

**THE EFFECT OF USING ANIMATED COMPUTER 3-D FIGURES ILLUSTRATION
IN THE LEARNING OF POLYHEDRON IN GEOMETRY**

by

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ABSTRACT

This study was carried out to investigate the effect of using animated computer 3-D figures illustration (ACTDFI) in the learning of polyhedron in geometry. By random sampling, intact group of four grade 9 classes in four different schools from a cluster of four educational district schools of Limpopo province in South Africa were selected.

The study involved quasi-experimental and inquiry research approaches, the quasi-experimental approach involved pre and posttest design while the inquiry research approach involve classroom observation. There were three experimental groups and a control group with a total of 174 study participants. ACTDFI was used as an intervention for two weeks in the three experimental groups while in the control group, chalk-talk traditional teaching approach was used. Pre-test and post-test was used to collect quantitative data while classroom observation was used to collect qualitative data

The findings from the quantitative Classroom observations were carried out to collect relevant data on how the study participants were taught stationary points in differential calculus, especially with the use of the constructivist pedagogical approach. A suitable observation checklist was developed for this purpose (Appendix 6 refers). Classroom observation checklist is a list of factors to be considered while observing a class. It gives a structure and framework for the observation.

suggested that the use of ACTDFI might have improved academic achievement in learning of polyhedron during the intervention, while the qualitative data analysis indicated that the use of ACTDFI in the experimental groups might have facilitated the learning of the concepts of polyhedron. It is therefore recommended that further research is necessary on the application of ACTDFI in the teaching of 3-dimensional shapes at the primary schools.

Key Terms: Polyhedron; Teaching of geometry; Medial-Affect-learning theory; Multiple representation principle; Mixed method research approach; Quasi-Experimental approach; Inquiry research approach; Computer-Aided Instruction; Pre-Posttest design; Classroom observation.

DECLARATION

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The Effect of Using Animated Computer 3-D Figures Illustration in the Learning of Polyhedron in Geometry

I declare that the above dissertation/thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

SIGNATURE

(ADEWOLE OLUSEYI ADENUBI)

DATE

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To GOD be all the Glory for the successful completion of this study.

Some achievements in life would not be possible without the contributions of some known and unknown individuals. We are product of what we have learnt from others. Below are just a few who have helped make this research work possible:

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DEDICATION

I dedicate this work to GOD ALMIGHTY, the Alpha and Omega, the unchangeable changer, the unshakeable shaker, who preserved and sustained my life and my entire household throughout this study.

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List of Abbreviations

ACTDFI - Animated Computer 3-D Figure Illustration

DoE - Department of Education

DGS - Dynamic Geometry Software

FET - Further Education and Training

GET - General Education and Training

3-D - Three Dimensional

2-D - Two Dimensional

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CHAPTER ONE

BACKGROUND OF THE STUDY

1.1 Introduction

It is generally accepted that geometry as a branch of mathematics has held great importance for mankind since 2000BC. It helps us to understand our geometric world, and is also a basic mathematical skill that every student needs, as it helps to develop spatial perception. The knowledge of geometry prepares students for more difficult mathematical courses and for a variety of occupations which require mathematical skills, deep thinking and problem-solving abilities. It also helps in developing both cultural and aesthetical values.

It is worrisome that South African learners experience serious conceptual learning difficulties in this area of mathematics (De Villiers, Roux, 2004). Understanding geometrical concepts requires the ability to think deep to solve problems and recall prior knowledge in trigonometry, properties of shapes and other similar areas of mathematics. Hence, it is essential that, from a young age, learners are systematically introduced to concepts of geometry that may serve to construct a sound foundation on which more intellectually demanding concepts may be built. This was corroborated by the Annual National Assessment (ANAs) 2010, which reported that learners' poor performance in mathematics stems from primary school. Mtshali (2012) also revealed that two thirds of learners in the Gauteng province go from primary to high school without the adequate required conceptual knowledge in mathematics. He went further to remark that such a set of learners will, throughout the secondary school education, continue to battle with proper conceptual mathematical understanding.

Perhaps what Mtshali (2012) noted was as a result of learners' inability to think deeply, this was also supported by Sitorus and Masrayati (2016). More so that

French (2004) and Kesili, Erdogan and Özteke (2011) linked the learners' abilities in mathematics in general to their conceptual abilities in geometry. In addition, other studies (de Villiers, 1997; 2006; Roux, 2004) have shown that South African learners (either in primary or high school) are experiencing conceptual learning difficulties in geometry. In fact, de Villiers advised that instructional approach in geometry class should be aligned to Van Hiele's instructional model, perhaps this will help to improve learners' conceptual understanding in geometry.

However, the researcher in this study being a secondary school teacher himself, acknowledged the difficulties experienced by South African learners in understanding the concepts in geometry and thought that good instructional approach might be an antidote in this type of situation. The researcher visited secondary schools in his neighborhood; he noticed that the traditional pedagogical approach used in all the schools visited, including his own school might have been a contributing factor to the challenges faced by the secondary schools students in learning of geometrical concepts. He is of the opinion that the theory of multiple representation instructional approach might be of help. This investigation is unpinned by the 'Media-Affects learning hypothesis' supported by the 'Multiple Representation theory'. It is based on the above theory and hypothesis of learning that this research wishes to explore the possibilities of improving the teaching of polyhedron with the aid of Small Stella Version 5.4 open-software referred to as animated computer 3-D figure illustration (ACTDFI) in this study as teaching aid.

1.2 The Importance of Learning Geometry in the Early School Years

The revised National Curriculum Statement for secondary schools pointed out the importance of learning two- and three-dimensional shapes as it would help learners to describe and represent the characteristics which exist between two-dimensional shapes and three-dimensional shapes in different positions and orientations. Not only will the study of shape and space inculcate in learners the ability to reason, calculate, justify, interpret, classify and visualize, it will also take their skills from simple recognition and description of shapes to meaningful classification and detailed descriptions in terms of the features and properties of objects.

It was suggested by Van Niekerk (1995) that the primary school curriculum for geometry should begin with the child's real world. Children usually display some intuitive notions during their exposure to spatial concepts, which provides a good foundation upon which the teaching and learning of shapes and space can be built on. As they mature, children will be able to reflect on them. It must be noted that geometry does not begin with the formulation of theorems, but rather when children are able to orientate themselves in their daily environments. This familiarization of children with their physical surroundings eventually results in the development of definitions and theorems (Freudenthal, 1991).

Geometry and geometric applications surround us. It is important for all learners to be conscious of the presence of geometric structures built by man. In real-life application, triangles are used by carpenters for structural support, and scientists make use of geometric models of molecules to define their physical and chemical properties. Traffic flow diagrams are also used by merchants to devise strategies on how to organize their stock. It is obvious that geometry plays an essential role in our everyday lives.

1.3 The Use of Technology as a Teaching Aid

Before computers were introduced into education, the figure below was referred to as a "didactic triangle" between the learner, the teacher and mathematics (see figure 1.1 below)

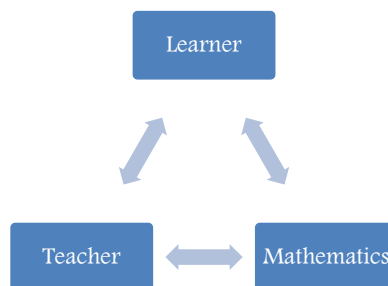


Figure 1.1: The Didactic Triangle Model (Kansanen and Merl, 1999:107)

The model above shows that the learner interacts with the teacher and the mathematical content knowledge. The teacher likewise interacts with the learner and the mathematical content knowledge. The mathematics teacher is regarded as a mathematics expert who has the mathematical content knowledge in his head. The mathematical knowledge in this situation is static in fixed words and diagrams; the only dynamic representation is through the verbal explanation of the teacher and any other diagrams that may be drawn on the chalkboard.

The advent of computers brought a new dimension to the concept of mathematical teaching and learning. Instead of three components, there are now four major components involved, which may be viewed as forming quadri-components in a suitable educational context.

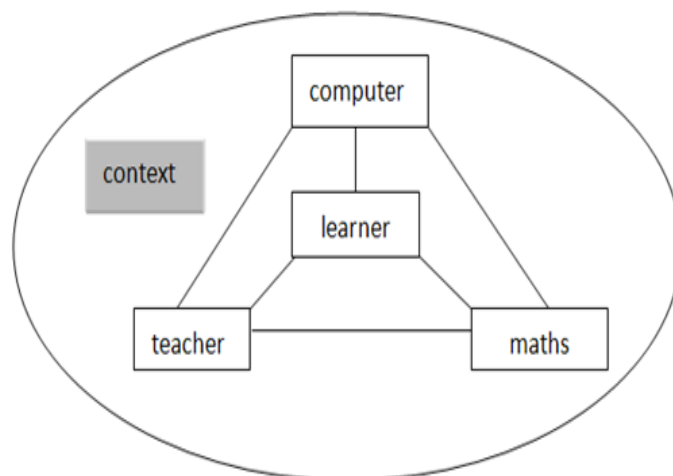


Figure 1.2: The Didactic Tetrahedron Model by Tall and Thomas (1986:60)

Figure 1.2 depicts technology as a significant role-player in the teaching and learning of mathematics. Learners now have to interact with the teacher, the mathematical knowledge and the technology. Zisow (2000:36) pointed out that computer access has changed from schools only having computers in their computer laboratories to making them available in each classroom. Various more advanced technologies have also found their way into today's classrooms, and many learners have access

to computers at home. If all these resources were to be channelled towards teaching and learning, it would greatly enhance learning.

Studies (Kadiyala & Crynes, 2000; Mayer & Moreno, 2003 in Moreno 2006b; Wiske, Franz & Bret, 2005) inform that, if technology is appropriately used in the teaching and learning of mathematics, it has significant potential to enhance the conceptual understanding of learners.

1.3.1 Small Stella as Polyhedron Software

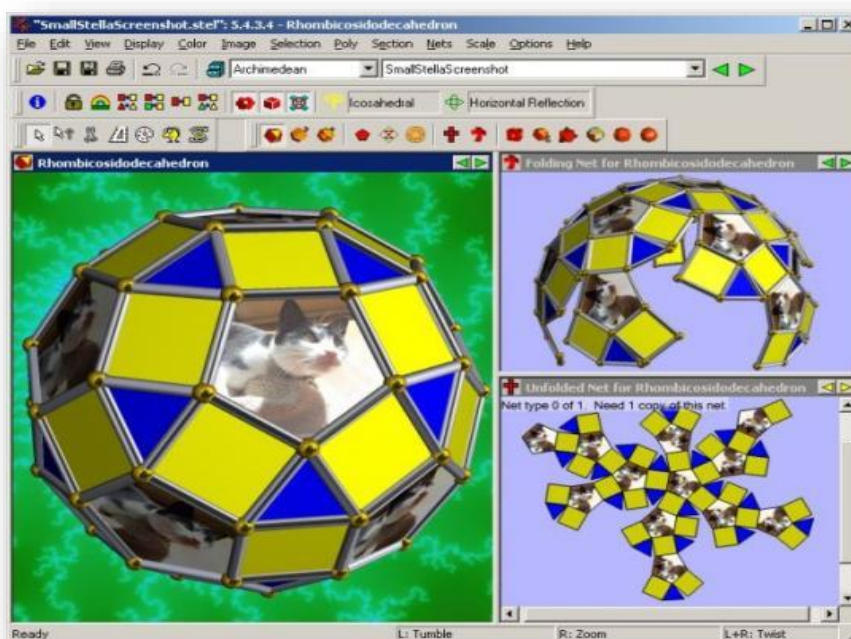


Figure 1.3: Picture of Small Stella Version 5.4

Small Stella version 5.4, shown in figure 1.3 above was developed by Robert Webb as geometrical polyhedron learning software. It has about 200 built-in Polyhedra besides an infinite series of prisms and antiprisms. Learners can print out the nets which can help them to build their own geometric paper models. One can even display images on a polyhedron's faces and print on the nets. This software can be easily manipulated by learners to explore the properties of each polyhedron, flatten the shape to see the net and also fold the net back to the normal polyhedron. All

these features in Small Stella make it one of the best open-source software that can be used by educators to bring about conceptual understanding of polyhedron in geometry.

Models provided in Small Stella include the Platonic solids, Archimedean solids, Kepler-Poinsotpolyhedra, prisms/antiprisms, Johnson solids, 'Near Misses', Stewart toroids, compounds and geodesic domes. Duals of all these models are also available. Learners can morph between any model and its dual using one of six different techniques provided by the software. In version 5.4, each built-in polyhedron has a link to my-paper-model online, and its nets in the library now include colouring for compounds of 10 tetrahedral. Coxeter symmetry notation has been added, as well as the ability to cut one edge in a net, and not just a whole edge type.

The researcher chose Small Stella version 5.4 over other geometry software because of its ease of use in the study context. It could be used at all educational levels to enhance conceptual understanding of three-dimensional shapes in geometry. It shall be referred to as animated computer three-dimensional figure illustration (ACTDFI) in this study.

1.4 Polyhedron and Non-Polyhedron

1.4.1 Polyhedron

Any solid with many flat faces is a polyhedron. The word “poly” is a Greek word for “many” and “-edron” meaning “face”. Each of the faces is a polygon, that is, a flat shape having straight sides. For any geometric solid to be called a polyhedron there must not be any curved surface. Cube, cuboids, prisms, pyramids and the platonic solids are examples of polyhedron. Each of the solids in figure 1.4 below is made of flat faces



Cubes



Prism



Pyramid



Platonic Solid

Figure 1.4: Examples of Polyhedron

1.4.2 Non-Polyhedron

If any surface of any geometric solid is not flat it is regarded as non-polyhedron. Examples of non-polyhedrons are shown in figure 1.5 below



Sphere



Cylinder



Torus



Cone

Figure 1.5: Examples of Non-Polyhedron

The solids above are not made of flat faces. This study shall focus on the teaching and learning of polyhedrons only.

1.5 Theoretical Consideration

As mentioned in subsection 1.1, this study is underpinned by the “Medial-Affect-Learning Hypothesis” and supported with the “Multiple Representative Theory”.

1.5.1 Medial-Affect–Leaning (MAL)

This hypothesis states that "advanced technology promotes deeper learning", (Moreno & Meyer 2002). This work will be underpinned by this learning hypothesis, since the researcher wants to investigate the effect of computer 3D animation on the learning of polyhedron in grade 9 classrooms in some South African schools.

In support of this hypothesis, Moreno (2006) argues that it is in line with current efforts in education circles to integrate newer technologies such as film, radio, television, and computers into education, and is based solely on the assumption that state-of-the-art technologies are more effective learning tools than older

technologies. This is especially important for grade 9 mathematics learners, who start to consolidate their understanding in mathematics in preparation for the grade 12 matriculation examination. Mejia-Flores (1999) reported that visual representation made abstract concepts “easier to understand and internalize”, which is why the difficult-to-learn aspect of geometry should be supported with technology that can present 3D pictorial objects in form to facilitate learning.

The researcher used Small Stella, which is able to display a polyhedron shape in its 3D format. This implies that the teacher will be able to explain the concept associated with polyhedron while showing all the faces of the polyhedron.

1.5.2 Multiple Representative Theory

The theory states that “It is better to present explanations in words and pictures than solely in words” (Mayer & Moreno, 1998). Mayer & Anderson (1991, 1992) explained this learning principle and claimed that students who listened to a narration on how a bicycle tire pump works while also viewing a corresponding animation generated twice as many useful solutions to subsequent problem-solving transfer questions, than students who listened to the same narration without viewing any animation (Mayer & Moreno, 1998: page 2).

Learning with multiple representations has been recognized as a potentially powerful way of facilitating understanding (Ainsworth & Van Labeke, 2002). This principle implies that if the learning of polyhedron is facilitated with conceptual 3D pictorial object display, the students may learn better than the present, abstract, teacher-centered learning approach.

1.5.3 Content Knowledge (CK)

1.5.3a Pedagogical Content Knowledge (PCK)

For teaching to be effective, the subject knowledge of the teacher is invaluable; knowledge or expertise in every domain of teaching is essential. The teacher's

expertise in the subject matter (the extent of knowledge of the subject to be taught), and the processes and practices of how to impart the subject matter knowledge (pedagogical knowledge) combine to make teaching effective. Lee Shulman introduced the idea of the knowledge the teacher has (subject matter knowledge) and the knowledge about teaching (pedagogical knowledge) in 1986, (Niess, Ronau, Shafer, Driskell, Harper, Johnston, Browning, Ozgün-Koen & Kersain, 2009). The teacher's subject knowledge and his pedagogical classroom practices are mutually exclusive aspects in the teaching domain. The duo is an important aspect of teaching and is referred to as 'Pedagogical Content Knowledge': one is not more important than the other.

Subject matter knowledge (SMK) refers to the content of the subject a teacher is supposed to know and teach. It is a common saying that 'one cannot give what one does not have'. A teacher needs to understand what he has to teach; otherwise he/she will not be able to succeed in classroom lesson presentation. For example, enquiries prior to this study inform that some secondary school teachers were not introduced to the Euclidean geometry included in the new CAPS. One should expect that the concerned teachers will avoid teaching this aspect of the CAPS curriculum, which might add to the existing problems facing the teaching and learning of mathematics in South Africa.

According to Hughes (2005), pedagogical knowledge (PK) entails deep knowledge about the processes and practices or method of teaching and learning. It involves everything about classroom management, lesson planning and the techniques to use in disseminating the lesson, as well as appropriate assessment strategies. According to Bruce and Hogan, (1998) technological teaching aids refer to digital computers and software, computer applications, the internet, and computer games. Technology knowledge (TK) is the use of a computer and its applications, and requires knowledge on how to install and uninstall computer programmes.

1.5.3b Technological Pedagogical Content Knowledge (TPCK)

Integrating the knowledge of pedagogy and technology into appropriate dissemination of the content in a way that facilitates learning is referred to as technology pedagogical content knowledge (TPCK). Technology is used in a constructive way to address concepts that are difficult to learn. Appropriate technological teaching aids may be used to build on learners' prior knowledge (Wallace, 2004).

The multiple representation theory and the medial-affect learning hypothesis lean on the concepts of TPCK. It is against this background that the researcher intends to study the possible impact of teaching polyhedron (three-dimensional shapes) in grade 9 mathematics using Small Stella animated computer three-dimensional figures illustration.

1.6 Statement of the problem

This study aims to find out whether or not the use of animated computer 3-D figures illustration has any effect on the learning of polyhedron in geometry. This shall be done by searching for answers to the following questions:

1. Will the use of animated computer 3-D figures illustration improve learners' achievement in geometry class?
2. Will the use of animated computer 3-D figures illustration facilitate conceptual understanding of geometry?
3. Does the use of computer 3-D figure illustrations have any influence on the problem-solving skills of the study participants?

The following hypothesis, stated in a null term at 0.05 probability significance level was used to guide the study:

H₀: There is no statistically significant difference in the study participants' post intervention mean achievement score in the polyhedron conceptual test.

H₁: There is a statistically significant difference in the study participants' post intervention mean achievement score in the polyhedron conceptual test.

