoGebra

The data obtained is simplified below as follows. Regarding the participants asked whether they prefer learning similarity of triangles using GeoGebra, 9% (4 learners) of the participants responded with a view of "no", whilst 91% (43 learners) participants responded "yes". One can deduce that most learners preferred learning similarity of triangles using GeoGebra from this study.

5.3.2 Learners explaining why they prefer using GeoGebra or why they don't prefer using GeoGebra

5.3.2.1 GeoGebra assists with learning more about angles and drawing

The GeoGebra programme exposes learners to more construction of diagrams associated with learning more about angles and most geometry concepts. During the orientation of the study, learners were orientated on how to use the GeoGebra programme, they were exposed to a variety of constructions that they drew on their own. Hence, it gives them the opportunity to learn about other geometry concepts that they could not understand properly. For instance, geometry of straight lines and triangles were used to familiarize learners to the geometry construction icons prior to learning about the similarity of triangles. Participants' perceptions were alluded as follows:

Participant 128 responded:

"It's because I learn a lot I learn how to draw at GeoGebra learn more about the angles."

Participant 124 responded:

"I learn how to draw at GeoGebra, learn more about the angles. I learn a lot."

Learners are usually taught in a traditional manner of being given a drawn diagram of a triangle instead of allowing learners to construct their own triangle, allowing learners to solve a sum that they have constructed on their own, allows learners to pay more attention on the properties of the diagram, for example if you draw a triangle above or below the size of 180° , the unknown angle would not be determined precisely. The opportunity to expose learners to GeoGebra learning allows learners to learn more about triangles, this was identified from the current study.

5.3.2.2 Accuracy

Some learners identified GeoGebra has a positive impact towards giving an accurate answer by providing the exact answer when constructing the diagram given to solve, this is evident from observing the screenshots of both the training on how to use GeoGebra as well as the posttests screenshots. Participant 406 responded:

"I prefer using GeoGebra because when I am calculating it give me the exact answer."

The learner is able to investigate whether the worked out answer for the problem is correct by validating or double checking with the GeoGebra programme. Hence, GeoGebra is an assistive

programme to empower the learners' knowledge and understanding through the provision of accurate answers.

5.3.2.3 *GeoGebra helps to understand similarity*

Most participants felt that GeoGebra played a significant role of enhancing their understanding of similarity of triangles. Many learners responded with different views, however that had a common ground of expressing how GeoGebra helps learners to understand similarity. Participant 422 responded:

“Because it is easy to understand similarity using GeoGebra, than using exercise books.”

Participant 417 responded:

“Because GeoGebra can easily help me to solve similarity and from now on I understand similarity.”

Participant 816 responded:

“I prefer using GeoGebra because I learnt more especially I understood the similarity of triangles”

Participant 129 responded:

“Because GeoGebra can easily help me to solve similarity and from now I understand similarity.”

This information gathered from the learners' shows that the application of GeoGebra programme is an assistive device to assist learners understand similarity of triangles. Godebo's (2018) study affirmed that learners being exposed to Euclidean geometry content which is designed within the GeoGebra program encourages learners to think critically and assisted them to establish mathematical relationships. Hence, learners were able to establish mathematical relationships associated with similarity of triangles.

5.3.2.4 *Learners opposing views to GeoGebra as a positive resource to learning mathematics*

Contrary to the positive comments shared by the participants, few participants did not share the same view as others. This is evident when reviewing comments that did not prefer using the GeoGebra programme such as: Participant 526 responded:

“I prefer to not use GeoGebra because it is the more I fail to understand similarity.”

Participant 309 responded:

“I prefer using it because it makes me understand it although it give me problems but maybe I will understand in time.”

There were learners who were not attending consistently in attending the extra lessons assigned for the GeoGebra training on how to use the GeoGebra programme. This was one of the challenges encountered during the training process, which could have contributed negatively in terms of knowing how to use the programme appropriately in terms of understanding how to use the different icons of the programme. The researcher identified through observation that those learners who were unable to consistently attend the GeoGebra training, had difficulty when it came to administering the posttest, this could be the reason few learners had a negative perspective to using the GeoGebra programme.

5.3.3 Learners’ opinion on what were the benefits they identified on learning mathematics using GeoGebra

5.3.3.1 Visualization

Participant 117 responded:

“I have benefits that is more easy to use it and you learn fast and I was able to answer and visualize.”

Participant 421 responded:

“I learn how to see similar triangles but they differ in size.”

The use of GeoGebra allows learners with more opportunities to visualize geometric concepts, which often accommodates below-average learners (Mthethwa et al., 2020). A study conducted by Vasque (2015) showed that the GeoGebra software, with its attributes in terms of visualisation, may assist in improving learners’ understanding of Euclidean Geometry.

