THE DEVELOPMENT OF A TEACHING TOOL USING SKETCHUP TO ENHANCE SURVEYING COMPETENCE AT THE DURBAN UNIVERSITY OF TECHNOLOGY

SUBMITTED IN FULFILMENT OF THE REQUIREMENTS OF THE DEGREE OF MASTER OF THE BUILT ENVIRONMENT (SURVEY) IN THE FACULTY OF ENGINEERING AND BUILT ENVIRONMENT AT THE DURBAN UNIVERSITY OF TECHNOLOGY

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ABSTRACT

Surveying concepts are difficult to understand, especially when students are exposed to surveying for the first time. Surveying is best understood when linked to field applications; however, students are only exposed to surveying and related field operation procedures during practicals. Two-dimensional (2D) explanations of surveying equipment used is shown during class lectures, which makes understanding of field procedures difficult to teach and learn during normal class lectures. A new approach to lecture delivery is required to make lectures more interesting and visually stimulating via three-dimensional (3D) animated models of levelling equipment and simulation of field observations and data collection. Additionally the learning of basic surveying concepts cannot be limited to field practicals, but in conjunction with learning that takes place in the classroom. Students' ability to properly learn the correct use of surveying equipment during time-tabled practicals is limited. The students do not have sufficient time in their normal scheduled practicals to learn to use surveying equipment to the required proficiency level.

The main objective of this research was to deal with these inadequacies by exposing students to (3D) animated models of surveying equipment during lectures and the corresponding field applications created within SketchUp software. Students were exposed to these animated 3D models during lectures, so that their actual field operation and application could be simulated. Quantitative analysis of the student achievement data revealed that there was a significant difference between the test scores of the control and experimental groups. Additional analysis of the developed Likert-type scale questionnaire revealed that students' had a positive attitude towards the teaching tool.

DECLARATION

This research, compiled by Mr. Darryl George Stuart (student number: 19702513) is being submitted to the Durban University of Technology (DUT), Department of Civil Engineering, Faculty of Engineering and the Built Environment.

I, **Darryl George Stuart** hereby declare that this research is the result of my own research and has not been submitted for any degree purpose to any other institution.

Submitted by:

Darryl George Stuart

Student Number: 19702513

DEDICATION

This research study is dedicated to my family because of their support and understanding for the full duration of this research study.

ACKNOWLEDGEMENTS

Firstly, to my family who supported me throughout this research process. Thank you for your understanding during my absence due to my thesis deadlines and your belief in me has not gone unnoticed.

Secondly, to the staff at the Durban University of Technology's Indumiso and Steve Biko campuses, this research would not have been possible without your encouragement and backing. From the reduction in my lecture load, to assisting me with specific deadlines has renewed my belief that any task can be achieved with the correct systems in place. Specific names will not be mentioned with the fear of leaving anyone out. Your contribution to the successful completion of this research will always be appreciated.

Finally, to my supervisors who showed immense patience with me throughout this journey. I have learnt a tremendous amount of valuable tips along the way, that I am sure will benefit me in my future career. I will always remember the sympathetic ear you provided when times were tough and the end did not seem a possibility. Your words of encouragement came at the right time, giving me that needed nudge in the right direction. I am sure that all the research students under your supervision have benefited from your valued instruction.

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GLOSSARY OF ACRONYMS

2D : Two-Dimensional

3D : Three-Dimensional

DUT : Durban University of Technology

LMS : Learning Management System

GPS : Global Positioning System

GIS : Geographic Information System

ASCE : American Society of Civil Engineers

ECSA : Engineering Council of South Africa

ExCEED : Excellence in Civil Engineering Education

CBI: Computer Based Instruction

CBT : Computer Based Teaching

CAL : Computer Aided Learning

Lidar: Light Detection and Ranging

EDM: Electronic Distance Measurement

PLATO: South African Council for Professional Land and Technical Surveyors

STEM: Science Technology Engineering and Mathematics

DEM: Digital Elevation Model

DTM: Digital Terrain Model

ITS: Integrated Tertiary Software

BIM: Building Information Management

Chapter 1: Introduction and Overview

1.1 Introduction

Surveying plays a vital role in civil engineering infrastructure projects, so it is important that all civil engineering students studying for a National Diploma qualification have a full understanding of surveying equipment operation. Students must also understand the related field application that is associated with the relevant equipment operation. The basic surveying equipment available during their studies includes the theodolite and automatic level. The majority of surveying work is carried out by registered surveyors; however, registered civil engineering technicians are required by industry to perform basic surveying tasks using a theodolite and automatic level. If the required competency at operating surveying equipment is deficient, the reliability of an entire civil engineering project will be adversely affected.