1.7 Significance of the study

A positive result from this study may be used to empower learners to discover other geometrical relationships which they would not ordinarily do if traditional instructional approaches are used. Also, teachers would be enabled to provide better learning opportunities for learners, and so help them obtain a new perspective on geometrical concepts.

1.8 Definition of key terms and concepts

Department of Education (DoE): This refers to South African Department of Basic Education.

Further Education and Training (FET): This refers to grades 10-12 of the South African school system.

General Education and Training (GET): This refers to Grade 0-9 of the South African school system.

Matric Examination: This is the short form for the Matriculation examination. It is a national examination written at the end of grade 12, when students exit FET education. It is generally used to gain admission to higher education and training or to secure employment.

Teaching: Teaching is used in this study to mean everything a teacher does to support the learning of his/her students. It means the interactive work of facilitating

lessons in the classrooms and all the tasks that arise in the course of the work (Ball, Thames & Phelps, 2008).

Traditional Teaching Approach: In this study, a pedagogical approach in which the teacher presents a preplanned content in a chalk-and-talk teaching and learning environment is referred to as a traditional teaching approach.

1.9 Structure of the thesis

The study will be structured as follows:

Chapter One – Introduction

This chapter provides the context of the study, describing the background of the study, problem statement, and motivation for the study, the research questions, and significance of the study, and gives a brief definition of the terms and structure of the thesis.

Chapter Two – Literature Review

A review of some related literature is presented in this chapter.

Chapter Three – Research Methodology

This section describes the methodology followed in addressing the research questions and hypotheses. Research design, the population and sample, the research instruments, the procedure for data collection, data analysis and interpretation, limitations of the study, and validity and reliability are all discussed.

Chapter Four – Data Analysis and Presentation of Results

The data analysis methods and procedures are described in this chapter. The results obtained from the analysis are used to answer the research questions.

Chapter Five – Summary, Discussion, Implications, Conclusion and Recommendations.

Chapter five is a summary of the study. A discussion of major findings, the implications of the study, a conclusion and recommendations are also included.

CHAPTER TWO

LITERATURE REVIEW

The conceptual framework of the study, and a review of similar studies that have been carried out, are presented in this chapter.

2.1 Conceptual Framework

2.1.1 Traditional Instructional approach

The traditional method of mathematics classroom instruction is mainly characterized by the “present-practice-test” format. The teacher, who is assumed to have the subject content knowledge, presents the pre-planned mathematics lesson while the students listen to the teacher throughout his presentation. At the end of the lesson the teacher gives the learners a formative test, which may be in the form of class work or a short class test, to evaluate the level of conceptual understanding of the students. Kalu (2012) describes the traditional classroom as a one-person show with largely uninvolved learners, seen as empty knowledge-seekers. He notes that traditional classes are usually dominated by direct and unilateral instructions from the teacher, who seeks to transfer thoughts and meanings to the passive learners, thereby leaving a limited chance for learner-initiated questions, independent thoughts or interactions among learners. Within this framework, learners are expected to blindly accept the information from the instructor without questioning. Corroborating this, Stofflett (1998), remarks that followers of the traditional approach assume that there is an existing body of knowledge that learners have to take in without question.

Kalu and Stofflett describe the traditional instructional approach as a passive transmission of information from the teacher to the learners. It takes learners for empty vessels meant to be filled by the teacher, who is recognized as the sole dispenser of knowledge. Learners have to absorb the ideas and knowledge transmitted to them, only to regurgitate such during examinations. In this

conventional instructional practice, the learning process is fully controlled by the teacher, thereby making it impossible for learners to exercise independence. Besides, the structure of the traditional classroom depends heavily on textbooks, workbooks, worksheets, established facts and curriculum content.

Studies (Kilavuz, 2005; Kim, 2005; Moyo, 2014; Nayak, 2012; Nkhoboti, 2002) have shown that the traditional instructional approach has failed to achieve maximal realization of learning outcomes. Most learners taught with this approach have regrettably been unable to connect what they learn in the Mathematics classroom to real life. Vander Berg and Louw (2006) observe that practical knowledge and school knowledge are not really seen as inter-related by the learners. In research conducted by Mochesela (2007), it was established that the traditional approach has produced learners whose performance in mathematics is not satisfactory and who are not sufficiently equipped with the critical problem-solving skills that are necessary in this dynamic world. In another investigation, Stofflett (1998) discovered that the traditional, teacher-dominated, knowledge-dissemination approach evidently promotes rule-bound, rote and mechanistic learning. Being ruled by memorization and learning of isolated concepts and procedures, it usually results in poor knowledge transfer, low academic achievement and under-performance.

In the light of the above, the traditional teacher, as information-giver to passive learners, and the textbook-guided classroom have been unable to bring about the desired outcome of producing thinking learners (Young & Collins, 2003). This is because the approach emphasizes the learning of answers more than the exploration of questions, memorization at the expense of logical thinking, bits and pieces of information against understanding in concepts in context. In addition, the learning approach does not involve learners in active knowledge construction. It fails to encourage them to work together, to contribute and share ideas with one another; hence, the clamour for the learner-centered constructivist instructional approach. With this realization comes the need to modify or replace the traditional learning approach with a more applicable and more useful one.

The teaching and learning scenario described in the above paragraph becomes more complicated when teaching geometric concepts. The learning of geometry requires deep reasoning on part of the learners, it involves definitions, theorems and proof. A chalk-and-talk instructional approach will make the learning geometry concepts not only difficult but also boring. Perhaps due to the shortcomings encountered in the traditional mathematics instructional classroom, the teaching and learning of mathematics lends itself to educational technology instruction to facilitate teaching and learning more efficiently.

2.1.2 The integration of Technology into the teaching of Mathematics

The advent of television and computers in 1927 and the 1960s respectively brought about the use of technological tools in the classroom (Reiser, 1987; Saeltler, 1990). Computers and video cassette recorders were used to aid the traditional teaching approach, including mathematics teaching. This role of technology in the classroom is termed "Technology in education". As technology became more sophisticated, its place in the mathematics classroom as a teaching aid began to change, and instructional approaches that are technologically driven began to evolve (Gregory & Derby, 2011). Gregory and Derby referred to this development as "Educational Technology". Educational technology involves the use of technological ideas to create learning enabling environments for students. This phenomenon should not be confused with technology in education, a term that implies the use of technology as a teaching aid.

The educational technologists have many learning hypotheses, theories and instructional approaches, some of which include the cognitive-affective theory of learning with multimedia, (CATLM), (Mayer, 1997); the dual coding learning theory (Paivio, 1986), the Multiple–Representation principle (Mayer & Moreno, 1998), and the Media-Affect learning theory (Moreno & Mayer, 2002). These learning theories may be coupled with a traditional teaching approach or other teaching approaches like a constructivist teaching approach in mathematics lesson delivery. The educational technology instructional approach takes advantage of the potential of its spatial demonstration of concepts to facilitate teaching and learning.

Educational technology instructional approaches require that the teacher has subject content knowledge (SCK), as well as technological pedagogical content knowledge (TPCK) (Wallace, 2004). Besides the teacher being able to familiarize him- or herself with what he/she teaches, it is important to be conversant with the use of the technology to present mathematics lessons. Good knowledge in either SCK or TPCK does not necessarily result in effective teaching. Teaching is effective when the required learning outcome is achieved, when the majority of learners gain deep conceptual understanding.

The use of the educational technology instructional approach in the teaching of mathematical concepts, has on one side met with a degree of resistance from some teachers (Colette, 2001; Garofalo, Drier, Harper, Timmerman & Shockey, 2000), while others embrace it. Stols and Kriek (2011) developed a model to study this phenomenon. Some teachers were unable to adapt to change (Stols & Kriek, 2011; Zhao & Cziko, 2001; Piece & Ball, 2009). These teachers deliver their mathematics lesson in the in same way they were taught and find any innovation difficult to implement. There is another group of mathematics teachers that have a phobia of using technology (Zhao & Cziko, 2001). This group of teachers cannot use technology in general, and even less in mathematics lesson delivery.

The researcher in this study adapted Small Stella to teach polyhedron in the grade 9 mathematics classroom. This research is supported by the Media-Affect learning theory in the learning of polyhedron. According to this theory, some subject matter concepts might be difficult to learn but they become easier when they are presented pictorially in 2D or 3D, especially geometrical concepts.

2.2 Review of Similar Studies

In this section, similar works that have been done on the application of technology in the teaching and learning of mathematics will be presented, together with teachers' attitudes towards its application.

2.2.1 The Use of Technology to Facilitate the of Mathematical Concepts

With the advent of different types of technologies, researchers in mathematics education started thinking how they could use technology in mathematics classrooms to facilitate the learning of different aspects of mathematics. From experiments carried out with students who used interactive multimedia animations created with Macromedia Flash in learning descriptive geometry, Ramon and others (2005) discovered that the creation of animations, together with their use in theory classes as a supplement to the work provided by the teacher, improved achievement and conceptual understanding of students in descriptive geometry.

While investigating the influence of computer use on the teaching and learning of functions, Zeslassie (2007) used MS Excel and RJS Graph software as intervention tools in grade 11 Eritrean mathematics classes. He made an empirical investigation using quantitative and qualitative research methods. The outcome of his study indicated that the use of computers had a positive impact on students' conceptual understanding of functions, problem-solving skills, motivation, attitude and the classroom environment.

Using multimedia learning software called GeoCal, based on van Hiele's geometric thinking level theory, Chang et.al (2007) explored the learning effects of GeoCal on second-grade elementary school students who had not previously received formal instruction in geometry. The result of their study (with the exception of recognition ability) indicated that GeoCal produces significant learning effects on visual association, description/analysis and abstraction/reflection as well as overall geometric thinking.

Eley (2008) conducted a study to find out if using computer software in classroom instruction would help students to better understand geometric and probability concepts. He used Geometer's Sketchpad and Probability Explorer software as treatment instructional tools during a two-week summer Geometry and Probability course, for two groups of middle grade students from a public secondary school system in central North Carolina. Eley wanted to establish if a treatment effect exists

between the pre- and post-tests administered on students after interventions were interchangeably carried out among the groups. Results from the analysis of the post-test scores, using quantitative and qualitative methods, showed that students were better motivated using computer software and their performance improved significantly.

Rafiq (2009) explored students' learning experiences when GeoGebra, a Dynamic Geometry Software (DGS), is used in the teaching of geometry. He conducted his study at a secondary school in Azerbaijan in what he called "a cooperative learning arrangement". Rafiq developed applets which represented some geometrical concepts. These applets provided students with the option to transform geometrical constructions during the mathematics lesson. He used the following instruments to gather the necessary data: a checklist and field notes during the classroom observation, pre- and post-test instruments to gather data on participants' knowledge before and after the intervention, and questionnaire and interview instruments. One of his major findings showed that the use of GeoGebra, as a DGS tool, brought about certain changes in students' learning experience of geometrical concepts. He further pointed out that participants' conceptual understanding and problem-solving strategies improved during the intervention.

Faleye (2011), in an attempt to facilitate the learning of fluid mechanics (an aspect of mathematics), developed an animated computer instructional aid that was used to teach fluid mechanics in some South African universities. In his study, he used a mixed method approach to conduct his investigation. Faleye found that (among many other results) the use of an animated instructional approach facilitated the learning of fluid mechanics in the experimental groups

Brow (2015) demonstrated in his study that, besides the mere application of technology in teaching, the complexity that accompany the use of technology and the associated TPCK matter as well. The study investigated the available technologies in the teaching and learning of a specific learning area or function. Sixteen affordances were identified in the process of the data analysis, and

grounded theory was used to explain, predict and guide actions in other digital environments.

Liu, Xiaoqing, Wang and Tang (2016) argue that digital plane geometry figures (PGF) learning aids are becoming readily available online, but noted that both educators and learners are finding it difficult to search and retrieve them for classroom use. A method called “Learning to Rank” was used as an intervention. The result of the features selection for ranking according to the equality and redundancy of several specific types of PGF features, suggest that the intervention enhanced the retrieval accuracy and efficiency of PGF.

2.2.2 Teachers’ Perception on the use of Technology in the Classroom

It is an accepted fact that teaching technology is available and accessible in some schools, and therefore in many mathematics classrooms. Technology in itself can not impart the expected knowledge if teachers don't adopt and use it. Researchers have tried to investigate why some teachers have adopted the use of technology in their classrooms and why others refused to make use of the available technology to aid their teaching pedagogy. Their findings are presented below.

In their quest to investigate the barriers to integrating technology into the teaching of Mathematics, Hew and Brush (2007) carried out a study to analyse existing studies from 1995 to 2016 in the United States and countries abroad with empirical research findings. They examined 48 studies that met their selection criteria using databases such as Academic Search Premier, ERIC, and PsycARTICLES and Professional Development Collection. Using constant comparative methods, they found a total of 123 barriers, which they further classified into six main categories with the relative frequency in which the barriers were mentioned in past studies. They identified the following: lack of resources (40%), institutional problems (14%), subject culture (2%), attitude and beliefs (13%), knowledge/skills (23%) and assessment (5%).

Robyn Pierce and Lynda Ball (2009) used a theory of planned behaviour (TPB) framework to conduct an email survey with twelve items targeting attitudes,

subjective norms and perceived behavioural controls in their study of perceptions that may affect teachers' intention to use technology in secondary mathematics classes. This survey was sent to 200 randomly selected secondary schools in Australia for their mathematics teachers to respond, to which 92 secondary mathematics teachers responded. They reported that 23 percent of the teachers believed that learners don't understand mathematics unless they do it by hand first, so these teachers restrained the use technology. 32 percent of the teachers claimed that technology is too expensive for their learners to access, while 34 percent were of the opinion that using technology would take more of their time and that they would not be able to cover the course. Their findings did however confirm that the majority of the respondents held positive attitudes and perceptions toward the use of technology for teaching mathematics.

An exploratory study investigating reasons why all mathematics teachers are not using dynamic geometry software in their classroom was carried out in South Africa by Gerri Stols and Jeanne Kriek (2011). They used what they called "The Combined Model" which emanated from the theory of planned behaviour (TPB), the technology acceptance model (TAM) and the innovation diffusion theory (IDT). The data used for this study was obtained by administering a questionnaire on 22 school teachers randomly drawn from both urban and semi-urban areas of South Africa, who took part in a three-week extensive workshop on the use of dynamic geometry software (GeoGebra, Cabri and Geometer's Sketchpad) in the mathematics classroom. They used correlation statistics and regression analysis to analyze the collated data and the results of their investigation revealed that teachers' beliefs about the perceived usefulness and their beliefs about their level of technological proficiency are the major factors determining teachers' adoption and use of the software.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter describes the research design, sampling, instrumentation, and data collection procedures. It also includes a discussion of the ethical issues involved in the study.

3.1 Methodology

3.1.1 Research Design

This study follows a mixed method research approach which includes a quantitative and qualitative research approach (Faleye, 2009; Ogbonaya 2010). The mixed method approach is considered appropriate for this study because the researcher wants to:

- Ensure that the Small Stella intervention (independent variable) was used, and properly so, in the experimental fields while the teacher in the control research field used the traditional lesson delivery method.
- Be able to account for, as well as justify, any improvement or decline in the study participants' learning performance in the topic of geometry taught at the end of the intervention.
- Validate the results from the quantitative data analysis with the results from the qualitative data analysis, and so triangulate the results.

Figure 3.1 below illustrates how the mixed method was applied in this study:



Figure 3.1: Mixed Method Approach Model

The quantitative approach involves the use of a quasi-experimental design, while the qualitative approach follows an enquiry research design.

3.1.1a Quasi- Experimental Design

The quasi-experimental design involves a pre- and post-test matching control research design in which the pre-test was used to measure the prior knowledge of the study participants before the intervention, as well as a basis on which to measure the performance of the study participants after intervention, while the post-test was used to measure their performance after intervention.

Experimental Group	O ₁	X	O ₂
Control Group	O ₁	----	O ₂

O₁: Pre-test

O₂: Post-test

X: Intervention

Table 1: Illustration of the Matching Control Causal-Comparative design

Table 1 above indicates that the pre-test (O₁) was administered to both the control and experimental groups at the start of the investigation. The intervention programme (X) was organized only for the experimental groups, which means there was no intervention for the control group. Both groups took the post-test (O₂) at the end of the enquiry. It's also important to note at this junction that the items of O₁ and O₂ were the same, but with different item numbers.

The pre-test/post-test design allowed the researcher to gather data on the study participants' performance in a class test. A pre-test was administered on all the groups, including the control group, after which all the groups were taught polyhedron for one week. At the end of the intervention week, a post-test was administered (the post-test items were the same as the items in the pre-test but the items were shuffled around so that question items did not retain the same item numbers).

3.1.1b Inquiry Design

The inquiry design involved non-structured, non-participant classroom observation. The researcher carried out two non-consecutive classroom observation sessions in each of the research fields. The purpose for this was threefold: firstly to gather non-numerical information in the teaching-learning continuum as it happened in the natural setting of the research field, secondly to ensure that the educational technology teaching by using Small Stella was correctly implemented in the experimental groups during the intervention, and thirdly, to gather qualitative data that could be used to justify the results from the quantitative data.

3.2 Sampling

The Limpopo province comprises of 10 educational districts. The researcher divided the 10 districts into four clusters. The names of all the schools in each cluster were written on pieces of paper, and put in a separate box for each cluster. A random sampling approach was used to select a school from each of the boxes representing the four clusters. Four randomly selected schools in Limpopo province were thus selected to participate in this study. Out of the selected four schools, one school was randomly selected to be the control group, while the other three groups formed the experimental groups.

An intact group of the grade9 students in each selected school formed the study participant for the study. The study participants were 174 in total: 39 in the control group, 47 in experimental group 1, 36 in experimental group 2, and 52 in experimental group 3, with 4 mathematics teachers.

3.3 Data Collection

The intervention lasted for a period of two weeks, from 19 October 2015 to 30 October 2015. This is the timeframe allocated in the curriculum for teaching

polyhedron in Grade 9 in the Limpopo province. Pre- and post-tests generated quantitative data while the classroom observation generated the qualitative data

3.3.1. Quantitative Data Collection

The pre-test was written in all the participating schools: the control group test was written on Tuesday, 13 October 2015, while the experimental groups 1, 2 and 3 wrote it on Wednesday the 14th, Thursday the 15th, and Friday the 16th of October 2015 respectively. The pre-test was carried out in the week before the intervention week. In all the experimental groups, geometry of polyhedron was taught using the Small Stella software as a teaching aid, while in the control group the concept was taught with a traditional chalk-and-talk approach. The classroom teaching started on Monday, 19 October 2015, and ended on Thursday, 29 October, 2015. The post-test was written by all the groups on Friday, 30 October 2015. The researcher collected the scripts from each participating mathematics teacher in each research cluster. The researcher marked the scripts and stored them for data analysis. The study participants' post-test scripts were also used as part of the data collected for the problem-solving data analysis.

3.3.2 Inquiry Intervention Administration and Data Collection

3.3.2a Administration of ACTDFI in the Experimental Groups

The ACTDFI was used to teach the concept of polyhedron in this study. On Monday, 12 October 2015, the participating mathematics teachers were trained in the use of the Small Stella software (the intervention instrument) so that they could acquire the TPCK aspect of the research, as they all have good teaching experience in mathematics, and were presumed to already have the SCK. The teachers had the whole week of 12 to 18 October 2015 to familiarize themselves with the intervention instrument. From Monday 19 October, 2015 the teachers in the experimental groups taught the concepts of polyhedron using the intervention instrument for two weeks.