5.3.3.2 Realizing mathematics is not difficult

It is reasonable to suggest that exposing learners to the GeoGebra software would give learners an opportunity to perceive mathematics as a subject that is not difficult. Learners that were subjected to the GeoGebra programme and had a positive experience with it, identified mathematics as no longer difficult. Considering statements such as:

“The benefits I have identified on learning mathematics is that mathematics is not hard and I can understand it.” by participant 126 and by participant 409 who said:

“That maths is not a difficult subject.”

Kekana (2016) found that, the use of GeoGebra may break the negative attitude that some learners are having towards mathematics as many learners perceive mathematics as a difficult subject, this is very true mentioned by Kekana, since this study found learners describing mathematics as a subject that is not difficult after the use of the GeoGebra software.

5.3.3.3 Learner participation is attained

Studies have attributed to the fact that GeoGebra facilitates learner participation, however in this study learners were able to identify on their own the GeoGebra establishes learner participation. According to Ahmed (2013) in a traditional classroom, learners become passive learners, or rather just recipients of teachers’ knowledge and wisdom. However, in a GeoGebra classroom, learners become active in their learner and are more participative.

Participant 515 responded:

“Because I learn more things and be participated.”

Participant 519 responded:

“It’s that I learn to participate and to connect with other people.”

This was very profound of learners to identify this aspect because it is very true. Learners when are using GeoGebra are engaged and are participating in the learning process.

5.3.4 Learners input on what are their other thoughts on using GeoGebra

5.3.4.1 Other learners should be introduced to the GeoGebra programme

Some learners shared the sentiments that it is recommended that other Grades should be exposed to the GeoGebra programme not only Grade 9 learners should have this kind of benefit.

Participant 113 responded:

“Well I think that even Grade 8 should be introduced to this so that they will see the fun in learning using GeoGebra.”

This perception raised by learners is interesting, it is very interesting that learners acknowledged the need for other learners to also use the GeoGebra programme, because if learners can know how to use the GeoGebra programme from lower Grades like Grade 8 this could be an advantage since learners would reach Grade 9 and others like Grade 10 and 11 knowing how to use GeoGebra programme. Which would provide opportunities for learners to utilize the programme when there

is a need to use it in any Grade without being limited by the fact that they do not know how to use the programme.

5.3.4.2 GeoGebra is fun

Learners found utilizing GeoGebra made learning mathematics fun and found GeoGebra exciting to use. Sentiments by learners revealed GeoGebra as fun, such as a comment by

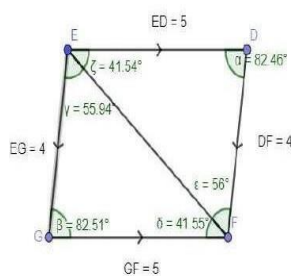
Participant 322 whom responded:

“It’s much fun.”

The fact that GeoGebra is fun, will increase learners’ interest towards learning mathematics. Most learners do not like learning mathematics based on the researchers teaching experience, however even those learners who do not like mathematics, began to have interest towards learning mathematics because of the excitement caused by using GeoGebra in a mathematics lesson.

5.3.5 Learners experience with the GeoGebra programme in a similarity of triangles lesson

Figure 5:1. Screenshot by participant 420 (Question 1.2)



In the pre-intervention assessment, participant 420 was able to use the law that opposite angles of a parallelogram are equal. The learner was able to identify that $\hat{G} = \hat{D}$. However, the learner could not identify and prove alternate angles from the diagram. Whereas in the post-test, the participant showed $\hat{G}\hat{E}F = \hat{D}\hat{F}E$ and $\hat{D}\hat{E}F = \hat{G}\hat{F}E$ alternate angles, from the GeoGebra programme based activities. The learner was able to support their claim with reasons in the post-test. This reveals the improvement of reasoning skills in geometry. Figure 5.1 indicates that participant 420 responded correctly to this question for the post test. This suggests that the participant understood the concept after using the GeoGebra software.