The ability to operate surveying equipment is not only a DUT academic requirement, (Durban University of Technology, 2010), but these skills are also necessary for students' future careers. Possessing the requisite competencies affects the accuracy of surveying data, consequently impacting on the success of civil engineering infrastructure projects (Smith, 2008)**.** Therefore, the teaching of the fundamentals of surveying equipment is vitally important however, there are barriers to teaching and learning. These obstacles include the normal lecture method, which has been documented not to be ideal to teach surveying equipment operation. Additionally, large class numbers make it difficult to teach first time students in class and in field practicals about surveying equipment. It has become evident at the DUT Indumiso campus that students have difficulty with surveying equipment operation when exposed to such apparatus for the first time. There is an average of six students per set of surveying equipment in any given semester. These barriers to teaching and learning have been experienced by many other universities, which have documented that the normal lecture method is not adequate to teach students about surveying equipment (Roberts and Gray, 2009).

Surveying teaching tools have been developed as a result of educators realising that certain surveying concepts are best understood with the help of visual aids (Shortis and Woodhouse, 2001); (Gibbings and McDougall, 2005); (Yoichi *et al.,*, 2006). The National Taiwan University developed SimuSurvey to teach students about surveying via virtual surveying instruments (Lu, Kang and Hsieh, 2007). This study documented the improvement in student learning, as SimuSurvey had the ability to mimic actual field procedures assisted with student learning, and. Feedback from students and instructors allowed improvements to be made to the original software. Further development of the software based on user and instructor input resulted in the improvement of SimuSurvey and was subsequently renamed SimuSurveyX (Lu *et al.,*, 2009) (Visualization Laboratory, 2011). This software was developed with the Microsoft XNA programming Language (Microsoft Development Network, 2013).

Research at the Nottingham University has shown that first year students generally have difficulty with the operation of surveying equipment, due to the normal lecture method inadequacies and large class numbers (Roberts and Gray, 2009). In response to this they have developed an online computer teaching and learning system to address this problem. In 1999, they originally developed an online learning training system in order to enhance student learning of surveying equipment operation and field procedure. This software was known as SurCal and was developed in-house with the assistance of a dedicated team (Roberts and Gray, 2009).

A similar approach will be used in this research where 3D models of surveying equipment will be created and their operation demonstrated via the 3D modelling and animation capabilities of Sketchup (Sketchup, 2013). Sketchup is a freely available 3D modelling software package that has 3D modelling and animation capabilities. The surveying equipment that will be modelled includes theodolites, automatic levels, tripods, levelling staves, ranging rods and tri-stands. These 3D models would then be animated to demonstrate their correct operation via a simulated survey during lectures. Many subjects have benefited from computer aided teaching and learning tools, and these tools have been used successfully in academic institutions both locally (Africa, 2013) and internationally (Costa, Alvelos and Teixeira, 2012).

This study will investigate whether students will be more proficient at completing their mandatory competency tests at the end of a semester after being exposed to Sketchup as a teaching tool. This proficiency will be assessed in terms of students' overall competency test results.

1.1.1 Surveying and Civil Engineering

Surveying plays an important function at both the beginning and end of civil engineering infrastructure projects (Cuomo, 2003). Without the support of surveying, civil engineering projects cannot be planned, designed and eventually set-out according to the design plan. These tasks are the responsibility of registered surveyors, however basic surveying tasks can be delegated to civil engineering technicians. The importance of surveying in civil engineering is further emphasized by its inclusion in civil engineering curricula i.e. first year National Diploma programmes.

1.1.2 Civil Engineering Curricula

Surveying is an important subject for first year students studying civil engineering at many Universities of Technology**,** locally and around the world. The curricula of local academic institutions offering the National Diploma in civil engineering qualifications also include surveying as an entry level subject for first year students (Central University of Technology, 2013). A study done by Russell and Stouffer, (2005), showed that the majority of civil engineering programmes offered an introduction Surveying subject at the first year level of studies.