3.3.2b Qualitative Data Collection

The data gleaned from the classroom observation was qualitative in nature. Classroom observations were carried out in the experimental groups and the control group. Classroom observation for the control group took place on 20 and 26 October 2015, and for experimental group 1, experimental group 2 and experimental group 3 on 21 and 27, 22 and 28, and 23 and 29 October 2015 respectively. All the classroom observations were recorded with video and field notes of important events were also taken.

3.4 Instrumentation

The two main variables in this study are the learners' knowledge of the subject and their performance. Learner knowledge of the subject was measured using the pre-test, while the performance of the learners was measured using the post-test. Small Stella version 5.4 was used as the animated computer 3-D Figure illustration, which served as an instructional aid for the intervention groups. A classroom observation checklist was filled out and a video camera was used to get a visual record, in order to verify the data with a variety of media.

3.4.1 Animated Computer 3-D Figures Illustration (ACTDFI)

Small Stella as an ACTDFI is a dynamic geometry software which allows one to create and then manipulate three-dimensional geometric shapes. This instrument was used as a teaching aid for the intervention, to teach the geometry of polyhedron in the experimental groups.

3.4.1a Development of ACTDFI

Small Stella version 5.4 was developed and released as dynamic geometry software on 10 May 2014 by Robert Webb (See <http://www.software3d.com/Stella.php>). It was purchased and adapted by the researcher. The topics to be taught, which cover the subject matter for this study, are already embedded in the software.

3.4.1b Validity of ACTDFI

ACTDFI was content validated. A validity rating form was designed and distributed to five selected judges, who were familiar with the software. They had to rate the software according to how well the package covered the topics to be taught in line with the National Curriculum Statement using the scale (see appendix 6):

1= not well covered

2= somewhat covered

3= very well covered

76% of the judges ruled that it was very well covered and 20% agreed with somewhat covered. Only 4% believed the topics were not well covered. 96.0% of them rated the software to have covered the content to be taught. It was therefore deduced that the judges were generally positive and that the package covered the topics in line with the Curriculum Assessment Policy Statements, which in turn ensured the content validity of the software.

3.4.1c Reliability of ACTDFI

An inter-judge' reliability test was carried out to assess the internal consistency of the software. The ratings of two of the five judges were used to measure the extent of agreement, while the Pearson Correlation Coefficient was used as the statistical tool. The result $r = 0.72$ was obtained, which indicates a high correlation between the two sets of scores obtained from the judges. The instrument was therefore considered to be reliable.

3.4.2 Pre-Test and Post Test

The researcher compiled a set of questions to measure learners' subject matter knowledge of polyhedron. The same set of questions was used for both the pre-test

and post-test; the questions were however shuffled in the post-test (see Appendices 1 and 2

3.4.2a Validity of Pre-Test and post Test Instrument

Face validity and content validity tests of the pre-test and post-test instruments were carried out by four mathematics teachers who are experts in the field, to ascertain that the items actually measured what they were assumed to measure. The experts judged the instrument by rating the level of relevance of each of the items using the following (see Appendix 3 for the validity form):

1=not relevant

2=fairly relevant

3= relevant

4= highly relevant.

According to the result, 80% and 20% of the judges rated the test instrument as relevant and highly relevant respectively. In doing so, all the experts indicated that the measurement procedure was valid.

3.4.2b Reliability of Pre-Test and Post-Test

In order to assess the reliability of the test instrument, the test-retest reliability on separate day's technique was used. 10 learners were randomly drawn from a list of 42 grade 10 learners in a school not included in the study population. It is believed that they had prior knowledge of the subject matter, as they were not exposed to any intervention before the instrument was administered on them. The test was administered in one day and they were retested after one week without creating any awareness of the retest.

The results obtained were compared for correlation. The Pearson Correlation Coefficient was used to assess the coefficient of correlation. The result of the test

indicated a high positive correlation coefficient, $r=0.66$ (see Appendix 9). This implied that the test instrument was reliable and stable.

3.4.3 Classroom Observation Checklist

An observation checklist was used to collect data during the classroom observation. A series of classroom visits were carried out during the intervention to ensure the proper use of Small Stella as a teaching aid in teaching polyhedron in the class and to triangulate the study.

3.4.3a Development of Classroom Observation Checklist

The observation checklist instrument developed by Gadsden educations was adapted for this study

(see,

<http://www.gadsdenstate.edu/ie/faculty/Classroom%20Observation%20Checklist.pdf>

) Faleye, 2011 (see Appendix 4). This was used to check if each classroom observation followed the appropriate teaching method during the intervention.

3.4.3b Validity of Classroom Observation Checklist

The checklist contents needed to meet the objectives for which the instrument was constructed to be able to measure what it was supposed to measure. Hence, the instrument was face validated. The instrument was validated by three mathematics experts in the field of education.

3.4.3c Reliability of Classroom Observation Checklist

Internal consistency reliability was used to measure the reliability of the instrument. This involved the consistency of objectives among the items in the checklist, matching it with the overall objective for constructing the instrument. The same three mathematics teachers who validated the instrument were also employed to check its

reliability. A reliability value of 0.67 was calculated by finding the score agreement percentage.

3.4.4 Video Camera

This was used to collect visual data, which could support the results obtained via other media. The camera was purchased, tested and ascertained to be in good condition before it was used.

3.5 Data Analysis

The data collected in this study are qualitative and quantitative. For quantitative data, the quantitative method of data analysis was followed and for qualitative data, a qualitative data analysis method was followed. The various data analysis methods are explained in detail in chapter four.

3.6 Pilot Study

A pilot study is a small scale preliminary study conducted in order to evaluate the feasibility of the study, instrument usability, time, cost and possible inherent factors. Thabane (2010) informs that the goal of a pilot study is to assess the feasibility of a proposed study and to investigate inherent possible impending factors that might pose a validity threat should the study be carried out.

The pilot study was carried out for this study in a school that was not part of the research fields between 20 and 24 October 2014. The grade 9 group consisted of three classes with a total of 72 learners. Grade 9B was randomly chosen for the pilot study as the researcher randomly drew from a closed box containing pieces of papers labeled 9A, 9B and 9C. The research instruments used were ACTDFI, pre-test and post-test, classroom observation checklist and video cameras, which were all meant to be used in the full scale study. See the result of the pilot study presented in chapter 4.

3.7 Ethical Issues

Ethical practices were ensured at every level of this study and its reports, by observing the following ethical guidelines.

3.7.1 Informed Consent of the Participants

The participants (teachers, learners and authorities of schools of participating learners and teachers) were informed of the purpose and aims of this study before they began to take part in the study. They were also informed about how the results of the study would be used. Consent forms with detailed information about the research were given to the participating teachers to sign, and only those who gave their consent could take part in the study (see Appendix 7 for the consent forms). Participation was voluntary and participants could withdraw at any time. Permission was also obtained from the Department of Education to conduct the study in the district.

3.7.2 Voluntary Participation

Ethics demands that participation in social science research be voluntary (Babbie, 2001; Creswell, 2008). Participants of this study were not coerced into participation and they were allowed to withdraw at any time in the process, as stated in the consent letters.

3.7.3 Confidentiality

Data gathered from participants, together with their other personal information, was only used for research purposes and is not to be used against them in some way. Participants were assured in the consent forms that their personal information would be treated confidentially. In addition, all the study participants remained anonymous within this study. The names of participants and their schools were not written in this report and as such they cannot be linked to any specific person or institution.

CHAPTER FOUR

DATA ANALYSIS AND PRESENTATION OF RESULTS

4.0 Presentation of Data Analysis Results

In this chapter, the data analysis strategy and the results of the data analysis are presented, including the pilot study's result. The investigation was conducted in four different research groups: one of them is the control group and the remaining three are experimental groups. In the control group, the teaching and learning were conducted without any intervention, while in the experimental groups; teaching and learning were conducted with the use of ACTDFI, which is the intervention. Quantitative data were collected from the pre-test and post-test while the classroom observation yielded qualitative data.

4.1 Data Analysis Strategies

As mentioned above, this study involved the collection of both quantitative and qualitative data, hence quantitative data analysis techniques were used to analyze the quantitative data gleaned from the pre-post design, while qualitative data analysis techniques were used to analyze data from the classroom observation.

4.1.1 Quantitative data analysis strategies

Descriptive and inferential statistical analysis techniques were used to study descriptive attributes, performance and perceptual trends of the collected quantitative data.

4.1.1a Descriptive Data Analysis Strategies

In each of the groups, descriptive statistical analysis was used to describe the initial result of the analysis. This includes presentation of the mean, standard deviation, skewness, and kurtosis of the performance of the study participants in both pre- and

post-test scores in all the groups. The standard deviation was used to calculate the range of the scores in which the majority of the scores could be found.

In addition, the normal distribution curve was used to calculate the 'Z' value (the actual number of the study participants' scores that may be found within a given interval in terms of percentage in the post-test) and also to analyze the quality of the scores. This was done using:

$$z_a = \frac{X_1 - \mu}{\sigma}$$

Where z is the z-score, X is the value of the element, μ is the population mean, and σ is the standard deviation.

4.1.1b Inferential Data Analysis Strategies

Inferential statistical analyses were carried out on pre- and post-test scores of both the control group and the experimental groups (the intervention groups). Tests for homogeneity of variances, the predicted plot and the least square means plot were performed. A one-way ANOVA test was conducted, together with an Analysis of difference by Group and Wilcoxon/Kruskal-Wallis Test.

4.1.1c Problem Solving Data Analysis Strategies

The test instrument items were structured according to Bloom Taxonomy cognitive levels (Bloom et al, 1956) Table 2 below shows cognitive hierarchies as given by the Bloom Taxonomy:

Bloom Taxonomy Cognitive Demand Level	Cognitive Domain
1	Knowledge
2	Comprehension
3	Application
4	Analysis
5	Synthesis

Table 2: Bloom Taxonomy showing the cognitive demand hierarchies (Bloom et al, 1956)

The Bloom taxonomy was used to categorize the test instrument items according to their cognitive demand as described below:

- Category A are the test instrument items that require demonstration of prior knowledge and applying the same to understand the present conceptual domain.
- Category B are the test instrument items that require using the conceptual knowledge learnt to analyze new problems and generate new ideas.
- Category C are the test instrument items that demand concrete deductive reasoning, make inferences that may be used to solve problems of higher cognitive demand and the ability to evaluate the results.

Table 3 and 4 below give the structure of the test instrument and their categories respectively.

Test Instrument Items	Content Structure with Marks
1	Knowledge of dimension and shapes/2marks
2	Identification of different types polyhedron/2marks
3	Application of definition of polyhedron/2marks
4	Apply internalised concepts of polyhedron to analyse different types of polyhedron/12marks

5	Demonstrate concretely the internalised concepts/10marks
6	Use the internalised concepts to calculate the Euler number for different types of polyhedron/20marks
7	Evaluate each polyhedron according to their Euler numbers/2marks

Table 3: The structure of the test instrument items. (See appendix 2)

Category	Question Item	Weight over 50 Marks	Weight over 100 Marks	Cumulative Weight
A	1, 2 and 3	6	12	12
B	4 and 7	14	28	40
C	5 and 6	30	60	100

Table 4: Categories of the Test Instrument Items

Categories B and C in table 4 above contain items that are of higher cognitive demand than the items in category A. More items and consequently more marks were allocated to categories B and C as the aim was to establish if the study participants gained deeper understanding in the experimental groups by using the intervention.

To analyze the study participants' problem solving approaches in the post-test, the researcher used:

- (i) The number of study participants that passed each question category

The total marks and whatever marks each study participants scored in each category was standardized (converted into percentages). Thereafter, the considered pass mark was 50% and above.

- (ii) Solution appraisal method

The script of each study participant was scrutinized and the reasoning behind each solution approach was studied.

4.1.1d Qualitative Data Analysis Strategies

Data gathered from classroom observations as well as the background information of each of the schools constituted the qualitative data for this study. The qualitative data collected from the video recorder was carefully transcribed; the researcher went through this process three times to ensure that no information was left out. The data collected from the field notes were merged with the transcribed data. The process of data analysis contained three steps: data classification, coding and tabulation. These steps are explained below:

(i) Data Classification

This stage entails arranging data into groups. These groups are called categories; these categories are structured according to the research questions.

(ii) Coding

This stage entails assigning numerical values to each category of responses so that they can be counted and tabulated.

(iii) Tabulation

This stage involves putting the coded data in a requisite row and column. In this way the data is in a compact form that facilitates data comparison and shows the relationship between two or more variables.

Emerging themes from these exercises were noted. This was performed on the qualitative data collected from each research field.

4.2 Presentation of the Results

The result of the pilot study is presented first, and followed by that of the main study. The result of the data analysis of the main study shall be presented according to each research field, starting with the control group and ending with the three

experimental groups. In addition, the profiles of each research field are provided, so that the readers can contextualize the discussion around the emanating results in this study. The nature of the data analyzed consists of quantitative and qualitative data: the quantitative data analysis results shall be presented first, followed by that of the qualitative data in each research group.

4.2.1 The Pilot Study

Here the results of the pilot study are presented. These include conducting the pilot study, the result of the pilot study and the implication of the results for the main study.

4.2.1a Conducting the Pilot Study

As stated in section 3.6 of this study, the pilot study was carried out in 2014 at the exact period of time the main study was carried out in 2015. It was a week-long pilot study; it started on 20 October, 2014 and ended on 24 October, 2014. The pre-test was written on Friday 17 October, 2014 and the post test was written on Friday 24th of October, 2014. Below are the initial challenges that were encountered on the first day of the pilot study:

1. The school did not know that the overhead projector was faulty. The principal borrowed from the nearby school but the first day was wasted.
2. On the second day of the pilot study, though the intervention was running very well, it was evident that the teacher was not comfortable using the intervention instrument (Small Stella software), despite receiving a full day's training on how to use the instrument.
3. During the lesson, the study participants were fascinated by the computer display and hence were more focused on the computer display than on the concepts to be learnt. The researcher drew the attention of the teacher to this.

In spite of these challenges, the pilot study was conducted throughout the week.

4.2.1b Results of the Pilot Study

(i). Results of the Quantitative Data Analysis

After marking the post-test, a t-test (this was calculated manually since it was not a large amount of data) was used to compare the pre- and post-test study participants' achievement scores. See the results of the pilot study in Appendix 8

The t-test gave a result of $t = -2$, which was less than $\alpha=0.05$. This implies that the difference between the pre- and post-test was statistically significant.

(ii). Results of the Qualitative Data Analysis

The classroom observation checklist was used to crosscheck the data collected from the observations to establish if the intervention was properly conducted as planned. The results of the data analysis of the classroom observation data showed that the study participants were enthusiastic about being taught with the software, the nature of the questions the study participants were asking suggested that they understood (i) what a 3D figure is, (ii) the difference between a polyhedron and other shapes, and (iii) the concepts of number of edges and number of flat surfaces.

4.2.1c Implications of the Pilot study results

The implications of the initial challenges and the results of the pilot study were:

- (a) The researcher borrowed three overhead projectors and three laptops that were in good condition and prepared for the study before the main study intervention.
- (b) The participating teachers were not only trained on how to use the intervention instrument but the instruments were also released to them a week before the main study intervention for practice.
- (c) During the participating teachers' training, they were informed of the possibility of the study participants focusing on the computer display and not concentrating on learning the concepts they are supposed to be learning. The teachers were asked to engage the study participants while teaching.

4.2.2 Presentation of the Initial Quantitative Data Analysis Results

Some initial data analysis that could assist the researcher in understanding the emerging results was conducted. These include:

1. Comparing the level of prior knowledge of all the study participants in all the research fields.
2. The test of homogeneity of variance of the data. This assisted in choosing between using the analysis of covariance (ANCOVA) or analysis of variance (ANOVA) for the inferential statistics.
3. A test to know which factors impact on the outcome of the study.

The results of the tested factors were:

4.2.2a Prior Conceptual Knowledge level of the Study Participants in Geometry of Polyhedron before the Intervention

In order to measure the prior conceptual knowledge level of the study participants, the mean scores of the pre-test were used.

Level	Number	Mean	Std Dev	Std Error	Lower 95%	Upper 95%
Control 1	39	8.56	3.78	0.67	7.24	9.89
Experimental 1	47	9.45	4.10	0.61	8.24	10.65
Experimental 2	36	11.50	4.12	0.70	10.12	12.88
Experimental 3	52	9.35	4.56	0.58	8.20	10.49

Table 5: One-way ANOVA of the Pre-test Scores

The means of the scores of the pre-test of the four groups before intervention and their respective standard deviations are presented in Table 5 above. In the control group, the mean score was 8.56, while the standard deviation was about 3.78. This implies that in the control group the majority of the pre-test scores were between 4.8 and 12.3. In the experimental group 1, the mean score of 9.4 was recorded while the standard deviation stood at 4.1. Most of the scores in this group were between 5.3 and 13.5. A mean score of 11.5 was calculated for experimental group 2, with a

standard deviation of 4.1. Most of the pre-test scores in this group were between 7.4 and 15.6. In the experimental group 3, a mean score of 9.3 and standard deviation of 4.6 were recorded. Most of the scores were between 4.8 and 13.9.

Looking at the means of scores of the pre-test of each of the research fields and their respective standard deviations, it is clear that the majority of the study participants' marks were within the 4.8% and 15.6% category, which indicates a relatively low cognitive level of understanding of the geometry of polyhedron.

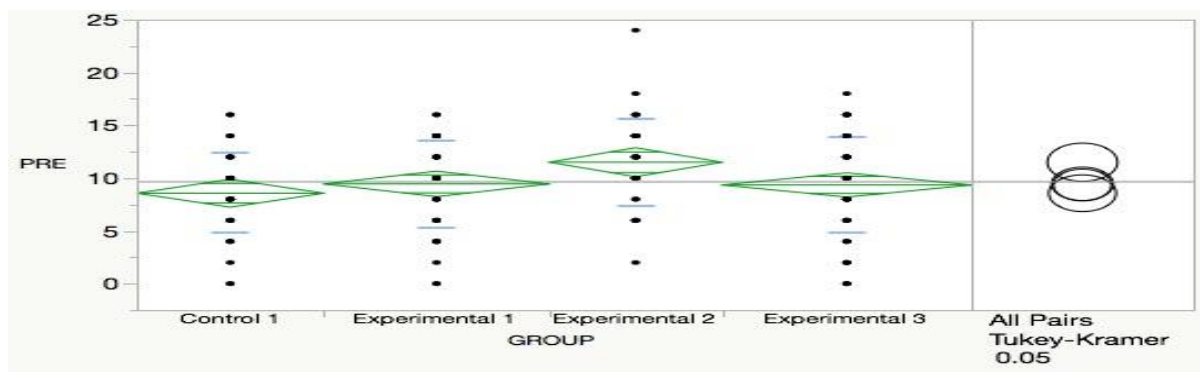


Figure 4.1: Turkey's Range Plot, showing the prior cognitive knowledge level of the study participants before intervention

The level of prior knowledge of the study participants before the intervention is graphically represented on Tukey's range plot in Figure 4.1 above. The middle line in the diamond represents the mean scores of the group. The vertical endpoints form the 95% confidence interval of the mean. The width of the diamonds indicates the relative sample size. In this case, it is observed that all the groups had almost the same mean score. This implies that all the groups had almost the same prior knowledge level in the learning of the geometry of polyhedron.