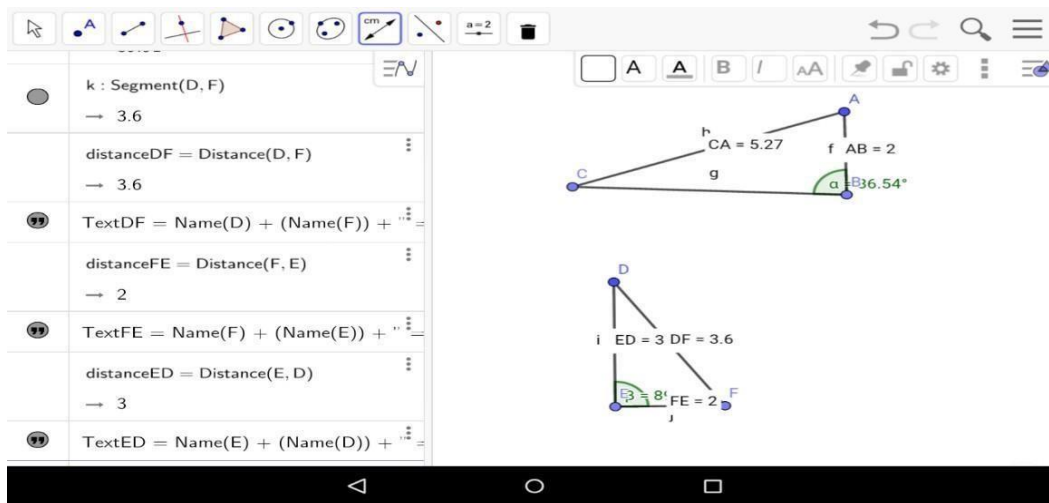


Figure 5:2. Screenshot by participant 514 showing errors performed on GeoGebra

The screenshot by participant 514 is a diagram showing that the learner could not use the GeoGebra programme properly for question 1.1, hence this hindered the learner to perform better in the post-test for this particular question. The participant was supposed to draw two similar triangles which were in proportion by a ratio in one combined diagram, however the participant drew two separate diagrams which were not similar even in the size, shape and not even in proportion to each other. Participant 514 was one of the learners that did not attend the GeoGebra programme training sessions properly, which could be the reason for encountering problems when using the GeoGebra programme for assessment purposes.

2.2 Hence, calculate the length of PV .

$$\frac{QP}{Lm} = \frac{PN}{mn}$$

$$\frac{3}{2} = \frac{PN}{16}$$

$$PN \cdot 2 = 16 \cdot 3$$

$$\frac{PN \cdot 2}{2} = \frac{48}{2} = PN = 6 \text{ cm}$$

(4)

Question Three

3.

In the figure, $\hat{B} = \hat{C}$, $AD = 9 \text{ cm}$, $AE = 7 \text{ cm}$ and $CE = 21 \text{ cm}$.
Prove that $\triangle ABD \cong \triangle ACE$.

3.1

Statement	Reason
$\hat{A} = \hat{A}$	Common Angle
$\hat{B} = \hat{C}$	is given
$E_1 = D_1$	Sum angles in \triangle
$\triangle ABD \cong \triangle ACE$	ASA

(8)

3.2 Calculate the length of BD .

$$\frac{AE}{AD} = \frac{AB}{AC}$$

$$\frac{7}{9} = \frac{AB}{21}$$

$$\sqrt{17} = 9 \cdot 3 = 27$$

$$\sqrt{17} = 27$$

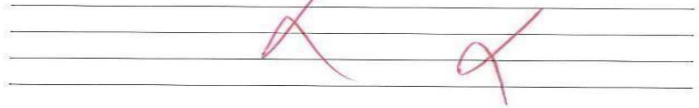
(4)

4

Figure 5:3. A participant's response to question 3.1 and 3.2 post-test

Participant 126 could not get even one answer correct for both questions 3.1 and 3.2 in the pre-intervention assessment, however after the intervention with the GeoGebra programme, there was a vast improvement since the learner was able to apply mathematical skills properly for the post-intervention assessment by scoring correct answers for all 3.1 and 3.2 post-test answers. Most learners that performed poorly for the pre-intervention assessment showed an improvement in the post-intervention assessment results, participant 126 was one of those learners who produced a better performance succeeding using the GeoGebra software.

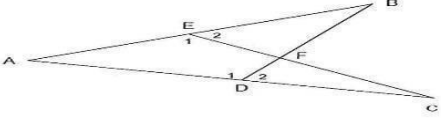
2.2 Hence, calculate the length of PN .



(4)

Question Three

3.




In the figure, $\hat{B} = \hat{C}$, $AD = 9\text{ cm}$, $AE = 7\text{ cm}$ and $CE = 21\text{ cm}$.
Prove that $\triangle ABD \parallel \triangle ACE$.

3.1

Statement	Reason
$\hat{B} = \hat{C}$	Given
$\hat{A} = \hat{A}$	Common Angles
$\hat{D} = \hat{E}$	

(8)

3.2 Calculate the length of BD .



(4)

4

Figure 5:4. Participant 401 response to question 3.1 and 3.2 post-test

This exhibits that some learners like participant 401 could not improve holistically in grasping the concepts learnt, however some learners showed a little improvement in the post – test performance unlike figure 5.3 where participant 126 improved immensely. Few learners showed a little improvement in the post- intervention assessment, however more learners showed a better improvement in contrast to the performance by participant 401.

5.4 Conclusion

In this chapter, data analysis methods, study results and a discussion of the findings were presented. This study aimed to investigate the capability of the GeoGebra program towards alleviating learner difficulty in learning the similarity of triangles. The study also aimed to explore learners' experiences and perceptions towards the similarity of triangles lessons using the GeoGebra programme. To address the two research questions of the current study, data were generated using a pre-intervention assessment, a post-intervention assessment, close ended questionnaire and open-ended questions. Findings from this investigation are consistent with the findings of several related studies on the use of the GeoGebra software in teaching and learning geometry.