Curricula must be designed to better prepare graduates for real life working scenarios. To ensure that standards are kept, accreditation of qualifications is done by the local Engineering Council of South Africa (ECSA) (Government, 2000). Additionally, international agreements between engineering professional organizations such as the Sydney, Washington and Dublin Accords were instituted to ensure accepted quality of academic qualifications (Sweeney, 2005). These are legislated bodies necessary to make sure that standards are kept and protection of consumers from misconduct of professionals (Patil and Codner, 2007).

1.1.3 Surveying Competence

Surveying competence is a key component of the assessment criteria used to gauge students' ability to correctly and safely demonstrate proficient operation of various surveying equipment. Evidence of competency testing for surveyors can be traced back to Roman time (Glasscock, 1974); (Dilke, 1971); (Fuller, 1973). These competency assessments are evident in surveying courses offered in South African (South African Qualifications Authority, 2001) and international academic institutions (Lam, 2008). Similar competencies are evident in civil engineering courses offering surveying.

To accomplish a survey, the operator must possess the necessary skills to use the surveying equipment competently (Fourie, 1994). To ensure that graduates obtain the necessary skills mandatory competency tests must be done by all students and the criteria that must be met are included in the assessments. Part of the assessment in the various academic programmes is the student’s ability to competently operate surveying equipment and to collect accurate field data in the regulated time. These assessments are a requirement for both civil engineering and surveying students at the DUT (Durban University of Technology, 2010). The operation of the equipment involves observations that need to be recorded in a field-book. Time taken and quality of the field observations are an important part of the assessment, as these two factors impact on the reliability of the survey plan needed for civil engineering infrastructure projects.

To get students to the desired level of competencies various teaching and learning methods must be employed. Many methods have been used to teach surveying to civil engineering students. Surveying is taught within a civil engineering environment, so the obvious link must be brought out through the teaching methods. The importance of surveying must also be highlighted with regards to the construction cost and human life that would be adversely affected if errors occur in survey plans.

The consequence of incompetent surveyors includes the risk to public safety if civil infrastructure is poorly set-out (Coutts and Grant, 2009). Inaccurate surveys for civil engineering infrastructure projects would negatively affect the project in the short term and the life-cycle of the infrastructure in the medium to long term.

1.1.4 Surveying Education

Surveying has primarily been taught via the traditional lecture method, and this teaching method has its advantages and disadvantages. The main advantage is that information can be transferred to a large audience, however this one way transfer hinders effective learning that is not catering for all learning styles. The development of the computer changed the way lectures are delivered; however the lecture method has remained fundamentally the same and has been found to be inadequate for teaching certain surveying concepts. These concepts, once understood, allow students to understand more technically demanding subject matter.

The increased use of computer technology available today has been found to enhance teaching and learning. Surveying is an important part of the civil engineering curriculum, where the Excellence in Civil Engineering Education (ExCEED) teaching model promotes the use of physical models and computers are recommended (Estes, Welch and Ressler, 2005). Students are automatically introduced to physical models of surveying equipment during practical periods. The exposure to these models affects learning as not all students have the opportunity to learn how to operate equipment due to the limited sets of equipment and large groups of students. This study will use 3D virtual models of surveying equipment to enhance student learning with in-class demonstrations of surveying equipment operation. These in-class lessons will be highlighted with further field practical lessons that demonstrate the same functionality of actual surveying equipment.

1.1.5 Computer-Based Teaching and Computer-Aided Learning

Over the years computers have influenced teaching and learning. Computer Based Instruction (CBI) and Computer Based Teaching (CBT) are terms used to describe computer centred teaching (Alessi and Trollip, 1991), (Molnar, 1997), (Opitz, 1998), (Nicholas, 2003). Computer-Aided Learning (CAL) (Godfrey and Brahan, 1984) (Forte and Ecole polytechnique fédérale de Lausanne., 1991); (Staples, 1998); (Grigg *et al.,*, 2004) and eLearning (via LMS) best describes computer learning technologies that allow students to learn at their own pace in an online environment.

Graphical display of educational materials (images and text) became possible with computers over the years. Computer advancements have allowed for multimedia content to be displayed in traditionally 2D to now in 3D format without compromising the quality of the displayed graphics and accompanying text. The animation of the 2D and 3D content ultimately became possible as technology progressed, making teaching and learning more visually appealing. Another dimension to the teaching and learning processes is interaction with the visual media. The use of 3D animated models, simulated surveys, videos have improved the way surveying lectures are delivered (Ustinova *et al.,*, 2012). These all assist with teaching students and help them to learn. This study will attempt to use a similar approach by developing 3D digital models of surveying equipment, displaying them during lectures and making these models available online via a LMS.