4.2.2b Test of Homogeneity of Variances with Levene's Test

Analysis of covariance (ANCOVA) would have been preferred for the inferential statistics but the data gathered failed the assumptions of ANCOVA and analysis of variance (ANOVA) was therefore used to carry out the inferential statistics. ANOVA

assumptions were satisfied. Figure 4.2 shows the equality of the variances as one the ANOVA assumptions.

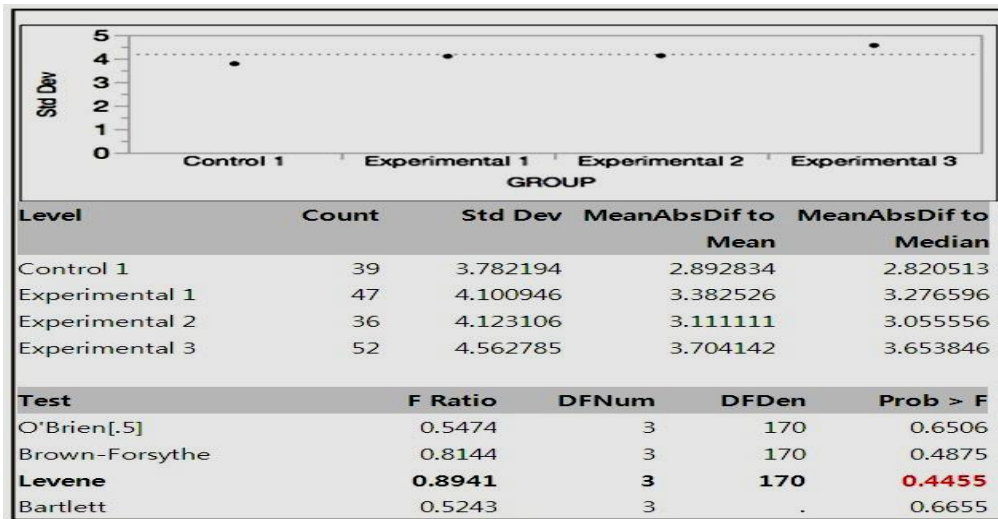


Figure 4.2: Tests That the Variances are Equal

In Figure 4.2 above, the p-value from the Levene's test is greater than 0.01 ($p=0.45$), that indicates equal variances at a 99% level of confidence.

The variances of the pre-test's scores of all the research groups were statistically homogenous. As they do not differ significantly, the assumption of equal variances holds.

4.2.2c Test of Factors that might have influenced the Result of the study

The researcher tested whether there were other factors that might have influenced the outcome of this research by looking at the following independent factors: Intervention, Age and Gender. The results below show how the three factors that had an impact on the research.

Source	Nparm	DF	Sum of Squares	F Ratio	Prob> F
Intervention	3	3	30851.367	135.313	<.0001*
Age	1	1	19.961	0.2626	0.6090

Gender	1	1	2.761	0.0363	0.8491
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Table 6: Impact of the factors on the Research

From Table 6 above, the F-value for intervention, Age and Gender are 0.0001, 0.6090, and 0.8491 respectively. Since it is only $0.0001 < 0.05$, it implies that age and gender did not have a statistically significant impact on the results. Only intervention as a factor had statistically significant impact on the research.

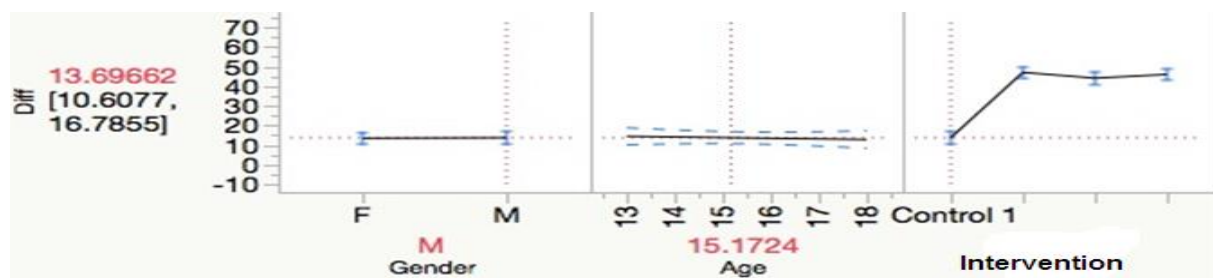


Figure 4.3: Pictorial illustration of the impact of the factors on the Study

Figure 4.3 above shows clearly that age and gender did not have any significant impact on the performance of the study participants, but that the intervention did.

4.3 Presentation of the Results of the main Study

4.3.1 Presentation of the Data Analysis Results of the Control Group

In this section, the profile of the control group, the profile of the mathematics teacher, the results of the quantitative data analysis (descriptive and inferential), and the results of the qualitative statistical data analysis are presented.

4.3.1.1 Profile of the Control Group

The school referred to as control group was a secondary school in Limpopo province. It had both senior phase and FET phase with learners' enrolment of about 546. It had a male principal, and a female deputy principal, three HOD's and 13 educators.

It had an arm of grade 9 consisting 39 learners, all of which formed the study participants for the control group. All the learners offered Mathematics. They were taught by a male mathematics teacher, who eventually taught the study participants during this study.

4.3.1.2 Profile of the mathematics Teacher in the Control Group

Gender: Male

Age: 44years

Academic Qualifications: Bachelor of Education (B. Ed.) in Mathematics

Teaching Experience: 10 years

4.3.1.3 Results of the Quantitative Data Analysis for the Control Group

4.3.1.3a Results of the Descriptive Statistical Analysis for the Control Group

Quantitative results presentation was used to answer research question 1.

Will the use of animated computer 3-D figures illustration improve learners' achievement in geometry class?

It should be noted that the study participants in the control group were taught without the use of the intervention instrument (Small Stella) throughout the study period, hence the above research question may not be answered in this group, but the results of the quantitative analysis are given below. These results are compared with the results from the experimental groups in the discussion.

Table 7 below provides a summary of the results of the descriptive statistics data analysis results of the control group as shown below.

	Pre-Test	Post-Test
Mean	8.56	22.05
Std Dev	3.78	8.28

Std Err Mean	0.61	1.33
Upper 95% Mean	9.79	24.73
Lower 95% Mean	7.34	19.37
N	39	39
Skewness	-0.26	0.11
Kurtosis	0.19	-0.77

Table 7: The summary of the results of the descriptive statistics data analysis results of the Control Group

From Table 7 above, it is evident that the study participants had a mean of 8.56 in the pre-test and a standard deviation of 3.78. This shows that the majority of the marks were between 4.8 and 12.3 (see Figure 4.4). In the post-test however, the mean and standard deviations were 22.05 and 8.28 respectively. This implies that majority of the marks were between 13.8 and 30.3 (see Figure 4.4).

The performances of the study participants in the control group in the pre-test and post-test are further illustrated by the histograms below.

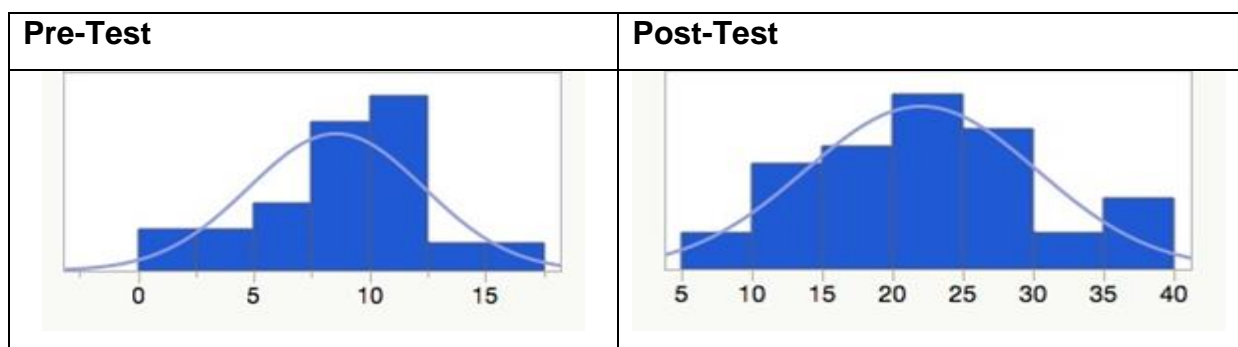


Figure 4.4: Pictorial representation of the Pre-test and Post-Test scores for the Control Group

The histograms in Figure 4.4 above show that the majority of the study participants scored between 5% and 12% in the pre-test and the majority of the study participants scored between 15% and 30% in the post test. Figure 4.4 corroborates the explanation given in support of table 7, where the majority of the marks are

around the mean of 8.5 in the pre-test whereas the marks in the post-test spread a little away from the mean of 22.05.

Moreover, from the normal distribution curve it was derived that the Z value was 67.64% for scores between 5 and 12.5 in the pre-test. This implies that 67.64% of the study participants had a score in this range. In the post-test, however the Z value was 88.66%, which implies that 88.66% of the study participants had a score within the range of 15 to 30. Since everyone in this group failed the post-test, the researcher could not examine the data analysis further. (See appendix 10 for the calculations)

4.3.1.3b Results of the Inferential Statistical Analysis for the Control Group

The paired t-test analysis for the Control group was used to test the null hypothesis:

“*H₀*: There is no statistically significant difference between the study participants’ pre- and post-test intervention mean achievement score in the learning of the concept of polyhedron.

Again the reader should remember that this data did not answer this question since there was no intervention in this group. It is only a comparison between the pre- and post-test.

Type of test	Mean	Standard deviation	t-value	p-value	Decision
Pre-test	8.56	3.78	-8.9	.0001*	Null hypothesis is rejected
Post-test	22.05	8.28			

Note: * P<0.05

Table 8: Paired t-test analysis for the Control Group

The paired t-test gave a t-value = -8.9 with a *p-value* = .0001. Since .0001 is less than 0.05, there is a statistically significant difference in the mean. Though there is a

statistically significant difference between the learners' pre-test and post-test mean scores, the improvement is below the 40% pass mark.

4.3.1.3c Results of the Problem Solving Approaches displayed by the Study Participants in the Control Group

The problem solving approaches data was gathered through scrutinizing the study participants' scripts. The results of the data analysis of this exercise were used to probe the answer to research question 3:

Does the use of computer 3-D figures illustration have any impact on the problem solving approaches of the study participants?

In this group, the study participants were taught without the intervention instrument. But this question was treated in order to be able to compare the problem-solving skills of this group with the other groups.

(a) The number of study participants that passed each question category in the post test.

Two of the study participants scored above 50% in question category A, one (1) scored above 50% in question category B, and no one scored above 50% in question category C.

(b) Solution appraisal method

2) Scripts showed some answer patterns for the question items 1 to 3. For example, question item 1 requires the study participant to write "False" next to the item that they considered false, many wrote FALSE next to all four sub-question items in question 1. In question items 2 and 3, some copied the letters A – D as their own answers, while the choice of the letters written by some showed that they just wrote for writing's sake.

Only two of the study participants answered 4 and 5 (not totally correctly), while one other person (not one of the two that answered questions 4 and 5) attempted question 6 (though incorrectly). None of the study participants attempted question 7. Figure 4.5 below is a sample script of the study participant that answered question item 6. Question item 6 is important because the question required learners to display understanding of dimensions of shapes, vertices, edges, faces and using this to calculate the Euler number.

Pre Test					Post Test							
6. Copy and complete the following table.					6. Copy and complete the following table.							
	Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F		Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F	
6.1	Tetrahedron	8	4	4	13	1 20	6.1	Hexahedron	8	12	6	2
6.2	Hexahedron	6	3	8	16		6.2	Octahedron	9	6	3	4
6.3	Octahedron	7	4	3	14		6.3	Tetrahedron	6	7	8	6
6.4	Dodecahedron	12	8	6	4		6.4	Icosahedron	20	6	9	3
6.5	Icosahedron	9	13	16	14		6.5	Dodecahedron	6	12	9	3
(20mks)					(20mks)							

Figure 4.5: Sample Script on question 6 of a study participant in the control group

This study participant scored 32% in the post-test. The script had one of the highest marks in this group with 8 out of 12 marks, 15 out of 28marks and 9 out of 60 marks in categories A, B, and C respectively in the post-test.

4.3.1.3d Results of Qualitative Data Analysis for Control Group

Classroom observation for this group was conducted on Tuesday 20th of October, 2015 and Monday 26th of October, 2015. The results of the observation in this group show that the concepts of polyhedron were taught with the traditional chalk-and-talk approach. The results of the data analysis showed that the teacher followed the same teaching routine in every lesson taught. The routine is outlined below:

The teacher enters the classroom with his prepared lesson notes and a textbook. He writes the topic to be treated on the chalkboard, asks the study

participants to open their books to where the topic is found in the book, gives a brief explanation of the concept he is teaching, gives an example to support his explanation, takes questions from the study participants and finally gives home/classwork.

The results of the data analysis showed that the teacher struggled considerably to explain the 3D shapes, edges and faces of shapes to the study participants in this group. The study participants asked questions like:

Study participant: *"You said 3D is three sided shapes, I can't see from what you drawn on the board."*

Teacher: *"I did not say that 3D is a three-sided shape, I said that it is a shape that can be represented with length, width and height. Look at the diagram that I drew on the board (pointing to the board)."*

The facial expression of the study participants also implied that they were confused. In the second round of classroom observation, the teacher punished the whole class (except two study participants who were asked to sit down) because they did not do the homework.

4.3.2 Presentation of the Data Analysis Results for the Experimental Group 1

In this section, the profile of experimental group 1, the profile of the mathematics teacher, the results of the descriptive, inferential and qualitative statistical data analyses are presented.

4.3.2.1 Profile of the Experimental Group 1

The school referred to as experimental group 1 was a secondary school in Limpopo province. It had 639 learners combined in the senior and FET phase. The school had a male principal, two HODs and fourteen educators. It had an arm of grade 9 consisting of 47 learners, all of which formed the study participants for the

experimental group 1. All the learners took mathematics. They were taught by a male mathematics teacher, who taught the study participants during this study.

4.3.2.2 Profile of the mathematics Teacher in the Experimental Group 1

Gender: Male

Age: 47 years

Academic Qualifications: Bachelor of Education (B. Ed.) in Mathematics and Diploma

Teaching Experience: 15 years

4.3.2.3 Results of the Quantitative Data Analysis for Experimental Group 1

4.3.2.3a Results of the Descriptive Statistical Analysis for Experimental Group 1

Quantitative results presentation was used to answer research question 1.

Will the use of animated computer 3-D figures illustration improve learners' achievement in geometry class?

Table 9 below provides a summary of the results of the descriptive statistics data analysis results for experimental group 1.

	Pre-Test	Post-Test
Mean	9.45	56.43
Std Dev	4.10	7.93
Std Err Mean	0.60	1.16
Upper 95% Mean	10.65	58.75
Lower 95% Mean	8.24	54.10
N	47	47
Skewness	-0.54	0.18
Kurtosis	-0.43	0.11

Table 9: Summary Statistics of Pre-Test and Post-Test scores of the Experimental Group 1

According to table 9 above, the study participants had a mean of 9.45 in the pre-test and a standard deviation of 4.1. The majority of the marks are between 5.4 and 13.6 (see figure 4.6). In the post-test, the mean and standard deviation was 56.4 and 7.9 respectively. This also indicates that the majority of the marks were between 48.5% and 64.3% (Figure 4.6). The performances of experimental group1 in the pre-test and post-test are further illustrated by the histograms below in Figure 4.6.

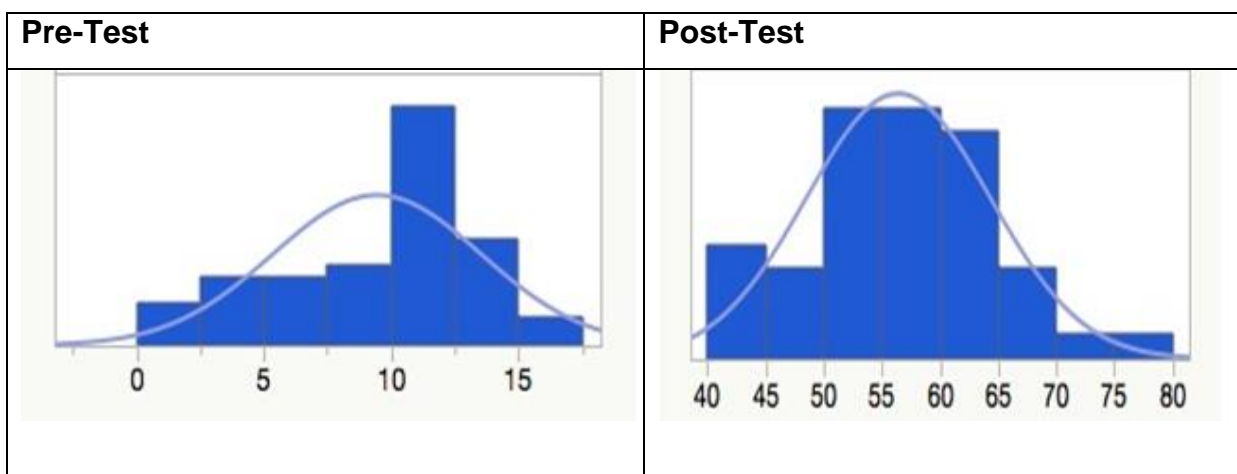


Figure 4.6: Pictorial representation of the Pre-test and Post-Test scores for Experimental Group 1

Figure 4.6 above corroborates the explanation given in support of the results presented in Table 9 above. The histograms in Figure 4.6 show that the majority of the study participants scored between 8% and 15% in the pre-test. In the post-test, the majority of the study participants scored between 50% and 65%.

In addition, it was derived from the normal distribution curve that the Z value was 77.14% for scores between 5 and 15 in the pre-test. This implies that 77.14% of the study participants had a score in this range. In the post-test, however, the Z value was 65%, which implies that 65% of the study participants had a score between 50

and 65. Further analysis shows that 78.95% of the study participants had a score in the range of 50 to 75. (See appendix 10 for the calculations)

Therefore, the research question 1 could be answered as follows:

The results suggest that the use of animated computer 3-D figures illustration might have improved learners' achievement in geometry class, more so in view of the results from 4.3.2.3a

4.3.2.3b Results of the Inferential Statistical Analysis for Experimental Group 1

The paired t-test analysis for experimental group 1 was used to answer the research hypothesis:

"H₀ : There is no statistical significant difference between the study participants' pre- and post-test intervention mean achievement score in learning the concept of polyhedron."