In consideration of these assessments, the teaching of similarity of triangles with technological resources, which were prepared with the GeoGebra software, is more favorably to learner achievement than the traditional 'chalk and talk' method. Accordingly, to integrate educational technology within mathematics lessons cultivates improved academic achievements by enhancing understanding and justification. According to learners' perceptions, GeoGebra is an effective tool to increase achievement in learning the similarity of triangles to promote accuracy, visualisation, learner participation, and to create enjoyment and learner interest towards learning mathematics.

Chapter 6

Findings, Recommendations, Limitations and Conclusion

6.0 Introduction

The purpose of Chapter Five was to analyse the results and discuss them. The present chapter provides a summary of the results of the study, bring forward limitations and provide a conclusion. Recommendations are also suggested for possible further studies within mathematics education.

6.1 Summary of research findings

This section summarises the results of the different data sources (the pre-intervention assessment and post-intervention assessment, close ended questionnaire and open-ended questions) to answer the two research questions. All the data generation tools were designed based on the research questions.

- *Does GeoGebra have the capability to alleviate difficulty towards learners' conceptual understanding of similarity?*
- *What are the learners' perception of learning the similarity of triangles using GeoGebra?*

The findings in this study seek to contribute to possible mathematics intervention through investigating the capability of the GeoGebra towards alleviating learner difficulty in learning similarity of triangles, as well as exploring the learners' experiences and perceptions when learning similar triangles using GeoGebra when teaching Grade 9 learners. To address these questions, participants were exposed to the pre-designed similarity of triangles activities. The tasks were designed within the GeoGebra software. During the GeoGebra software application, teaching and learning process were captured utilizing the data generation instruments. These data have been analysed and some important aspects emanated which were discussed and summarised in this section in accordance with the research questions.

According to the findings of this study the GeoGebra programme can be used for similarity of triangles learning as a learning tool. Learners mainly used the GeoGebra programme to draw figures and to measure the dimensions of the similar triangles. The learners used the results of their measurements to verify and justify Similarity of figures axioms and theorems. The findings equally revealed that the school learners had positively perceived the use of GeoGebra in teaching mathematics. According to learners' perception, GeoGebra is an effective tool to increase achievement in learning geometry concepts; to promote accuracy, visualization; learner

participation; and to create enjoyment and learner interest towards learning mathematics.

6.2 Recommendations

Professional teacher education programmes and workshops are required from the department of education for teachers, have to be established to develop teachers on how to use the GeoGebra software to implement effective teaching in classrooms especially with geometry learning concepts. School principals should introduce ICT learning devices in schools to provide learners with the opportunity of learning mathematics with various software such as the GeoGebra software, which is one of the proven software to be an effective tool to assist learners in learning mathematics. I strongly recommend mathematics teachers equip themselves on learning how to use the GeoGebra software, since there are tutorials from the internet on how to use the software on different topics in order to expose learners to a GeoGebra user friendly mathematics classroom for the enrichment of their mathematics lessons.

6.3 Limitation of the study

Although the statistical tests on the data suggested a hypothesis that GeoGebra helps learners understand similarity of triangles better, the p -values need to be used only as guidelines. As a consequence, the results in this study need to be treated as tentative until confirmed by subsequent studies in similar contexts.

6.4 Conclusion of the study

The use of GeoGebra in teaching school mathematics helps learners understand similarity of triangles in comparison to only use the traditional method of teaching. Ensuring learners are well trained on how to use properly the GeoGebra programme is important to ensure learners are well equipped on how to use the programme. The proper use of GeoGebra does not only increase the learners' performance but also motivates them to gain interest and study mathematics. GeoGebra software enhances the creativity and visualization of concept about different shapes.

The learners' attitude played a determinant role in their learning. With regard to learners' experiences and perceptions, the present study found that mathematics learning within the GeoGebra enhances learners' interest and engagement in learning mathematics. This implies that the integration of the GeoGebra software into the mathematics curriculum can encourage learners to enjoy learning mathematics as well as break the mindset that mathematics is difficult. Finally, the study recommends that mathematics teachers need to use GeoGebra for productive teaching and learning, especially when learning geometry concepts.