1.2 Statement of Problem

Previous research has shown that the majority of first year students find it difficult to understand surveying equipment operation (Bai, 2007). Additionally, large class numbers also impact on many students' contact time with the surveying equipment during designated practical periods (Roberts and Gray, 2009). A similar problem exists at the DUT, where limited surveying equipment results in 5 to 7 students per set of equipment.

The normal lecture method allows for the transfer of information to a large audience, but does not adequately facilitate the teaching of the various types of surveying equipment. Students are not always engaged with the teaching material and thus their learning is negatively affected. Practical time is also compromised as surveying equipment parts and functions have to be explained in the field.

1.3 Rationale for Study

The purpose of this research is to determine the impact that 3D animated models of surveying equipment, developed in Sketchup software has on students' surveying competency skills test results at DUT.

This research is significant because of the potential it has to improve students' competency and understanding of surveying field procedures. This research adds an element of student interaction with the software, thereby enhancing their learning experience. Students will make better use of practical times where all students can have an opportunity to operate the equipment. Students' understanding of surveying and its significance to civil engineering will consequently be increased. Students will see the significance of surveying in the successful completion of civil engineering projects.

1.4 Research Aim, Questions and Hypotheses

The main aim of this research is to determine whether, animated 3D models of surveying equipment, have the potential, in conjunction with traditional lectures, to enhance a student's competency, with regards to survey equipment operation. The research will be addressed by answering the following research questions and corresponding null hypotheses.

1. Have the 3D animated models of surveying equipment, had an influence on students' competency test results, between the control and experimental groups?

   H_{01}: There is no significant difference between the control and experimental groups competency test results at a 95% confidence interval.

2. Have the 3D animated models of surveying equipment influenced student's competency test results between the control and experimental groups when comparing individual tasks (task 1 to 6)?

   From the second research question six sub-hypotheses were developed.

   $H_{02.1}$: There is no significant difference in competency test results when setting up a theodolite (task 1), at a 95% confidence interval.

   $H_{02.2}$: There is no significant difference in competency test scores when orienting a theodolite (task 2), at a 95% confidence interval.

   $H_{02.3}$: There is no significant difference in competency test when observing an arc of observations using a theodolite (task 3), at a 95% confidence interval.

   $H_{02.4}$: There is no significant difference in competency test scores when observing vertical angles using a theodolite (task 4), at a 95% confidence interval.

   $H_{02.5}$: There is no significant difference in competency test scores when observing and booking a tacheometry shot using a theodolite (task 5) at a 95% confidence interval.

   $H_{02.6}$: There is no significant difference in competency test scores when observing and booking the height difference between points using an automatic level (task 6) at a 95% confidence interval.

3. Have students' characteristics (gender and age), influenced competency test results?

   From the third research question two sub-hypotheses were developed.

$H_{03.1}$: There is no significant difference in competency test results at a 95% confidence interval between the male and female test results.

$H_{03.2}$: There is no significant difference in competency test results at a 95% confidence interval between the various age groups.

4. How have the students' perceived the teaching tool as a means to understanding how to operate surveying equipment?
   H_{04}: The students' perceptions regarding the 3D animated models of surveying equipment were positive.

1.5 The Development of the Teaching Tool

This research investigated the effects that 3D animated models of levelling surveying equipment developed and displayed within Sketchup™ software, had on students' attitude towards Sketchup™ as a teaching tool.

Photographs from different perspectives of actual levelling equipment were taken and appropriately dimensioned. The 3D models developed from these dimensioned photographs were drawn to scale within Sketchup software. Five models were developed, namely: (1) the theodolite, (2) the ranging rod (3) the automatic level, (4) the tripod and (5) the levelling staves. Additionally, a 3D area of the campus where surveying was to take place, was also modelled. All models were appropriately textured and coloured to represent virtual reality. Animation to the theodolite, automatic level and tripod, was added using a third party add-on called proper animation, to ensure that the operation of the surveying equipment was correctly simulated. Actual viewing through the theodolite and automatic level telescopes was made possible to allow students to experience field conditions before they take physical equipment out to the field.