Type of test	Mean	Standard deviation	t-value	p-value	Decision
Pre-test	9.45	4.10	-35.1	.0001*	Null hypothesis is rejected
Post-test	56.43	7.93			

Note: *p<.05

Table 10: Paired t-test analysis for Experimental Group 1

In table 10 above, the paired t-test shows a t-value = -35.1, with a *p-value* = .0001. Since .0001 is less than 0.05, there is statistically significant difference in the mean and hence the null hypothesis (H₀) is rejected and the alternative hypo (H₁) is accepted. It may be suggested that:

There is statistical significant difference between the study participants' pre- and post-test intervention mean achievement score in the learning of the concept of polyhedron.

4.3.2.3c Results of the Problem Solving Approaches displayed by the Study Participants in Experimental Group 1

The problem solving skill data was gathered by scrutinizing the study participants' scripts. The results of the data analysis of this exercise were used to find the answer to research question 3.

Does the use of computer 3-D figures illustration have any impact on the problem solving skill of the study participants?

- (a) The number of study participants that passed in each question category in the post-test.

40 out of 47 of the study participants scored above 50% in question category A, 28 scored above 50% in question category B, and 17 scored above 50% in question category C.

- (b) Solution appraisal method

Scrutinizing the answer scripts of the study participants in this group revealed that the study participants gave full answers in most cases, which suggest that they understood the learnt concepts of polyhedron. Most of them scored good marks in question items 1 to 3, which cover foundational concepts in the learning of polyhedron. Question items 5 and 6 required answers which were of a higher cognitive level: question item 5 demanded abstract sketching of a regular polyhedral, while question item 6 required knowledge of vertices, edges and face in polyhedron. 39 of the study participants attempted questions 5 and 6, and 28 of this number got 50% and above. 31 of the study participants got question item 7 correct out of the 43 study participants that attempted to answer it. A sample script is shown below:

Pre Test					Post Test								
6. Copy and complete the following table.					6. Copy and complete the following table.								
	Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F		Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F		
6.1	Tetrahedron	3	4	4	7	4 20	6.1	Hexahedron	8	12	6	19 20	
6.2	Hexahedron	6	6	6	3		6.2	Octahedron	6	12	8		2
6.3	Octahedron	15	7	8	4		6.3	Tetrahedron	4	6	4		2
6.4	Dodecahedron	13	8	12	2		6.4	Icosahedron	12	30	20		2
6.5	Icosahedron	29	25	10	4		6.5	Dodecahedron	20	30	12		2
(20mks)					(20mks)								

Figure 4.7: Sample Scripts on question 6 of a study participant in the experimental group 1

This learner scored 80% in the post-test. The script had one of the highest marks in the group with 8 out of 12 marks, 20 out of 28marks and 52 out of 60 marks in categories A, B, and C respectively in the post-test.

4.3.2.3d Results of Qualitative Data Analysis for Experimental Group 1

The result of the qualitative data analysis for experimental group 1 was used to probe research question 2

“Will the use of animated computer 3-D figures illustration facilitate conceptual learning of polyhedron in geometry”.

Classroom observation was carried out on Wednesday 21st of October 2015 and Tuesday 27th of October, 2015 as mentioned in subsection 3.3.2b. The results of the classroom observation data analysis showed that the mathematics teacher in this group taught the concepts of polyhedron with the aid of the intervention instrument, (Small Stella) throughout the intervention period. The picture of one of the classroom computer's display of the intervention instrument is shown in Figure 4.8 below. It also emerged from the data analysis that the study participants showed interest in learning polyhedron concepts with the aid of the intervention instrument. It was also noted that the faces, edges and vertices of all the objects displayed were shown and

the teacher were pointing to each of them on the computer display as he was teaching.

Part of the results that emerged indicated that the type of questions they were asking suggested that the study participants enjoyed the lesson and that they understood the concepts of polyhedron as the teacher was teaching. They were asking questions like: "I could not finish counting the faces and the edges, can we do that again? Sir, how can we sketch polyhedron exactly as we are looking at it now in our books? What is the difference between polyhedron and other shapes? Can we also use paper to mold the polyhedron?" and so on.

In addition, the results also show that the study participants performed well in the formative assessment (classwork or homework) the teacher gave.

Below is an excerpt from the second classroom observation which took place on Tuesday 27th of October, 2015. It was the second week of the intervention. The lesson observed was the first period on the time table for that day and it was a 45 minute lesson. The teacher had set up the projector showing ACTDFI on the board in front of the classroom, while study participants were seated. It appeared that the study participants were now used to being taught with ACTDFI because they were quietly waiting for the teacher to start his lesson. The researcher was prepared for the lesson: having an examination pad to take field notes. The video recorder accompanied him.

The Teacher: *"Good morning students."*

Study Participants: *"Gooooood morning, Sir."*

Teacher: *"Submit the homework that I gave to you yesterday. Pass your notebooks to the front."*

All the notebooks are gathered at the front seat of each row. The teacher exchanges the notebooks among the rows; he asks the two study participants sitting at the first

row to distribute the notebooks given to each row among the row members and mark the notebooks as the answers are given.

Teacher: *"Now let us do the homework together."*

The teacher writes the question on the board:

- Sketch: (i) triangular prism
(ii) the net of the triangular prism

Teacher: *"For the sake of time, I will put the answers on the board."*

The teacher goes to the ACTDFI to display the picture of a triangular prism, rotating it so that all the sides can be seen.

Teacher: *"Do you see the faces, edges, and vertices. We want to sketch this picture on the board, now. But remember what I said yesterday when we were sketching the rectangular prism that the picture is a 3D in the ACTDFI but the board is a 2D, hence we can only try to show the width, length and the height when we are sketching the shapes, we shall do the same thing again now."*

He waits for few seconds, looking round the class, possibly to let the study participants to assimilate what he has just said. He continues:

Teacher: *"Follow how I will sketch the shape now."*

He puts the sketch (question i) on the board and the net (question ii). After that he faces the class:

Teacher: *"Mark and return the books back to the owners."*

The study participants mark and start shouting the different names on the notebooks they have marked.

Teacher: *"Do this in time and let us continue."*

The teacher paces up and down, he stands at the left corner of the class and ask for those that got everything right (2 over 2 marks) to raise their hands. About twenty of the study participants raised their hands (however, they could not be counted properly because the video did not capture all the study participants who raised their hands). Then he calls for 1 out of 2 marks, many hands are raised, more or less equal to the first set of hands that were raised. Lastly, he calls for those that got 0 marks, and five hands go up.

Teacher: *"Yes, any other answer? What type of shape is it?"*

The class is silent; there is no answer from any of the study participants.

Teacher: *"Now we want to look at a shape that has more faces than either triangular or rectangular prism. We want to look at the Icosahedron."*

Teacher: *"How many faces, edges and widths does an Icosahedron have?"*

There was no answer from anyone. The teacher looks around the class as the whole class is silent. One study participant raises his hand.

Study Participant: *"I want to use how you thought us last week Friday, how to name the polygons, for example tri – 3 sides, quad – 4 sides, ..."*(the student pauses for few minutes and continues). *"Can you help me?"*

Teacher: *"Yes, you see in polyhedron I told that the naming is such that you take into account the number of sides and the number of faces. For example in the triangular prism, the "tri" means each side has three sides. Foricosahedron, it is a 20-faced polyhedron".*

He goes to the ACTDFI to display the picture of Icosahedron. As he normally does, he starts rotating the picture so that the study participants can see all the sides of the shape. See the picture of Icosahedron in figure 4.8 below:

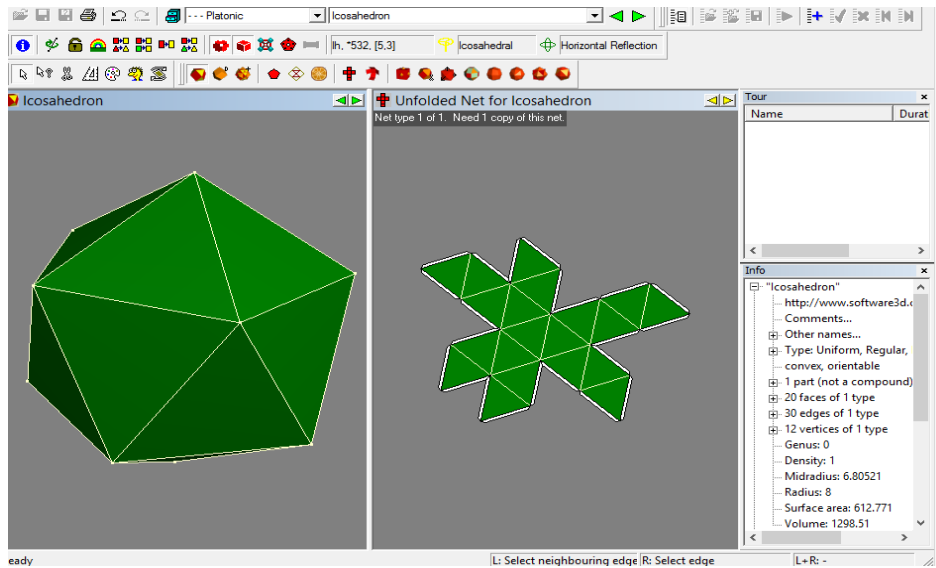


Figure 4.8: Sample Picture of ACTDFI projected in Experimental Group 1

Teacher: *As we did before, let us count the number of faces, edges and vertices.*

He continues to rotate the picture while the whole class counts the number of faces, edges and vertices. He goes to the board to write the following question:

Classwork

- (i) Sketch Icosahedron
- (ii) Sketch the Icosahedron net.
- (iii)

The teacher waits a little bit; he checks his wrist watch and continues:

Teacher: *"We have only 15 minutes more. Take the classwork as homework."*

He waits a little to get response from the class.

Teacher: *"I believe you know what to do in the classwork."*

Study Participants (all the class): *"We will do it, we know it."*

Teacher: *O.K, we shall quickly talk about the Euler's polyhedral formula.*

He goes to the chalkboard and writes the following:

The number of vertices V , faces F , and edges E in a convex 3-dimensional polyhedron, satisfy $V - E + F = 2$.

Teacher: *"We already know how to count the number of the vertices, edges and faces; we only have to put it in the formula."*

The teacher pauses for few minutes, and continues:

Teacher: *"We shall use the Icosahedron picture displayed in the ACTDFI as an example."*

The teacher goes to the board again to write:

Calculate the Euler number for the Icosahedron

Teacher: *"Who is going to help us with this."*

Many hands are raised and the teacher points at a study participant in the front of the class.

Teacher: *"Yes, you."*

The study participant goes to the board and writes:

: $12 - 30 + 20 = 2$

Teacher: *"I have always been telling you to write properly (facing the whole class). What is equal to 2 in what you wrote?" (facing the student). "Can somebody put the answer in a proper form?"*

Many hands are raised again, and the teacher points at one of the study participants in the left row sitting at the back.

Teacher: *"Yes, come and help us."*

The study participant called writes the following:

Euler number of Icosahedron = $20 - 30 + 12 = 2$

Teacher: *"Yes, good."*

As the teacher wants to continue, the bell rings for the next period.

Teacher: *"We shall continue in the next class, go to your next class."*

The class ended at exactly 8:30am

4.3.3 Presentation of the Data Analysis Results for the Experimental Group 2

In this section, the profile of the experimental group 2, profile of the mathematics teacher, results of the descriptive, inferential and qualitative statistical data analyses are presented.

4.3.3.1 Profile of the Experimental Group 2

The school referred to as experimental group 2 was a secondary school in Limpopo province. It had both senior phase and FET phase with 583 learners. It had a male principal, two HODs and ten educators. A group of 36 grade 9 learners formed the study participants for the control group. All the learners were taking mathematics as a subject. They were taught by a female mathematics teacher, who taught the study participants during this study.

4.3.3.2 Profile of the Teacher of the Experimental Group 2

Gender: Female

Age: 39 years

Academic Qualifications: Bachelor of Education (B. Ed.) in Mathematics.

Teaching Experience: 11 years

4.3.3 3 Results of the Quantitative Data Analysis for Experimental Group 2

4.3.3 3a Results of the Descriptive Statistical Analysis for Experimental Group 2

Quantitative results presentation was used to answer research question 1.

Will the use of animated computer 3-D figures illustration improve learners' achievement in the learning of the concepts of polyhedron?

	Pre-Test	Post-Test
Mean	11.5	55.61
Std Dev	4.12	6.43
Std Err Mean	0.69	1.07
Upper 95% Mean	12.90	57.79
Lower 95% Mean	10.11	53.44
N	36	36
Skewness	0.36	0.44
Kurtosis	1.51	1.10

Table 11: Summary Statistics of Pre-Test and Post-Test scores of the Experimental Group 2

From Table 11 above, it can be seen that the study participants had a mean of 11.50 in the pre-test and a standard deviation of 4.12, which means that the majority of the study participants' marks were between 7.4 and 15.6 (see figure 4.9). In the post-test, however, the mean and standard deviation was 55.61 and 6.43 respectively. This shows that majority of the marks were between 49.18 and 62.04 (see Figure 4.9).

The performances of the study participants in experimental group 2 in the pre-test and post-test are further illustrated by the histograms in figure 4.9 below.

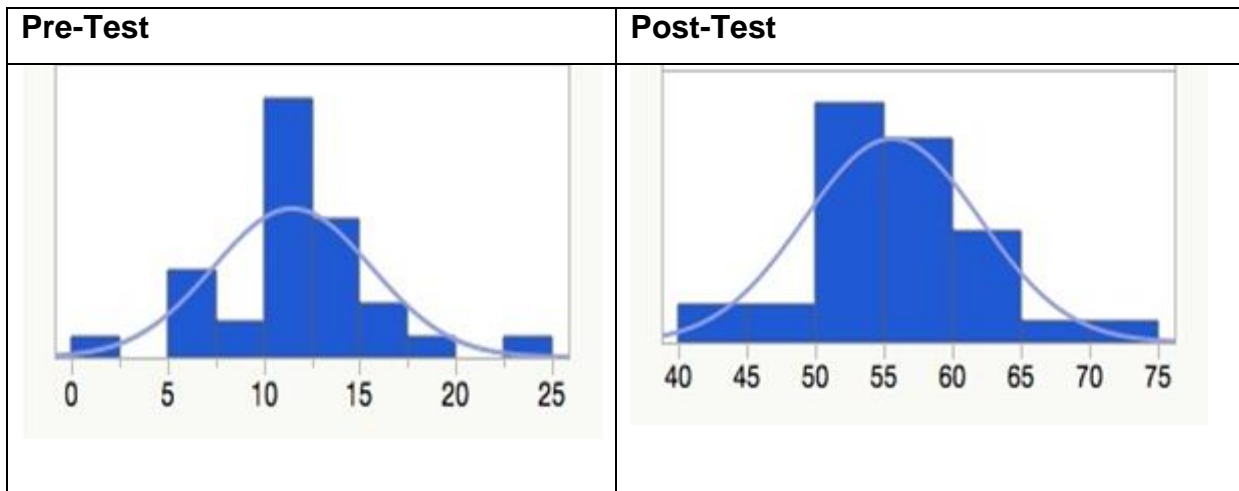


Figure 4.9: Pictorial representation of the Pre-test and Post-Test scores for Experimental Group 2

The histograms in Figure 4.9 above support the explanation given in support of the results shown in Table 11. The histograms illustrate that the majority of the marks in the pre-test are close to the mean of 11.5 (see figure 4.9, under pre-test), whereas the marks spread away from the mean in the post-test, with only about 12% around the mean of 55.61 (see Figure 4.9 under pre-test).

In addition, it was derived from the normal distribution curve in the pre-test that the Z value was 64.12% for scores between 7 and 15 in the pre-test. This implies that 64.12% of the study participants had a score in this range. In the post-test, however, the Z value was 80.89%, which implies that 80.89% of the study participants had a score in the range of 49 to 65. Further analysis shows that 80.65% of the study participants had a score between 50 and 75. (see appendix 10).

Therefore, the research question 1 could be answered as follows:

The use of animated computer 3-D figures illustration might have improved the learners' achievement in the learning of polyhedron.

4.3.3 3b Results of the Inferential Statistical Analysis for Experimental Group 2

The paired t-test analysis for Experimental group 2 was used to answer the research hypothesis:

“ H_0 : There is no statistically significant difference between the study participants’ pre- and post-test intervention mean achievement score in the learning of the concept of polyhedron.”

Type of test	Mean	Standard deviation	t-value	p-value	Decision
Pre-test	11.5	4.12	-34.88	.000	Null hypothesis is rejected
Post-test	55.6	6.43			

* $p < .05$

Table 12: Paired t-test analysis for Experimental Group 2

The paired t-test gave a t-value = -34.88 with a p -value = 0.000. Since 0.000 is less than .05, there is statistically significant difference in the means, hence the null hypothesis (H_0) is rejected and the alternative hypo (H_1) is accepted.

The results therefore suggest that:

There is a statistically significant difference between the study participants’ pre- and post-test intervention mean achievement score in the learning of the concept of polyhedron.

4.3.3 3c Problem Solving Skill of Participants in the Experimental Group 2

The problem-solving skill data was gathered by scrutinizing the study participants’ scripts. The results of the data analysis of this exercise were used to extract the answer to research question 3:

Does the use of computer 3-D figures illustration have any impact on the problem-solving skills of the study participants?

(a) The number of study participants that passed in each question category in the post test.

31 out of 36 of the study participants scored above 50% in question category A, 27 scored above 50% in question category B, and 15 scored above 50% in question category C.

(b) Solution appraisal method

The results of the study participants in this group are similar to that of experimental group 1. The results revealed that the study participants demonstrated that they understood the learnt concepts of polyhedron in their approach in their answers to the post-test. Most of them scored good marks in question items 1 to 3, even though it emerged that some could not sketch the polyhedral and attach correct names to them. In question items 5 and in question item 6 some were confusing the faces and edges, but overall most of the study participants did not have many difficulties in question category C. 32 of the study participants attempted questions 5 and 6, and 15 of them got 50% and above. Most of the study participants did not have problems with question 7, as 29 of the study participants answered it correctly. A sample script is shown in figure 4.10 below:

Pre Test	Post Test
----------	-----------

6. Copy and complete the following table.

	Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F
6.1	Tetrahedron	4	5	3	2
6.2	Hexahedron	6	8	6	20
6.3	Octahedron	3	4	4	25
6.4	Dodecahedron	5	5	3	11
6.5	Icosahedron	6	4	5	15

(20mks)

6. Copy and complete the following table.

	Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F
6.1	Hexahedron	8	12	6	2
6.2	Octahedron	6	12	8	7
6.3	Tetrahedron	4	6	4	2
6.4	Icosahedron	6	12	20	2
6.5	Dodecahedron	12	16	12	2

(20mks)

Figure 4.10: Sample script on question 6 of a study participant in the experimental group 2.

This learner scored 80% in the post-test. He/she had 8 out of 12, 16 out of 28, and 42 out of 60 marks in categories A, B, and C respectively in the post-test.

4.3.3 3d Results of Qualitative Data Analysis for Experimental Group 2

The result of the qualitative data analysis for experimental group 2 was used to answer research question 2.

“Will the use of animated computer 3-D figures illustration facilitate the learning of the concepts polyhedron?”

In experimental group 2, classroom observation was also carried out twice: 22 and 28 October, 2015 as mentioned in 3.3.2b. The results of the classroom data analysis that emerged in this group are similar to that of experimental group 1.