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Appendix A

**SIMILARITY ACHIEVEMENT TEST (SAT)
GRADE 9 MATHEMATICS
TEST**

MARKS	
35	

TIME: 1 hour

PROVINCE: _____

DISTRICT: _____

SCHOOL NAME: _____

PARTICIPANTS NUMBER: _____

CLASS (e.g. 9A): _____

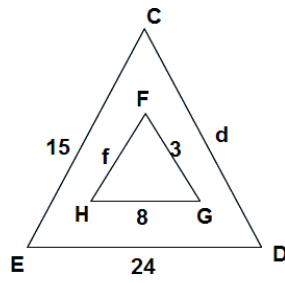
GENDER: (✓)

BOY	
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GIRL	
-------------	--

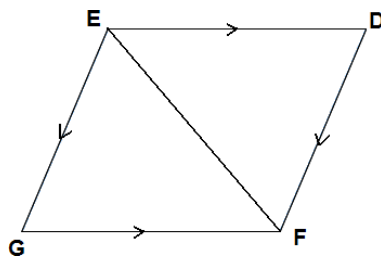
Question One

1.1 If $\triangle CDE \sim \triangle FGH$ calculate the value(s) of d and f .



(6)

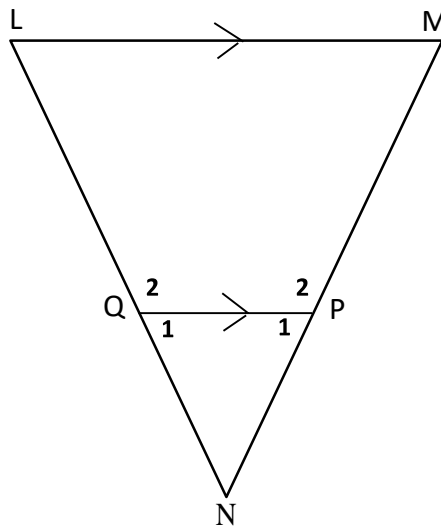
1.2 Prove that $\triangle DEF$ and $\triangle GFE$ will be similar.



Statement	Reason

(6)

Question Two



2 In $\triangle NML$ below, P and Q are points on the sides MN and LN respectively such that $QP \parallel LM$.

$MN = 16$ cm, $QP = 3$ cm and $LM = 8$ cm.

2.1 Complete the following (give reasons for the statements): Prove with reasons that $\triangle QPN \parallel \triangle LMN$.

In $\triangle QPN$ and $\triangle LMN$

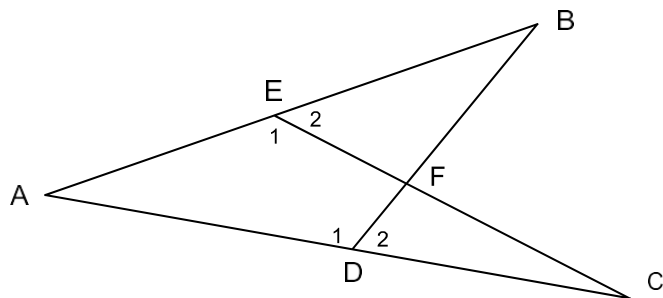
Statement	Reason
1. $\angle N =$
2. $\angle P1 =$
3. $\angle Q1 =$
$\therefore \triangle QPN \parallel \triangle LMN$

(7)

2.2 Calculate the length of PN .

Question Three

3.



In the figure, $\hat{B} = \hat{C}$, $AD = 9\text{ cm}$, $AE = 7\text{ cm}$ and $CE = 21\text{ cm}$.

Prove that $\triangle ABD \cong \triangle ACE$.

3.1

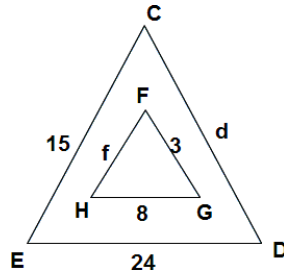
(8)

3.2 Calculate the length of BD.

(4)

Memorandum

Question 1



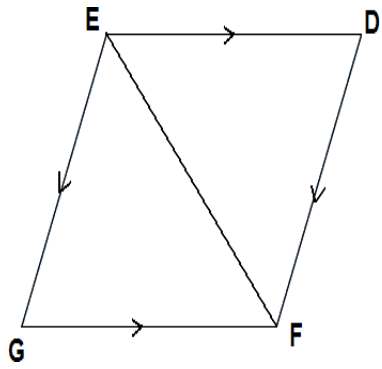
$$\frac{CD}{FG} = \frac{ED}{HG} \quad \checkmark \qquad \frac{EH}{CE} = \frac{HG}{ED} \quad \checkmark$$

$$\frac{d}{3} = \frac{24}{8} \quad \checkmark \qquad \frac{f}{15} = \frac{8}{24} \quad \checkmark$$

$$d = 9 \quad \checkmark \qquad f = 8 \quad \checkmark$$

(6)

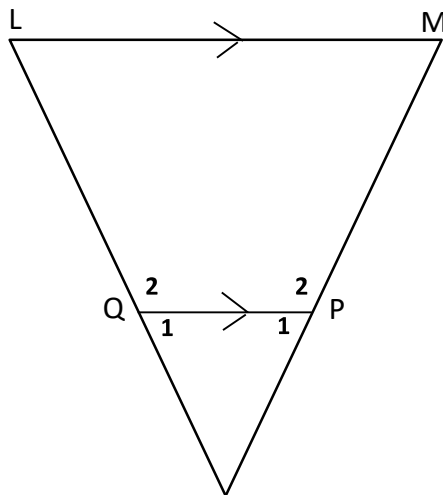
1.2 Prove that $\triangle DEF$ and $\triangle GFE$ will be similar.