The automatic level comprises mainly of a telescope attached to the upper main body, circular bubble, foot-screws, and a triangular base (tribrach) connected to the lower body. These were modelled as separate components so that the telescope and main body could rotate about the vertical axis independent of the lower body and tribrach. Sketchup™ software has built-in drawing utilities such as solid 3D objects that can easily be manipulated to shape according to the users requirements. Sketchup™ software also has built-in viewing perspectives, allowing the user to view scenes from various angles. The 3D navigation tool also allows the user to manipulate 3D scenes to very intricate degrees. This was especially useful when specific parts of the automatic level were zoomed in. Various parts of the surveying equipment were labelled to further enhance learning.

1.6 Research Methodology

Students are required to pass a competency test at the end of a semester. This test is broken down into six different tasks, but these tasks are linked together to produce various survey data important for civil engineering projects. The results of this study (3 semesters) will be compared to 3 previous semesters where no intervention of this nature was implemented.

This will be a quantitative research, where achievement levels between semesters with and without the intervention will be compared. This study will attempt to improve the overall competency test results between the control and experimental groups, using various statistical tests to achieve this end. Additionally, a Likert-type scale questionnaire, developed internally was administered to gauge students' perceptions regarding the educational intervention.

1.7 Data Analysis

The analysis of the collected student competency test data was achieved via quantitative methods. Quantitative data included student achievement from the control and experimental groups. The collection of this data was for quantitative data analysis of student achievement compared over 3 semesters where the educational intervention was not used to subsequent semesters where the educational intervention was employed. Additionally, a 5-point 19 question Likert-scale questionnaire was also administered and analysed quantitatively to determine students' attitude towards the educational intervention. Various statistical analysis techniques were used to answer the research questions, will be expanded upon in Chapter 4 and 5.

1.8 Assumptions, Limitations and Delimitations

This study is limited to first semester Surveying 1 students at Indumiso campus. It is a deliberate attempt not to limit this study to only one task (aspect) of the competency test as they are all linked and it is feared that students will not grasp the full understanding of their practicals and thus fail to see the significance of surveying in civil engineering. Students are given a random task from the six standard tasks to assess their surveying competence at the assessors' discretion; however one single task cannot be isolated from the six tasks that a student must perform, therefore students' must know an arbitrary task will be chosen by the assessor. The tasks include the following (Appendix A):

1. Set-up a theodolite
2. Orientate a theodolite (set a direction)
3. Observe and book an arc of observations
4. Observe and book a vertical angle
5. Observe and book a tacheometry shot (ground detail)
6. Observe and book height differences using an automatic level

1.9 Sequence of Chapters

Chapter 2: Literature review - which supports the rationale behind this research.
Chapter 3: Development of the Teaching Tool
Chapter 4: Describes the methodology adopted and documents the process followed to reach the research objectives.
Chapter 5: Data collection, analysis of results and findings
Chapter 6: Conclusions and Recommendations

1.10 Summary

Surveying provides an essential service to the civil engineering industry, as civil engineering projects rely on accurate surveying data. This information is collected by qualified surveying and civil engineering graduates who should be competent at using appropriate surveying equipment. If the required competency at operating engineering surveying equipment is deficient, the reliability of the entire civil engineering project would be adversely affected. This study will investigate the use of a freely available 3D modelling software Sketchup, as a means to create 3D models of engineering surveying equipment and animate important elements related to their correct operation and field application. These 3D models and animations will be shown during lecture periods and will be made available online in video format so that students can learn at their own pace, and to further reinforce their understanding. Competency tests will be compared to previous semesters to verify whether Sketchup animations have improved the quality of competency test results.

Chapter 2: Literature review

2.1 Literature Review

This chapter documents why surveying competency has been and still is important for surveying and civil engineering. This chapter discusses the theoretical framework relating to the survey process, the history of surveying instruments and the importance surveying in the civil engineering curricula. In addition, teaching and learning tools and 3D in education are discussed in relation to the main objectives of this research.

During the literature survey, the importance of surveying in civil engineering emerged. Additionally, evidence from the majority of academic institutions offering civil engineering, offer surveying in first year, further highlights the significance of surveying. Surveying is also included in other closely related disciplines such as architecture and town planning. Furthermore, professional regulatory organisations are included to show their influence on curriculum content as well as the future professional development of surveying and civil engineering graduates.

Finally, the teaching and learning tools used in academia are explored. The traditional teaching methods are documented to reveal the advantages and disadvantages, especially in an engineering environment.