The results of the classroom observation data analysis showed that the participating mathematics teacher in this group taught the concepts of polyhedron with the aid of “Small Stella” throughout the intervention period and that the teacher allowed the study participants to interact with ACTDFI, as they were able to turn the shape around, count the number of vertices and edges of each of the polyhedron.

The picture of the intervention used during the second classroom visit is shown in Figure 4.11 below. The data analysis also revealed that the study participants showed interest in learning the polyhedron concepts with the aid of the intervention instrument (the first visit data revealed how the study participants were all eager to watch the computer displays). It emerged that the teacher showed and explain the faces, edges and vertices of all the objects displayed. They were asking questions to the teacher that implied conceptual understanding, and also discussed among themselves. One notable comment from the field notes on the second visit to this group was the question one of the study participants from the last row (fourth row from the right) asked the teacher. The participant was one of the four sitting at least two rows from the back, in the same row as those who were arguing this question, which was:

Study participant: *"Do you have the picture of the rugby ball in the computer, we want to see it? Is a rugby ball a polyhedron?"*

Teacher: *"No, the picture of a rugby ball is not here (touching the computer) but the rugby ball is a 3D shape. Since it is not a polyhedron we shall not learn about its shape but as I said it is a 3D shape."*

After the lesson ended, some of the study participants came back to check the concepts they learnt again, operating the computer by themselves. Below is one of the ACTDFI displayed during one of the lessons.

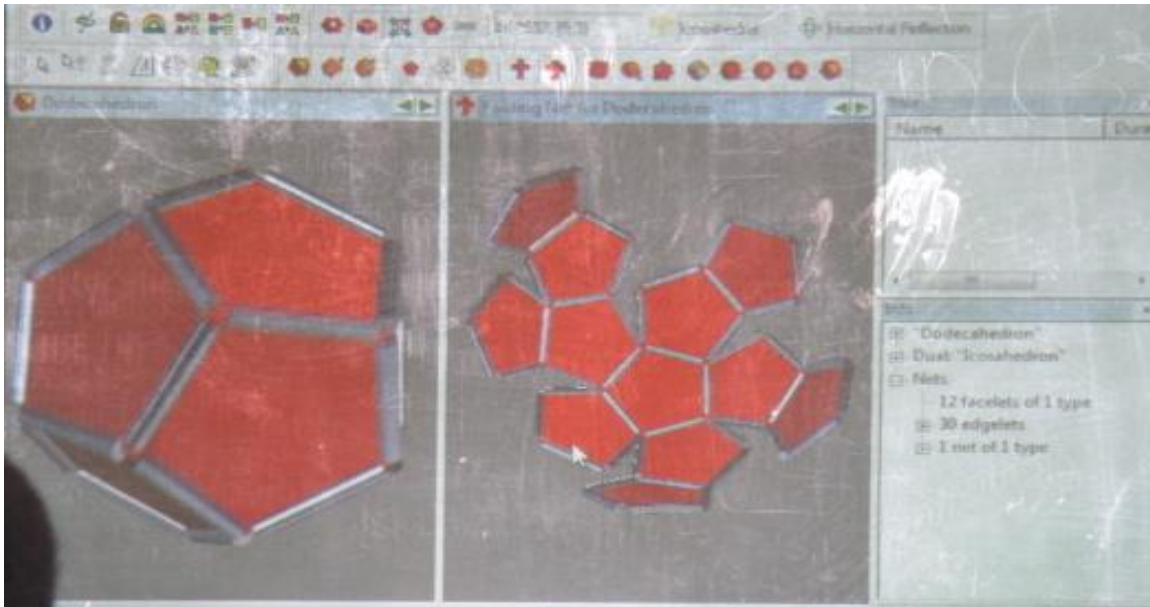


Figure 4.11: Sample Picture of ACTDFI projected in Experimental Group 2

4.3.4 Presentation of the Data Analysis Results for the Experimental Group 3

In this section, the profile of experimental group 3, the profile of the mathematics teacher, and the results of the descriptive, inferential and qualitative statistical data analyses are presented.

4.3.4.1 Profile of the Experimental Group 3

The school referred to as experimental group 3 was a secondary school in Limpopo province. It had both senior phase and FET phase with 904. It had a male principal, a male deputy principal, four HODs and seventeen educators. It had two arms of grade 9, namely 9A and 9B, consisting of 30 and 22 learners respectively, all of whom formed the study participants for the control group. All the learners were taking mathematics. They were taught by a male mathematics teacher, who taught the study participants during this study.

4.3.4.2 Profile of the Teacher of the Experimental Group 3

Gender: Male

Age: 35 years

Academic Qualifications: Bachelor of Science. Hons in Mathematics and Diploma
Teaching Experience: 8 years

4.3.4.3 Results of the Quantitative Data Analysis for Experimental Group 3

4.3.4.3a Results of the Descriptive Statistical Analysis for Experimental Group 3

Quantitative results presentation was used to answer research question 1.

Will the use of animated computer 3-D figures illustration improve learners' achievement in geometry class?

	Pre-Test	Post-Test
Mean	9.34	55.15
Std Dev	4.56	7.94
Std Err Mean	0.63	1.10
Upper 95% Mean	10.62	57.36
Lower 95% Mean	8.08	52.94
N	52	52
Skewness	-0.32	0.04
Kurtosis	-0.49	-0.62

Table 13: Summary Statistics of Pre-Test and Post-Test scores of the Experimental Group 3

Table 13 above shows that the study participants had a mean of 9.34 in the pre-test and a standard deviation of 4.56, which indicates that majority of the study participants' marks were between 4.78 and 13.9 (see figure 4.12). In the post-test, however, the mean and standard deviation was 55.15 and 7.94 respectively. This means that the majority of the marks were between 47.21 and 63.09 (see Figure 4.12).

The performances of the study participants in experimental group 3 in the pre-test and post-test are further illustrated by the histograms below.

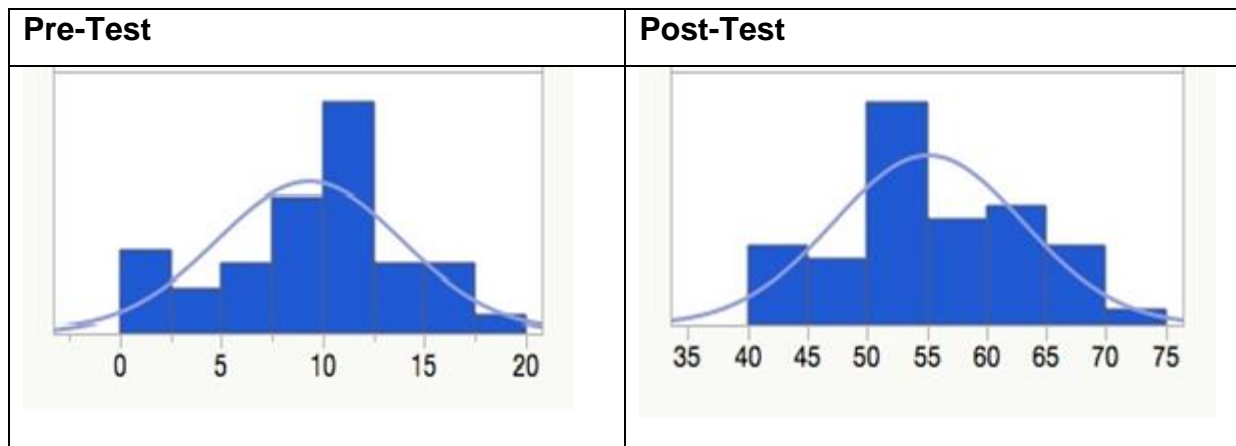


Figure 4.12: Pictorial representation of the Pre-test and Post-Test scores for Experimental Group 3

The histograms in Figure 4.12 above substantiate the explanation given in support of the results found in Table 13 above. The figure shows that majority of the marks in the pre-test are close to the mean of 9.34 (see Figure 4.12 under pretest), while the marks in the post-test spread away from the mean, with only about 14% around the mean of 55.15 (see Figure 4.12 under pretest).

Furthermore, it was evident from the normal distribution curve of the pre-test that the Z value was 71.96% for scores between 5 and 15 in the pre-test. This indicates that 71.96% of the study participants had a score in this range. In the post-test, however the Z value was 54.5%, which implies that 54.5% of the study participants had a score in the range of 48 to 60. Further analysis shows that 73.60% of the study participants had a score between 50 and 75.

Therefore, research question 1 could be answered as follows:

The use of animated computer 3-D figures illustration might have improved the learners' achievement in the learning of polyhedron.

4.3.4.3b Results of the Inferential Statistical Analysis for Experimental Group 3

The paired t-test analysis for Experimental group 3 was used to answer the research hypothesis:

“ H_0 : There is no statistically significant difference between the study participants’ pre- and post-test intervention mean achievement score in the learning of the concept of polyhedron.”

Type of test	Mean	Standard deviation	t-value	p-value	Decision
Pre-test	9.35	4.56	-39.79	.0001	Null hypothesis is rejected
Post-test	55.15	7.93			

* $p < .05$

Table 14: Paired t-test analysis for Experimental Group 3

The paired t-test gave a t-value = -39.79, with a p -value = 0.001. Since 0.001 is less than .05, there is a statistically significant difference in the means. The null hypothesis (H_0) is therefore rejected and the alternative hypothesis (H_1) is accepted.

Hence the result suggests that:

There is statistically significant difference between the study participants’ pre- and post-test intervention mean achievement score in the learning of the concept of polyhedron.

4.3.4.3c Problem Solving Skill of Participants in the Experimental Group 3

The data on problem-solving skills was gathered by scrutinizing the study participants’ scripts. The results of the data analysis of this exercise were used to probe the answer to research question 3:

Does the use of computer 3-D figures illustration have any impact on the problem-solving skill of the study participants?

(a) The number of study participants that passed in each question category in the post-test.

43 out of 52 of the study participants scored above 50% in question category A, 34 scored above 50% in question category B, and 42 scored above 50% in question category C.

(b) Solution appraisal method

The results of examining the answer scripts of the study participants in this group are similar to that of experimental groups 1 and 2. The results suggest that the study participants understood the learnt concepts of polyhedron by the way they answered the post-test question items. As in experimental groups 1 and 2, the majority of the study participants in this group scored good marks in question items 1 to 3, some of them struggled to sketch the polyhedron nets in question item 5, and in question item 6 some were also confusing the faces and edges (as was found in group 2). They were however able to calculate the Euler number required in question item 7.

Pre Test		Post Test																																					
6. Copy and complete the following table.		6. Copy and complete the following table.																																					
	<table border="1"> <thead> <tr> <th></th> <th>Polyhedron</th> <th>Number of Vertices (V)</th> <th>Number of Edges (E)</th> <th>Number of faces (F)</th> <th>Calculate V-E+F</th> </tr> </thead> <tbody> <tr> <td>6.1</td> <td>Tetrahedron</td> <td>4</td> <td>6</td> <td>4</td> <td>2</td> </tr> <tr> <td>6.2</td> <td>Hexahedron</td> <td>10</td> <td>18</td> <td>18</td> <td>10</td> </tr> <tr> <td>6.3</td> <td>Octahedron</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>6.4</td> <td>Dodecahedron</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>6.5</td> <td>Icosahedron</td> <td>6</td> <td>9</td> <td>8</td> <td>5</td> </tr> </tbody> </table>		Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F	6.1	Tetrahedron	4	6	4	2	6.2	Hexahedron	10	18	18	10	6.3	Octahedron					6.4	Dodecahedron					6.5	Icosahedron	6	9	8	5		
	Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F																																		
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6.2	Hexahedron	10	18	18	10																																		
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6.4	Dodecahedron																																						
6.5	Icosahedron	6	9	8	5																																		
	(20mks)		(20mks)																																				

Figure 4.13: Sample scripts on question 6 of a study participant in the experimental group 3.

At the end of the intervention, a notable improvement could be noticed in the problem-solving skills of the participants. The majority of the learners who could not solve some of the problems in the pre-test were able to solve the problems in the post-test. The sample script in Figure 4.13 above shows that the learner could not answer some of the items in question 6; he only got 4 items right out of 20. But at the end of the intervention, in the post-test, he got 15 of the 20 items right. In this regard, it could be said that the use of computer 3-D figures illustration had a positive influence on the problem-solving skills of the study participants in this group.

4.3.4.3d Results of Qualitative Data Analysis for Experimental Group 3

The result of the qualitative data analysis for experimental group 3 was used to answer research question 2.

“Will the use of animated computer 3-D figures illustration facilitate conceptual learning of polyhedron in geometry?”

In the school of experimental group 3, there were two arms of grade 9, namely 9A and 9B. All 52 learners constituted the study participants for this study and they were taught by the same mathematics teacher. Classroom observation was done twice for this group on 23 and 29 October, 2015.

Again, the results of the data analysis that emerged from this group are all similar to the results gathered from experimental groups 1 and 2. The results indicated that the study participants understood the concepts of polyhedron taught to them. One of the questions asked that had a profound effect was:

“Study participant: “From your explanation, does it mean that a box or cylinder is a 3D object?”

Teacher: *"I am not going to answer that question, I want you."*(pointing to other class members to answer the question and hand were raised). *"Yes, anybody?"*

One of the study participants from the back of the class stands up to answer the question.

Study participant: *"Yes, because all the faces and edges can only be represented in 3D."*

It seems the teachers is not satisfied with the answer; he calls another person.

Teacher: *"Can anyone add to that? Yes, you."* (He calls another study participant).

"Study participant: *"Box or cylinder has height, length and width"*

Teacher: *"Good."*

Analysis of this question shows the high cognitive level of reasoning that was going on in the class. Below is one of the ACTDFI displays during one of the lessons:

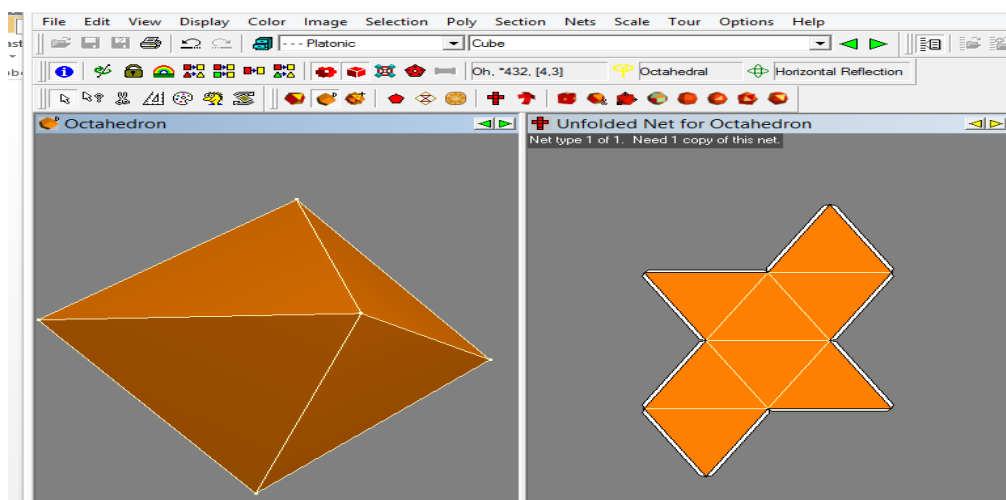


Figure 4.14: Sample Picture of ACTDFI projected in experimental Group 3

4.4 Post Hoc Analysis

The post hoc analysis of inter-group data aims to establish where the intervention really had the greatest impact. The HSD threshold Matrix was used for this purpose.

	Experimental 1	Experimental 2	Experimental 3	Control 1
Experimental 1	-4.14	-3.63	-2.77	30.03
Experimental 2	-3.63	-4.73	-3.89	28.93
Experimental 3	-2.77	-3.89	-3.93	28.85
Control 1	30.03	28.93	28.85	-4.54

Table 15: Means Comparisons for all pairs using Tukey-Kramer HSD

Positive values show pairs of means with statistically significant differences.

It was observed in table 15 above that a mean difference of 30>0 was recorded in row 2, column 5, where experimental group 1 was compared with the control group. In row 3, column 5, a mean difference of 29>0 was recorded, where experimental group 2 was compared with the control group. In row 4, column 5, a mean difference of 29>0 was recorded comparing experimental 3 with the control group. It is evident that there were statistically significant differences in paired means of experimental groups where there was intervention, versus the control group, which had no intervention.

Level	- Level	Difference	Std Err	Lower CL	Upper CL	p-Value
		Dif		r CL	r CL	
Experimental 1	Control	34.37	1.67	30.03	38.72	<.0001*
Experimental 2	Control	33.56	1.79	28.92	38.20	<.0001*
Experimental 3	Control	33.10	1.64	28.85	37.35	<.0001*
Experimental 1	Experimental 3	1.27	1.56	-2.76	5.31	0.85
Experimental 1	Experimental 2	0.81	1.71	-3.63	5.26	0.96
Experimental 2	Experimental 3	0.46	1.68	-3.89	4.81	0.99

Table 16: Ordered Differences Report

From table 16 above, it can be concluded that the intervention was responsible for the statistically significant differences in each of the experimental groups. Comparing each of the experimental groups with the control group (where there was no intervention), a statistically significant difference was recorded. But when experimental groups were compared with each other, no statistically significant difference was recorded.

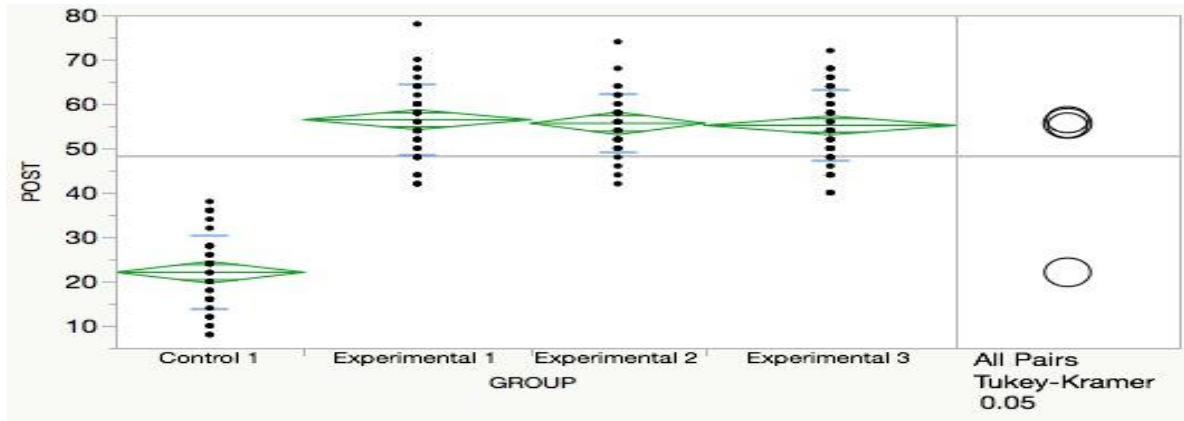


Figure 4.15: Pictorial view of the results of the Post-Test Scores by Group

CHAPTER FIVE

SUMMARY, DISCUSSION, IMPLICATIONS, CONCLUSION AND RECOMENDATION

This chapter discusses the results of the data analysis presented in chapter 4. The summary of the main findings of the study and their implications are discussed in light of the research questions and hypotheses. In addition, the limitations, conclusion and suggestions for further research are also discussed.