$\hat{D} = \hat{G}$ ✓ Opp \angle 's in // Alternate ✓
 $\hat{DEF} = \hat{FEG}$ ✓ \angle 's ED//GF ✓
 $\hat{EDF} = \hat{FGE}$ ✓
 $\therefore \triangle DEF \sim \triangle GFE$ \angle, \angle, \angle ✓✓

(6)

Question Two



2.1 In $\triangle QPN$ and $\triangle LMN$

$$\angle N = \angle N \checkmark \quad (\text{corr } \angle\text{s, } QP \parallel LM) \quad \checkmark$$

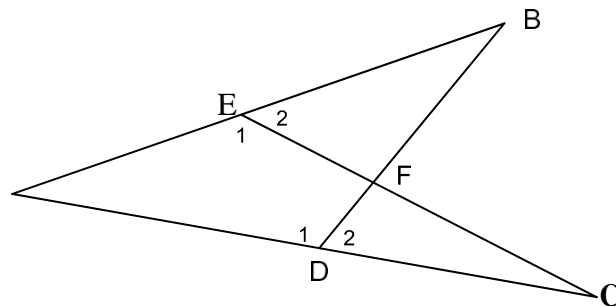
$$\angle P_1 = \angle M \checkmark \quad (\text{corr } \angle\text{s, } QP \parallel LM) \quad \checkmark$$

$$\angle Q_1 = \angle N \checkmark \quad (\text{corr } \angle\text{s, } QP \parallel LM) \quad \checkmark$$

$$\therefore \triangle QPN \parallel \triangle LMN (\angle\angle\angle) \quad \checkmark$$

(7)

Question Three



In the figure, $\hat{B} = \hat{C}$, $AD = 9 \text{ cm}$, $AE = 7 \text{ cm}$ and $CE = 21 \text{ cm}$.

Prove $\triangle ABD \parallel \triangle ACE$

Prove $\triangle ABD \parallel \triangle ACE$

3.1	Statement	Reason
	In $\triangle ABD$ and $\triangle ACE$	
	$\hat{A} = \hat{A} \quad \checkmark$	common $< \quad \checkmark$
	$\hat{B} = \hat{C} \quad \checkmark$	given \checkmark
	$E1 = D1 \quad \checkmark$	sum of. \angle s of $\Delta = 180 \quad \checkmark$
	$\triangle ABD \parallel \triangle ACE$	$\angle \angle \angle \quad \checkmark$
3.2	Statement	Reason
	$\frac{AB}{AC} = \frac{BD}{CE} = \frac{AD}{AE} \quad \checkmark$	proportional sides of similar Δ s \checkmark
	$\frac{BD}{21} = \frac{9}{7} \quad \checkmark$	
	$BD = \frac{9(21)}{7} \quad \checkmark$	
	$BD = 27 \text{ cm} \quad \checkmark$	

(12)

Appendix B
RESEARCH QUESTIONNAIRE

1. DEMOGRAPHIC INFORMATION (*Tick where appropriate*)

Participants Number:

Class: (e.g. 9A)

Date:

2. REFLECTIONS ON LEARNING SIMILARITY OF TRIANGLES USING GEOGEBRA

- *Please only tick one answer from four possible given using the following numbers designed below:*

1=Strongly disagree, 2=Disagree, 3=Agree & 4=Strongly agree

Items	1	2	3	4
1. I enjoyed learning similarity of triangles using GeoGebra software.				
2. I like studying similarity of triangles lessons with GeoGebra software.				
3. I learnt a lot using GeoGebra more especially I understood the similarity of triangles concepts taught.				
4. I felt confident using the GeoGebra software during activities since there is accuracy.				
5. I was very engaged in the learning process.				
6. I benefited a lot through interaction with the teacher.				
7. I was able to visualize and answer the questions after each activity.				
8. I was excited to learn similarity of triangles in geometry much using GeoGebra.				
9. I believe I will do well in Similarity problems.				
10. Knowing Similarity of triangles will help me improve my mathematics results.				

Appendix C

OPEN-ENDED QUESTIONS

a) Do you prefer learning Similarity of triangles using GeoGebra?

.....

b) Please explain why you prefer using GeoGebra or why you don't prefer using
GeoGebra?

.....
.....
.....

c) What are the benefits you have identified on learning mathematics using
GeoGebra?

.....
.....
.....

d) What are your other thoughts on using GeoGebra?

.....
.....
.....

YOUR PARTICIPATION IS HIGHLY APPRECIATED!!!

Thank you so much!!!

Appendix D



Informed Consent Letter to School Principal

Dear Principal

Ms/Mrs/Mr/Dr.....