5.1 Summary of the Study

This study was carried out to investigate the effect of using animated computer 3-D figures illustration (ACTDFI) in the learning of the concepts of polyhedron in geometry. The study was carried out in the Limpopo province. The Limpopo province comprises of 10 educational districts. The researcher divided the 10 districts into 4 clusters. All the schools in each cluster were considered together and a random sampling approach was used to select a school from each cluster. Thus, the researcher ended up with 4 randomly selected schools in Limpopo province to participate in this study. A school was randomly selected to be the control group, while the other three groups were the experimental groups.

An intact group of the grade 9 students in each selected school formed the study participants for the study. The study participants were 174 in total: 39 in the control group, 47 in experimental group 1, 36 in experimental group 2 and 52 in experimental group 3, with 4 mathematics teachers.

A mixed method approach involving both quantitative and qualitative research designs was used. A two-week intervention was carried out in the three experimental groups. The study participants were taught the geometry of polyhedron using ACTDFI while the control group was traditionally taught. During the intervention, classroom observation was carried out twice in all the participating schools.

Quantitative data was collected through the pre-test and post-test, while qualitative data was collected using the video camera and field notes during the classroom observations. The quantitative collected data was analyzed using a number of statistical approaches like descriptive statistics and inferential statistics, while the qualitative data analysis procedure was used to describe the performance of the study participants. In addition, the initial tests carried out include: a test of homogeneity of variances, a predicted plot and least square means plot test, a one-way ANOVA test, and Analysis of difference by Group and Wilcoxon/Kruskal-Wallis test.

The findings of the study showed that:

- The use of animated computer 3-D figures illustration (ACTDFI) improved learners' achievement in geometry class
- Study participants in the experimental groups showed better problem-solving skills compared to the control group
- The use of animated computer 3-D figures illustration facilitated conceptual learning of polyhedron in geometry.
- Age was not a significant factor in learning with the aid of ACTDFI.
- Gender was not a significant factor in learning with the aid of ACTDFI

5.2 Discussion

Before the intervention, the researcher measured the level of the study participants' prior knowledge in polyhedron by using the pre-test. It was found that the study participants in all the research groups were almost at the same level (see figure 4.1). The mean mark of the pre-test for the control group, experimental group 1, 2 and 3 were 8.6, 9.4, 11.5 and 9.3 respectively. This provided a baseline to which all the emerging results in the post-test could be compared. Further analysis of the initial

data revealed that gender and age factors did not influence the outcome of the data analysis results. This suggests that the outcomes of this research might have been due to the intervention. The findings of this study will be discussed in relation to the subheadings mentioned above:

The use of animated computer 3-D figures illustration (ACTDFI) improved learners' achievement in geometry class.

Though there was no intervention in the control group, the result of the data analysis of the pre-test and the post-test indicated a statistically significant difference between the means of the pre-test and post-test (being 8.56 and 27.05 respectively, see Table 7, subsection 4.3.1.3a). The results also indicated that majority of the study participants scored below 30 percent in this group, (see the presentation of results under Figure 4.4). In addition, it was revealed from the Z-value calculated from the normal curve that 88.66% of the study participants had scores between 15% and 30%.

Although there is a statistically significant difference in the academic achievement of the study participants in this group when the achievement in the pre-test is compared to that of the post-test, the results also reveal that the study participants are still at an underperforming level. Perhaps this could be due to the traditional pedagogical approach used (see figure 4.4). This would be in line with the findings of Taraban et. al. (2004) that showed that students could not use the conceptual knowledge taught in the traditional class to gain deeper understanding.

The results of the data analysis in all three experimental groups are similar and they indicate that the study participants showed a statistically significant improvement in the academic achievement in the concepts of polyhedron learnt during the intervention, to the extent that the quality of these achievements are of a good standard when rated. The result showed that the experimental groups 1, 2 and 3 had a mean of 9.45, 11.5 and 9.35 in the pre-test respectively, but a mean of respectively 56.43, 55.61 and 55.15 in the post-test (see Tables 9, 11 and 13). In all three groups there was a statistically significant difference between the means of the pre-test

and post-test (see Tables 4.6, 4.8 and 4.10). There were big differences in mean achievement scores between the pre- and the post-test. The results also indicated that the majority of the study participants in experimental groups 1, 2 and 3 scored between 5.4 and 13.6, 7.4 and 15.6, and 4.8 and 13.9 respectively in the pre-test, while in the post-test, the majority of the study participants in experimental groups 1, 2 and 3 scored between 48.5 and 64.3, 49.18 and 62.04, and 47.21 and 63.09 respectively.

Furthermore, it was revealed from the Z-value calculated from the normal curve that in experimental group 1, 77.14% of the study participants had scores between 5 and 15 in the pre-test, but in the post-test, 65% of the study participants had scores between 50 and 65, and 78.95% got a mark between 50 and 75. Similarly, in experimental group 2, 64.12% of the study participants had scores between 7 and 15 in the pre-test, whereas in the post-test, 80.65% of the study participants had scores between 49 and 65, and 80.65% got a mark between 50 and 75. Lastly, in experimental group 3, 71.96% of the study participants had scores between 5 and 15 in the pre-test, whereas in the post-test, 54.5% of the study participants had scores between 48 and 60, and 73.60% got a mark between 50 and 75.

These results show that that there were not only significant differences in the achievements between the pre- and post-test mean scores, but the difference is such that in the post-test the majority of the study participants scored good marks (see from above, the percentage of the study participants that scored between 50 and 75). However, Figure 4.1 shows that at the start of the of the study, all the study participants were on the same cognitive knowledge level in terms of what they knew about the concepts of polyhedron, but this changed in the post-test. The study participants in the posttest performed exceptionally well, while none of the study participants in the control group got more than 50% in the post test. Again, the post hoc analysis in Table 15 shows that this notable difference only occurred in the research groups where there was intervention. Since the major difference between the intervention and non-intervention groups is the intervention, then perhaps the intervention could have been responsible for the academic achievements in the experimental groups. Again, table 15 shows that it might be that the only statistical

significant factor that is responsible for the difference in academic achievement when all the groups are compared is the intervention

These results conform to the theoretical foundation of this study and the literature on the use of technology in the classroom. Alper (2009), Ogbonnaya (2010), Faleye (2012) and Yegambaram (2012), have all used technology in one way or another to improve teaching and learning in mathematics. ACTDFI might have enhanced the study participants' achievement in the learning of polyhedron.

Study participants in the experimental groups showed better problem-solving skills compared to the control group.

The academic performance of the intervention and none-intervention groups might have actually stemmed from the problem solving skills gained during the classroom teaching. The substantive statistical significant improved academic achievements recorded in the learning of the concepts of polyhedron in the experimental groups (and the otherwise in the control group) was further probed by looking at the approaches the study participants used in solving problems in the post-test. This includes looking at the number of the study participants that passed each category question, (this is important since the whole content of the test instrument was categorized according to their cognitive demand level), and by scrutinizing the study participants' scripts solution approaches for each question item.

In the control group, the results of the data analysis indicated that 2 study participants scored above 50% in the question category A comprising items 1, 2, and 3. These question items require foundation knowledge of the concepts of polyhedron and yet only 2 of the study participants were able to score above 50%. This might be a prime indication that study participants did not gain much understanding throughout the time they were taught the concepts of polyhedron. One will not be surprised to find out that only one study participant and none were able to score 50% and above in the question categories B and C which are question categories that require more cognitive approach than the question items in the category A. In addition, the answer pattern displayed in the study participants' posttest scripts as

well showed that the study participants did not gain much understanding during the teaching of polyhedron concepts in a traditional chalk-and-talk approach. Many wrote “FALSE” or “TRUE” throughout the question items that required FALSE or TRUE and the results show the same answer approach where they need to write A, B, C, or D as an answer, some just wrote for example B throughout the answers. This implied that the study participants did not think or consider about what to write before writing their answers which an indication of unlearned. Majority of them could hardly solve any of the problems in the test instrument correctly and this situation deteriorates as they move from question category A to C. See the sample script in figure 4.5. This implies that the questions that require the study participants to think and demonstrate conceptual understanding of the polyhedron were not answered by the majority of the study participants in the control group.

Faleye (2012) anecdotally remarked that “One of the negatives of traditional teaching and learning is that students are expected to be fed with knowledge, with the supposition that it builds superficial understanding of the required knowledge in them.” During the classroom teaching of polyhedron, even if some of the study participants understood any part of the concepts taught, their understanding was not concrete, it was superficial. Maybe that is why one or two of the study participants was able to get above 50% in the question category that did not require much cognitive reasoning but could not attempt a higher cognitive demand question categories. These results suggest that the study participants did not gain deep understand of the concept taught; hence they were not able to connect the conceptual knowledge to the needed procedural knowledge in solving problems, (Taraban et. al., 2004).

On the other hand, despite the results in figure 4.1 that shows that both the control and the experimental groups were on the same conceptual cognitive level in the knowledge of polyhedron after the intervention the ways by which the study participants in the experimental groups approached the problem solving changed positively. The results that emerged from the experimental groups suggest that the study participants in these groups gained enough understanding such that they were able to use the knowledge gained in solving higher cognitive demand problems.

Moreover, it was revealed that majority of them attempted all the question categories and even had good marks in them. Question item 5 and 6 (which belong to the question category C) require abstract thinking, yet majority of the study participants in these groups were able to attempt these set of questions successfully, even though it was not all of them that attempted the category C questions that finished them or did well in every parts of the questions but majority did, see figures 4.7, 4.10 and 4.13 (sample scripts).Mayer and Moreno, (1998) in presenting the “Multiple Representation Principle” informed that students learn better when they listen to verbal and pictorial concepts presentation. In the following year, Mejia-Flores (1999) informed that visual representation made abstract concepts easier to understand and internalized. Moreover, the polyhedral pictures were presented by technology that was able to show the polyhedral as if they were real. Perhaps Mayer and Moreno, (2002) noted this and formulated the “Media-Affect Learning theory”. Therefore, the outcomes of this study are in line with the theories that underpin this study.

The study participants in the experimental groups showed signs of deep thinking in the way they presented their answers in the post test. Question 5 is about sketching the nets of polyhedron; it required the study participants to put their abstract thinking in a concrete form. This was also supported by Moreno and Meyer (2002) who informs that advance technology promotes deeper learning. Without gaining deep knowledge, study participants may not be able to concretize their abstract thinking.

The results of the solution appraiser analysis show that in the experimental group 1, 40 of the study participants scored above 50% in the question category A, 28 scored above 50% in the question category B and 17 scored above 50% in the question category C. Analyzing their approach to solving the question items revealed that the study participant gave taught full answers in most cases which suggest that they understood the concepts of polyhedron learnt: 39 of the study participants attempted questions 5 and 6, and 28 out of 39 got 50% and above, 31 got question item 7 correctly out of the 43 study participants. An example of the performance of the study participants in this group is shown in figure 4.7.

Moreover, in experimental 2, 31 out of the study participants scored above 50% in the question category A, 27 scored above 50% in the question category B and 15 scored above 50% in the question category C. Analyzing their approach to solving the question items revealed that most of them scored good marks in the question items 1 to 3, 32 of the study participants attempted questions 5 and 6, and 15 of this number got 50% and above. Most of the study participants did not have problem with question 7, 29 of the study participants got question item 7 correctly. An example of the performance of the study participants in this group is shown in figure 4.10. In experimental 3, 43 of the study participants scored above 50% in the question category A, 34 scored above 50% in the question category B and 42 scored above 50% in the question category C. Analyzing their approach to solving the question items revealed that majority of the study participants in this group scored good marks in the question items 1 to 3, some of them struggled to sketch the polyhedron nets in question items 5, and in question item 6 some were also confusing the faces and edges, as was found in group 2 but were able to calculate the Euler number required in question item 7.

In addition, looking at the data from the schools' profile, the teacher in the control group is the youngest (age 34years) and had the least teaching experience in all the participating teachers. Does the age of the participating teachers have impact on the outcome of the study? The researcher cannot answer this question in this research. But in the experimental groups, the teacher for the experimental group 2 had the least age (39years) and classroom teaching experience (11years) but had the second best mean mark (55.61%) among the three experimental groups. The teacher in the experimental group 3 is the oldest (45years) and teaching experience (16years) but had the least mean. More research will be needed in this area to answer the question raised.

The use of animated computer 3-D figures illustration facilitated conceptual learning of polyhedron in geometry”.

The intervention was used only in the experimental groups. One of the results from the qualitative data analysis showed that there was a good classroom dynamics compared to the control group where there was no intervention, the study participants in the experimental groups interest were aroused and were motivated to study the concepts of polyhedron with the Small Stella (intervention material), and there were indications in the result that the study participants in the experimental groups understood the concepts of polyhedron taught. These results are discussed below:

The result indicated that there was a good classroom dynamics compared to the control group. The study participants in the experimental groups were enthusiastic to be taught the geometry of polyhedron using ACTDFI. They were eager to manipulate ACTDFI by themselves to see the polyhedral and their respective nets on the computer using the Small Stella intervention material. They wanted to see as many polyhedral as possible. The teachers in the experimental groups explained the concepts of the polyhedron to study participants while they were watching the computer picture presentation. It was revealed that their facial expression suggested that these groups of study participants were happy while watching the computer pictures; they were enjoying what the teacher was teaching. While in the control group, it was revealed that while the teacher was teaching the study participants in this group, they were quiet while they were watching and listening to the teacher teaching, their facial expression suggested that they were not happy as they found what the teacher was teaching difficult.

Closely related to the classroom dynamics result was that the study participants in the experimental groups' interest were aroused and were motivated to study the concepts of polyhedron with the Small Stella (intervention material). It emerged that the study participants in the experimental groups were motivated to learn the concepts of polyhedron using ACTDFI as they were watching the computer pictures, their interest were arouse in the concepts of polyhedron the teacher in each group was teaching. In the experimental group 2, one of the study participants asked "*Do you have the picture of the rugby ball in the computer, we want to see it? Is rugby ball a polyhedron?*" This might show how much the study participants were enjoying

and following the concepts taught in the lessons. Osborne and Hennessy (2003) noted that motivation may facilitate the learning of difficult concepts. Hanafin (2001) informed that students liked doing geometry on computers, and that technology motivates students to work hard. It emerged that majority of the study participants in the control group were not doing their homework but in the experimental groups, majority of the study participants always attend to their homework. Perhaps they were motivated to work hard by the computer that was used to teach them. On the other hand, in the control group, their facial expression showed that they were not happy (did not understand) with what the teacher was teaching, they hardly ask questions and were either sleeping or making noise. All these are signs that the study participant showed little interest in the lesson taught.

It might have been that the overall effect, the classroom dynamics effect, the aroused interest in the learning of the concepts of polyhedron with the Small Stella intervention and the learning motivation that accompanied the interest cumulated (or resulted) in the emerged result that the study participants in the experimental groups might have understood the concepts of the polyhedron learnt during the intervention better than their counterpart in the control group. This is because the results of the analysis revealed that during the classroom teaching, the study participants in the experimental groups were asking and answering questions that may imply that they understood the polyhedron concepts they were taught. They also attended to their homework very well. While on the other hand, the results of the analysis revealed that during the classroom teaching in the control group, the study participants quietly sat down while the teacher did all the talking, the type of questions they were asking suggest that they might not have understood what the teacher taught. It also emerged that they could not do their homework correctly (that is if they attempted it at all).

The intervention might have facilitated the learning of the concepts of the polyhedral taught more so the results from all the experimental groups were similar to each other, while the results in the control group showed that the teacher struggled to teach the study participants as much as the study participants struggled to follow what the teacher was teaching.

The age of the study participants was not a significant factor in learning the concepts of polyhedron through the use of ACTDFI

The ages of the study participants that participated in this study ranged between 15 and 18. The results from this finding indicated that the age of the study participants did not have a significant impact on the outcome of the study. The result gave a p-value of $0.60898 > 0.05$, which was not significant (see table 6 in subsection 4.2.2c) and in figure 4.3, the horizontal line under age indicate that age of the study participants did not impact on the outcome of the study. Actually, the oldest student was in the experimental group 2 and the highest score in the posttest (80%) came from group 1.

Gender was not a significant factor in learning through the use of ACTDFI

It also emerged that in this study, the gender of the study participants that participated in this study that the gender of the study participants did not have a significant impact on the outcome of the study. The result gave a p-value of $0.8491 > 0.05$, which was not significant (see table 6 in subsection 4.2.2c) and in figure 4.3, the horizontal line under gender indicates that the gender of the study participants did not impact on the outcome of the study. This conforms to the findings of Kotze (2007) who also shows that there was no distinction in the performance of male and female in spatial and space geometry.

5.3 Implications of the Results

The poor achievement of the control group in this study confirmed the inherent weakness of the traditional method of instruction as a means of enhancing learning in geometry class. Learning of geometry of polyhedron should be made concrete, and not abstract, hence the need for ACTDFI. In today's world the use of technology in the teaching and learning of mathematics is inevitable.

The Department of Education, as a matter of necessity, should make the acquisition of computer skills compulsory for all mathematics educators so that they can be relevant in today's technological classrooms. Educators need to upgrade their skills from time to time. Achor, Imoko and Uloko (2009) pointed out that educator's non-utilization of an appropriate teaching method results in learners' low achievement. Not only should the Department of Education ensure that educators acquire computer skills, but schools without computers (which is still common) should be equipped with enough computers.

The mathematics curriculum should be written in such a way that it accommodates and stresses the use of ACTDFI and some other software that can enhance or facilitate the conceptual understanding of learners.

5.4 Limitations of the Study

This study was carried out despite some intrinsic limitations. The findings and consequently the conclusions drawn may have been affected in one way or the other as a result of some unavoidable limitations. These limitations are listed and explained below:

1. The researcher would have used a larger sample size to improve the possibility of generalization of the research findings, but that will require more time and resources.
2. Computers were not readily available in experimental group 2; hence the researcher provided a projector for the educator to use during the intervention. The researcher could therefore not have the study participants in this group sit in groups during the intervention.

5.5 Conclusion

In view of the learning support role technology can play in the teaching of mathematics, professional development opportunities need to be provided for

educators in order to prepare them for this challenge of effectively integrating technology into their teaching. Presently, technology is rarely integrated into everyday teaching in many schools in the Limpopo province, perhaps as a result of educators lacking the computer expertise and/or many schools being technologically under-resourced.

The findings of this study have indicated that using ACTDFI might have improved study participants' academic achievement in the learning of geometry of polyhedron. It also facilitated their conceptual understanding. In that regard, educators must not shy away from using technology when it is available and appropriate. The Department of Education should look into making policies that provide room for adequate use of technology in teaching mathematical concepts across all educational levels. It is the belief of the researcher that if these are done, students' performance in mathematics will improve tremendously. Learners might be motivated to take science and technology-oriented courses at tertiary level if they are doing well in mathematics. This may provide the lasting solution to the skill shortages in the area of engineering that South Africa is facing.

The key to the technological development and economic empowerment of South Africa and Africa in general lies in the hand of the mathematics teachers. With highly knowledgeable and dedicated mathematics teachers, South Africa will be elevated to a higher level of economic and technological advancement (Ogbonnaya, 2011).

5.6 Recommendations for Further Studies

The results of this study show that there is positive potential in using ACTDFI in teaching the geometry of polyhedron in secondary schools, but further research investigating the effects of using ACTDFI in teaching 3-dimensional shapes on primary school level is necessary, as the learning of geometry begins there already.

Finally, a study that will include a bigger sample space in South Africa may be needed to further confirm the potency of ACTDFI in facilitating and improving the conceptual understanding of mathematical concepts.

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APPENDICES

Appendix 1

PRE-TEST

THE EFFECT OF USING ANIMATED COMPUTER 3-D FIGURES ILLUSTRATION IN THE LEARNING OF POLYHEDRON IN GEOMETRY

Surname:

Other Names:

Age: Gender Time: 1 Hour

Total: 50 marks Ref:

Instruction: Answer ALL the questions. Circle the correct option and show your workings.

1. Which of the following statement is FALSE?
- A. A point has no dimensions, only position.
 - B. A line is one – dimensional (1-D)
 - C. A solid is two - dimensional (2-D)
 - D. A polyhedron is three-dimensional (3D). Which of the following is not a polyhedron?



A



B



C



D

3. Which of the following objects has the shape of a regular polyhedron?



A



B



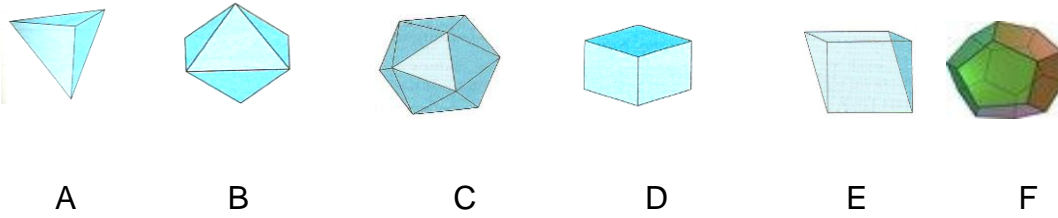
C



D

(6mks)

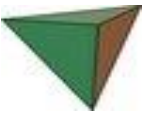

4. Copy and complete the table below. Identify each given polyhedron by matching the letter to the name.






	Solid	Letter	Number of pairs of parallel faces
4.1	Octahedron		
4.2	Hexahedron		
4.3	Tetrahedron		
4.4	Triangular Prism		
4.5	Icosahedron		
4.6	Dodecahedron		

(12mks)

5. Sketch the net of the five regular polyhedra known as the five platonic solids. (10mks)

	Platonic Solid		Net
5.1		A	
5.2		B	

5.3		C	
5.4		D	
5.5		E	

6. Copy and complete the following table.

	Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F
6.1	Tetrahedron				
6.2	Hexahedron				
6.3	Octahedron				
6.4	Dodecahedron				
6.5	Icosahedron				

(20mks)

7. Is the Euler formula: $V-E+F=2$ true for all polyhedra?

.....

(2mks)

Total: 50marks

Appendix 2

POST TEST

THE EFFECT OF USING ANIMATED COMPUTER 3-D FIGURES ILLUSTRATION IN THE LEARNING OF POLYHEDRON IN GEOMETRY

POST-TEST

Surname:

Other Names:

Age: Gender Time: 1 Hour

Total: 50 marks Ref:

Instruction: Answer ALL the questions. Circle the correct option and show your workings.

1. Which of the following statement is FALSE?

- A. A polyhedron is three-dimensional (3D)
- B. A solid is two - dimensional (2-D)
- C. A line is one – dimensional (1-D)
- D. A point has no dimensions, only position.

2. Which of the following is not a polyhedron?



A



B



C



D

3. Which of the following objects has the shape of a regular polyhedron?



A



B



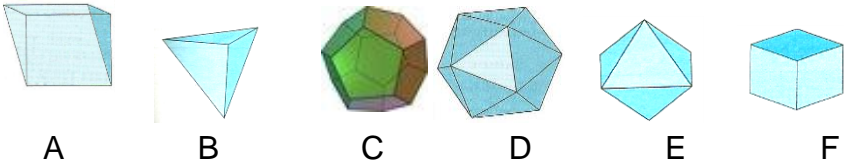
C



D

(6mks)



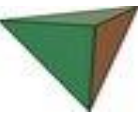

4. Copy and complete the table below. Identify each given polyhedron by matching the letter to the name.




	Solid	Letter	Number of pairs of parallel faces
4.1	Octahedron		
4.2	Hexahedron		
4.3	Tetrahedron		
4.4	Triangular Prism		
4.5	Icosahedron		
4.6	Dodecahedron		

(12mks)

5. Sketch the net of the five regular polyhedra known as the five platonic solids. (10mks)

	Platonic Solid		Net
5.1		A	
5.2		B	
5.3		C	
5.4		D	

5.5		E	

6. Copy and complete the following table.

	Polyhedron	Number of Vertices (V)	Number of Edges (E)	Number of faces (F)	Calculate V-E+F
6.1	Hexahedron				
6.2	Octahedron				
6.3	Tetrahedron				
6.4	Icosahedron				
6.5	Dodecahedron				

(20mks)

7. Is the Euler formula: $V-E+F=2$ true for all polyhedra?

.....

(2mks)

Total: 50marks

Appendix 3

Pre-Test and Post Test Instrument Validation Form

The attached instrument – learner geometry of polyhedron performance scale (LGPPS) was developed to measure Grade 9 mathematics learners' level of understanding of the concepts of geometry of polyhedron after being taught in line with National Curriculum Statement in Mathematics.

I hereby request that you evaluate the questions and indicate the level of relevance of each question to test Grade 9 mathematics learners' knowledge of geometry of polyhedron in line with the National Curriculum Statement using the following scale:

1= not relevant; 2= fairly relevant; 3= relevant; 4= highly relevant

Question	Relevance	Comment on the question (If any)
1		
2		
3		
4.1		
4.2		
4.3		
4.4		
4.5		
4.6		
5.1		
5.2		
5.3		
5.4		
5.5		
6.1		
6.2		
6.3		
6.4		
6.5		

7		
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Please, comment the extent to which the instrument covers the entire content of the Grade 9 geometry of polyhedron curriculum.

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

Personal information of Evaluator

Qualification:

Status:

Signature: Date:

Appendix 4

CLASSROOM OBSERVATION CHECKLIST

Case Study.....

School:

Topic Treated.....

.....

Date: Time:

Below are the activities observed and the rating scale.

		Observable Characteristics	YES	NO	NI*	NA*
CLASSROOM RESOURCES	1.1	Classroom is equipped with data projector, white board screen, chalkboard or computer.				
	1.2	Classroom is very spacious and learners are comfortably sited.				
	1.3	Materials presented is appropriate to the grade level				
	1.4	Material is appropriate to the topic.				
PRESENTATION	2.1	Class began at the scheduled time				
	2.2	Learners are seated in groups				
	2.3	Previous work is reviewed				
	2.4	Objectives were stated for the immediate class period				
	2.5	Introduction of the day's topic is made				
	2.6	The DGS is displayed and used to teach the concept.				
DISCUSSION & INTERACTION	3.1	Learners engaged in group discussion				
	3.2	Learners interacted with DGS				
	3.3	Teacher went round each group discussion				
	3.4	Each group made group presentation				
	3.5	Real-life problems were discussed and solved in each group.				
	3.6	Individual learners presented solutions to problems as discussed and understood in their groups.				
	3.7	Teacher summarized major concepts.				

Field Notes

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Appendix 5

Classroom Observation Checklist Instrument Validation Form

The attached instrument- classroom observation checklist was developed to be used by the researcher to collect observable data while animated computer 3-D figures illustration is being used to teach geometry of polyhedron in Grade 9 mathematics classes in some secondary schools in South Africa.

The study participants would start to use the instructional aid, during which time the researcher is expected to conduct series of classroom observation. The data collected through the observation checklist instrument, will be used to measure the learning facilitative component of the study and also to corroborate the quantitative results. I, therefore, solicit few moments of your time to help me to judge the instruments' items.

Please judge each items on: **Sureness and Relevance.**

Use the following scale for sureness:

1 = not very sure; 2 = pretty sure; 3 = very sure

And the following scale for relevance:

1 = not relevant; 2 = somewhat relevant; 3 = highly relevant.

Item No:	Sureness	Relevance
1.1		
1.2		
1.3		
1.4		
2.1		
2.2		
2.3		
2.4		
2.5		

2.6		
3.1		
3.2		
3.3		
3.4		
3.5		
3.6		
3.7		

Personal information of Evaluator

Qualification:

Status:

Signature: Date:

Appendix 6

Animated Computer 3-D Figure Illustration (ACTDFI)

Instrument Validation Form

My Msc(Ed) research seeks to investigate the effect of using animated computer 3-D figure illustration (ACTDFI) in the teaching of geometry of polyhedron. The CD accompanying this form contains ACTDFI package which would be installed on computers and be used by geometry teachers as teaching aides to teach geometry of polyhedron.

As part of the validation procedures, you are selected as one of the judges to rate ACTDFI as an intervention instrument in this project as per how well the ACTDFI covers the topics to be taught in line with the Curriculum Assessment Policy Statements using the scale:

1= Not Well Covered; 2= Somewhat Well Covered; 3= Very Well Covered.

Topic	Rating
Name of 3D objects	
Polyhedron and its properties	
Platonic solids and their properties	
Net of 3D models	
Use of Euler's law	

Please, comment the extent to which the instrument covers the entire content of the Grade 9 geometry of polyhedron curriculum.

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.....

.....

Personal information of Evaluator

Qualification:

Status:

Signature: Date:

Appendix 7
Institute for Science and Technology Education
University of South Africa (Unisa)

Teacher's consent form

Title of study: The effect of using animated computer 3-D figures illustration in the learning of polyhedron in geometry.

Dear Respondent,

You are invited to participate in an academic research study conducted by Mr. Adenubi Adewole of the Institute for Science and Technology Education at Unisa.

The purpose of this research is to investigate whether the use of animated computer 3-D figures illustration in the learning of polyhedron in geometry has any significant effect on the performance of Grade 9 secondary school learners.

Please note that:

Your participation in the study is voluntary. You may choose not to participate and may withdraw your participation at any time without any negative consequences.

Your information will be treated confidentially and your identity will by no means be revealed in any publication.

The result of this study will be used for academic purposes only and may be published in the academic journal. I will provide you with a summary of the results of my findings on request.

Should you have any queries, please do not hesitate to contact me on 0719922336 or by email at zionwol@yahoo.co.uk

Please sign this form to indicate that:

You have read and understood the information above.

You give your consent to participate in the study on voluntary basis.

Respondent's signature

Date

Appendix 8
Pilot Studies' report

ID	PRE-TEST	POST-TEST	DIFFERENCE D	D ²
1	6	15	-9	81
2	8	9	-1	1
3	4	7	-3	9
4	7	8	-1	1
5	10	16	-6	36
6	20	23	-3	9
7	6	7	-1	1
8	14	15	-1	1
9	10	11	-1	1
10	11	10	1	1
11	11	11	0	0
12	10	13	-3	9
13	8	24	-16	256
14	10	17	-7	49
15	4	8	-4	16
16	8	12	-4	16
17	15	17	-2	4
18	4	12	-8	64

19	5	12	-7	49
20	11	7	4	16
21	5	10	-5	25
22	21	17	4	16
23	18	14	4	16
24	30	22	8	64
25	16	15	1	1
26	12	11	-1	1
27	9	14	-5	25
28	14	12	2	4
29	12	10	2	4
30	5	5	0	0
TOTAL	324	384	-58	776
N=30	$X_{pre} = 10.8$	$X_{post} = 12.8$		
Diff of Xpre and Xpost = 10.8-12.8 = -2				

tcv = ± 2.04522964

(Obtained from <http://www.danielsoper.com/statcalc3/calc.aspx?id=10>)

Degree of freedom = $(N-1) = 30-1=29$ and Alpha Level = 0.05

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

Dependent t-test = -2.290

Appendix 9

Result of the reliability test of pre-test and post-test instruments

ID	TEST X	RETEST Y	x=X-X	y= Y- \bar{Y}	x ²	y ²	xy
1	21	21	-0.5	-6.6	0.25	43.6	3.3
2	10	16	-11.5	-11.6	132.3	134.6	133.4
3	17	17	-4.5	-10.6	20.3	112.4	47.7
4	33	30	11.5	2.4	132.3	5.8	27.6
5	31	32	9.5	4.4	90.3	19.4	41.8
6	32	36	10.5	8.4	110.3	70.6	88.2
7	22	28	0.5	0.4	0.25	0.2	0.2
8	17	32	-4.5	4.4	20.3	19.4	-19.8
9	20	26	-1.5	-1.6	5.1	2.6	2.4
10	12	28	-9.5	0.4	90.3	0.16	3.8
N=10	215 X =21.5	276 \bar{Y} =27.6			601.7	408.8	328.6

Using

$$r = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}}$$

$$r = \frac{328.6}{24.5 \times 20.2} = 0.66$$

$$r = 0.66$$

Appendix 10

Z-Values for the All the Groups

CONTROL GROUP

PRE - TEST

$$\mu = 8.56$$

$$\delta = 3.78$$

$$X_1 = 5$$

$$X_2 = 12.5$$

$$Z_i = \frac{X_i - \mu}{\delta}$$

$$Z_1 = \frac{5 - 8.56}{3.78}$$

$$= \frac{-3.56}{3.78}$$

$$= -0.94180$$

$$= 0.17361$$

$$= 0.32639$$

$$Z_2 = \frac{12.5 - 8.56}{3.78}$$

$$= \frac{3.94}{3.78}$$

$$= 1.04233$$

$$= 0.85083$$

$$= 0.35003$$

$$= 0.6764$$

$$= 67.64\%$$

POST-TEST

$$\mu = 22.05$$

$$\delta = 8.28$$

$$X_1 = 10$$

$$X_2 = 30$$

$$Z_i = \frac{X_i - \mu}{\delta}$$

$$Z_1 = \frac{10 - 22.05}{8.28}$$

$$= \frac{-12.05}{8.28}$$

$$= -1.45531$$

$$= 0.07353$$

$$= 0.4265$$

$$Z_2 = \frac{30 - 22.05}{8.25}$$

$$= \frac{7.95}{8.25}$$

$$= 0.96014$$

$$= 0.46014$$

$$= 88.66\%$$

EXPERIMENTAL GROUP 1

PRE - TEST

$$\mu = 9.45$$

$$\delta = 4.10$$

$$X_1 = 5$$

$$X_2 = 15 = \frac{-6.43}{7.93}$$

$$Z_i = \frac{X_i - \mu}{\delta} = -0.81084 = 0.20897 = 0.2903$$

$$Z_1 = \frac{5 - 9.45}{4.10}$$

$$= \frac{-4.45}{4.10} = -1.0854 = 0.14007 = 0.35993$$

$$Z_2 = \frac{15 - 9.45}{4.10}$$

$$= \frac{5.55}{4.10} = 1.3537 = 0.91149 = 0.41149 = 77.14\%$$

POST-TEST

$$\mu = 56.43$$

$$\delta = 7.93$$

$$X_1 = 50$$

$$X_2 = 65$$

$$Z_i = \frac{X_i - \mu}{\delta}$$

$$Z_1 = \frac{50 - 56.43}{7.93}$$

$$= \frac{-6.43}{7.93} = -0.81084 = 0.20897 = 0.2903$$

$$Z_2 = \frac{65 - 56.43}{7.93}$$

$$= \frac{8.57}{7.93} = 1.08071 = 0.85993 = 0.3599 = 65\%$$

EXTENDED:

$$Z_2 = \frac{80 - 56.43}{7.93}$$

$$= \frac{23.57}{7.93} = 2.97226 = 0.99851 = 0.4985$$

EXPERIMENTAL GROUP 2

PRE - TEST

$$\mu = 11.5$$

$$\delta = 4.12$$

$$X_1 = 7.4$$

$$X_2 = 15$$

$$Z_i = \frac{X_i - \mu}{\delta}$$

$$Z_1 = \frac{7.4 - 11.5}{4.12}$$

$$= -4.1$$

$$\frac{4.12}{4.12}$$

$$= -0.99515$$

$$= 0.16109$$

$$= 33.89\%$$

$$Z_2 = \frac{65 - 55.61}{6.43}$$

$$= 9.39$$

$$\frac{6.43}{6.43}$$

$$= 1.46034$$

$$= 0.92785$$

$$= 0.42785$$

$$Z_2 = \frac{15 - 11.5}{4.12}$$

$$= \frac{3.5}{4.12}$$

$$= 0.84951$$

$$= 0.80234$$

$$= 30.23\%$$

$$Z_3 = \frac{75 - 55.61}{6.43}$$

$$= \frac{19.39}{6.43}$$

$$= 3.01555$$

$$= 0.99874 = 0.49874$$

POST-TEST

$$\mu = 55.61$$

$$\delta = 6.43$$

$$X_1 = 48$$

$$X_2 = 65$$

$$X_3 = 75$$

$$Z_i = \frac{X_i - \mu}{\delta}$$

$$Z_1 = \frac{48 - 55.61}{6.43}$$

$$= \frac{-7.61}{6.43}$$

$$= -1.1851$$

$$= 0.11900$$

$$= 0.38100$$

EXPERIMENTAL GROUP 3

PRE - TEST

$$\mu = 9.34$$

$$\delta = 4.56$$

$$X_1 = 5$$

$$X_2 = 15$$

$$Z_i = \frac{X_i - \mu}{\delta}$$

$$Z_1 = \frac{5 - 9.34}{4.56}$$

$$= \frac{-4.34}{4.56}$$

$$= -0.95175$$

$$= 0.17106$$

$$= 0.3289$$

$$= 32.89\%$$

$$Z_2 = \frac{15 - 9.34}{4.56}$$

$$= \frac{5.66}{4.56}$$

$$= 1.24123$$

$$= 0.89065$$

$$= 0.39065$$

$$= 39.07\%$$

$$Z_1 + Z_2 = 71.96\%$$

POST-TEST

$$\mu = 55.15$$

$$\delta = 7.94$$

$$X_1 = 48$$

$$X_2 = 60$$

$$X_3 = 75$$

$$Z_i = \frac{X_i - \mu}{\delta}$$

$$Z_1 = \frac{48 - 55.15}{7.94}$$

$$= \frac{-7.15}{7.94}$$

$$= -0.90050$$

$$= 0.18406$$

$$= 0.3159$$

$$Z_2 = \frac{60 - 55.15}{7.94}$$

$$= \frac{4.85}{7.94}$$

$$= 0.61083907$$

$$= 0.2291$$

=

$$Z_3 = \frac{75 - 55.15}{7.94}$$

$$= \frac{19.55}{7.94}$$

$$= 2.5$$

$$= 0.99379$$

$$= 0.4938$$

$$Z_4 = \frac{50 - 55.15}{7.94}$$

$$= \frac{-5.15}{7.94}$$

$$= -0.64861$$

$$= 0.25785$$

$$= 0.24215$$

Therefore

$$Z_{50-75} = 0.4938 + 0.24215$$

$$= 73.60\%$$