Name of school

Re: Permission to conduct a research study in your school

I am writing to request your permission to conduct a research study in your school. This research study is entitled: **A Case Study: The use of GeoGebra to alleviate difficulty in learning the similarity of triangles in a South African Grade 9 classroom.**

My name is Nompumelelo Mpanza and I am currently studying towards a Master in Education Degree at the University of KwaZulu-Natal (UKZN). As part of the requirements of this degree, I am required to complete a research thesis. This study focuses on the effectiveness of a teaching method, which is called a GeoGebra.

I require all Mathematics learners in Grade 9, who will be willing to participate, ranging from any age to participate in this research. I would be very grateful if you would consent to these learners participating in this study. They will be selected from your school.

If you agree to this, learners will write the Similarity Achievement Test (SAT) will be administered in both the pre-test and post-test. The test will be based on the Grade 9 and 10 CAPS document, as well as ANA (Annual National Assessment) past papers, to measure learners' understanding on learning the similarity of triangles.

The second instrument will be a researcher designed self-report questionnaire for the participants which will be a blended in that, it will consist of close- ended questions, to measure the learners' experiences. Furthermore, the close – ended items from the questionnaire will be a researcher designed instrument that will be a 4-point Likert-scale questionnaire in which participants demonstrate their degree of agreement will be used: Strongly Disagree; Disagree; Agree and Strongly Agree.

Data generation activities will also take place in the school premises, with your consent. If I am unable to collect my data during school hours, I will make arrangements with your consent and that of my participants' parents/guardians, to perhaps do this after school hours, on days when school closes early or during weekends.

Please note:

- * Times and dates of this data generation process will be at your sole discretion. I have merely presented you with an outline of what I intend to do, however you are free to make any changes and suggestions, if necessary.
- * Participation is completely voluntary and participants have the right to withdraw from this study at any time. They will not be penalized if they choose to do so.
- * Confidentiality and anonymity will be maintained at all times. The identity of your school and all participants will not be revealed at any time, as pseudonyms (different names) will be used to protect everyone's right to privacy.
- * Any information provided by the participants will not be used against them, or against the school, and will be used for purposes of this research only.
- * Participation in this study will not result in any cost to your school or the participants.
- * Neither the participants nor your school will receive financial remuneration. However, costs incurred by participants as a result of their involvement in this project will be covered.
- * This study does not intend to harm the participants in any way.
- * Both parents/guardians as well as participants will be handed letters of consent which they will have to carefully read and sign, before I begin data collection.

I may be contacted at:

Email address: mpumelindimyeni@gmail.com

Tel: 073 140 3033

My Supervisor's contact details are:

Email: shongweb@ukzn.ac.za

Dr. B. Shongwe's office: 031 260 3435

You may also contact the Research Office through:

HSSREC Research Office,

E- mail: HSSREC@ukzn.ac.za

Tel: 031 260 4557/ 8350/3587

If you would like any further information, or if you are unclear about anything, please feel free to contact me at any time. Your co-operation and consent will be greatly appreciated.

If you grant permission to conduct this research at your school, please complete the form below and return to me.

Warm regards

Mrs. Nompumelelo Mpanza

DECLARATION

I..... (Full name/s of school principal) of
..... (Name of school) hereby confirm that I understand
the contents of this document and the nature of this research project, and I consent to the learners
participating in this research project. I also grant permission for my school to be used as the
research site.

Additional consent

I understand that learners will be writing a Similarity Achievement Test (SAT), a questionnaire
and open ended questions and I grant permission for this.

YES/NO

I understand that the learners and the school are free to withdraw from the research project at any
time

YES/NO

SIGNATURE OF SCHOOL PRINCIPAL

DATE

.....

.....

Appendix E

PARTICIPANTS INFORMED CONSENT FORM

Title: A Case Study: The use of GeoGebra to alleviate difficulty in learning the similarity of triangles in a South African Grade 9 classroom.

My name is Nompumelelo Mpanza. I am a Masters of Education in Mathematics candidate studying at the University of KwaZulu-Natal, Edgewood campus, South Africa. I am interested in conducting research in your School to explore the use of GeoGebra to alleviate difficulty in learning the similarity of triangles in a South African Grade 9 classroom.

The study aims to explore the capability of the GeoGebra program towards alleviating learner difficulty in learning similarity of triangles. The study also aims to explore the learners' experiences and perceptions when learning similar triangles using GeoGebra.

To gather the information, I am interested in asking you some questions.

Please note that:

- Your participation in this research is voluntary, this means that if you decide to withdraw your participation during the course of this research, you will not be penalized, and your relationship with me will not be jeopardized.
- Your name as a participant will not be revealed, and pseudonyms (not real names) will be used instead.
- There shall be no gifts or rewards given to those who will choose to participate in this study.

- Also, the research is not going to expose you to any danger or risk. Every participant will be given a chance to ask question.
- The test, questionnaire and the open-ended questions will take approximately 1 hour to 1h30min.
- You are informed that feedback will be sent to you at your school on the findings obtained during the study. You will have access to full results if you wish to view.
- The researcher will provide you as a participant with a summary of the research results.
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- You are signing this informed consent exactly knowing that there are no legal obligations that will be ignored. A copy of this informed consent will be handed to you, and the original will be kept as proof of your participation.

I may be contacted at:

Email address: mpumelindimyeni@gmail.com

Tel: 073 140 3033

My Supervisor's contact details are:

Email: shongweb@ukzn.ac.za

Dr. B. Shongwe's office: 031 260 3435

You may also contact the research office through:

HSSREC Research Office,

E- mail: HSSREC@ukzn.ac.za

Tel: 031 260 4557/ 8350/3587

If you are voluntarily willing to participate, please indicate (by ticking as applicable ✓) whether or not you are willing to allow the following to be done by you as a participant:

Task to be done	Willing	Not willing
Writing a Similarity test.		
Answering a questionnaire.		
Answering open ended questions.		

DECLARATION

I..... (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

SIGNATURE OF PARTICIPANT

DATE

.....

.....

Appendix F

INFORMED CONSENT LETTER TO PARENTS OF PARTICIPATING LEARNERS

(ISIZULU VERSION)

Mzali

Mnu/ Nks/ Nkz

ISICELO SOKWENZA UCWANINGO

Ngingu Nkz.Mpanza uthisha ofundisa izibalo eSondelani. Ngenza ucwaningo eNyuvesi Yakwa Zulu Natali. Isihloko socwaningo sithi: Ukuseshenziswa kwe – GeoGebra kwithebulethi (into yokubalela) ngenhloso yokunciphisa ukungaqondi kahle kwabafundi ekufundeni onxanthathu abalinganayo (similar triangles) ebangeni lesishagalolunye eNingizimu Afrika. Inhloso yocwaningo ukufunda izibalo besebenzisa uhlelo iGeoGebra kwithebulethi yesikole ngenhloso yokunciphisa amaphutha abawenzayo nokukhulisa ulwazi lwabo umangabe befunda onxanthathu abalinganayo (similar triangles).

Ngokukhulu ukuzithoba ngicela umntwana wakho abe yingxenye yocwaningo oluzokwenzeka esikoleni afunda kusona ngenyanga uMandulo (September) 2021. Ulwazi lalolucwaningo alukhokhelwa olokufunda kuphela. Ababambe iqhaza bayogcinwa beyimfihlo futhi amagama abo ayokuba imfihlo. Ukubambakomfundi iqhaza kulolucwaningo kuyoba ngemvume yakho, angayeka uma ezizwa efisa ukwenza kanjalo, noma ngasiphi isizathu, akukho okomvelela. Ngicela umangabe nifisa ukwazi ngokuthile okumayelana nocwaningo;

Ningithinthe kuleminingwane engezansi:

Ikheli le - imeyili: mpumelindimyeni@gmail.com

Inombolo yocingo: 073 140 3033

Imininingwane yomphathi wami:

Ikheli le -imeyili: shongweb@ukzn.ac.za

Ihhovisi lika Dr. B. Shongwe: 031 260 3435

Imininingwane yehhovisi locwaningo:

HSSREC Research Office,

Ikheli le - imeyili: HSSREC@ukzn.ac.za

Inombolo yocingo: 031 260 4557/ 8350/3587

Ngicela ugcwalise ngezansi

Yimina Ozithobayo

UNompumelelo Mpanza

Isignature yomcwaningi _____

Mina _____ (amagama aphelele omzali
noma umbheki womntwana), mzali ka _____ ofunda ibanga
lesishagololunye (Grade 9) ngiyakuqonda konke okuqokethwe yilencwadi Kanye nomumo
wocwaningo.

Ngiyavuma

Angivumi

Isignature Yomzali: _____

Usuku : _____

Appendix G



28 October 2021

Nompumelelo Mpanza (220108396)
School Of Education
Edgewood Campus

Dear N Mpanza,

Protocol reference number: HSSREC/00003530/2021

Project title: The use of GeoGebra to alleviating learner difficulty in learning similarity in a South African grade 9 classroom.

Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 21 October 2021 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 28 October 2022.

To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,



Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee

Postal Address: Private Bag X54001, Durban, 4000, South Africa

Telephone: +27 (0)31 260 8350/4557/3587 Email: hssrec@ukzn.ac.za Website: <http://research.ukzn.ac.za/Research-Ethics>

Founding Campuses:  Edgewood  Howard College  Medical School  Pietermaritzburg  Westville

INSPIRING GREATNESS

Appendix H

A Case Study: The use of GeoGebra to alleviate difficulty in learning the similarity of triangles in a South African Grade 9 classroom

ORIGINALITY REPORT

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