2.2 Surveying

Surveying is a science as it includes fundamental knowledge from areas such as Mathematics, Physics, Astronomy, Geology, Hydrology and Law (Witness Tree Surveying, 2013). For correct decisions to be made in the field and accurate survey data collection, the operator of surveying equipment must possess the required competencies.

Surveying has been referred to as geomatics which is a fairly new and emerging science and technology that incorporates all methods of geospatial data activities, such as collection, processing, analysis, design and plotting (Kavanagh, 2003). Therefore, geomatics includes traditional surveying methods as well as other data collection methods such as remote sensing and GPS, and the storage of field data in a database such as a Geographic Information System (GIS) (Geomatica, 2005). It can be confidently said that Geomatics is a more modern term that is sometimes used to describe surveying, due to the advancements in technology.

2.2.1 A Brief History of Surveying Equipment

The Greeks learnt basic geometric techniques from the Egyptians, and are recognised for further improvements in Mathematics and Science. These advancements further developed surveying calculations and field data collection techniques (Crone, 1953).

Mathematical and scientific principles were adapted into practical surveying methods by the Romans (Richeson, 1966). Richeson, (1966), further highlights that ancient archives demonstrate that Egyptian and Greek land measurement and recording methods were incorporated into Roman practice. Evidence of surveying for construction can be traced back to Roman times (Glasscock, 1974); (Dilke, 1971); (Fuller, 1973).

Mathematics and science improved over the centuries resulting in surveying becoming more diverse and complex. These scientific developments demands of those in this industry to possess a thorough knowledge of the fundamentals of Physics and Mathematics (Roy, 2010).

The development of surveying is closely linked with the type of equipment used in the different era. The type of equipment developed and used relied heavily on the available technologies of the relevant time. Surveying benefited from the developments in trigonometry, astronomy and geometry.

2.2.2 Engineering Surveying Equipment

Surveying equipment, by today's standards, was very rudimentary during the Egyptian, Chinese, Greek and Roman times. The two major instruments that were used by the Egyptians, Chinese, Greeks and Romans and subsequent centuries were instruments that performed the function of the modern theodolite and level. The ancient instruments were designed to measure angles and heights respectively. The theodolite and level are used in many branches of surveying and has become particularly useful in engineering surveying applications. Similar instruments to the modern level and theodolite were used extensively in surveying thousands of years ago. The principles of geometry that were built into ancient theodolites and levels are still evident in more modern equipment. The basic surveying equipment that existed from the ancient times performed similar functions to the modern theodolite and level. The more modern theodolite and level are more sophisticated but perform basically the same function they were designed for thousands of years ago.

2.2.2.1 The Theodolite

The earliest recording of land surveying indicates that special ropes were used to measure the land. The skilful land surveyors of that era, the Harpedonaptai (Egyptian rope stretchers) managed to accurately survey property boundaries and later civilian infrastructure. The Akkadians, Assyrians, Babylonians, Hebrews also employed this technique (Dauben, 1998). This simple yet effective surveying instrument laid the foundation for the development of the Egyptian groma (Price, 1955), (Dilke, 1962). The combination of the groma and rope stretching led the way for more accurate and complex surveying tasks. The Egyptians used the groma (figure 1) and knotted ropes to accurately set-out angular and distance dimensions respectively (Wallis, 2005b).

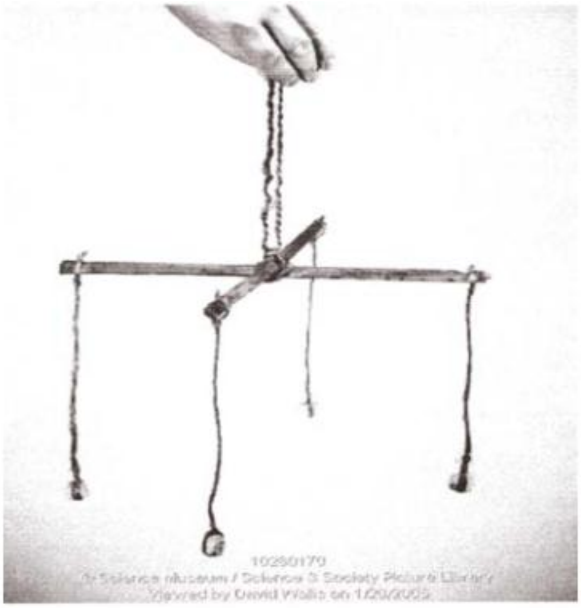


Figure 1. Model of the Egyptian Groma (Wallis, 2005)

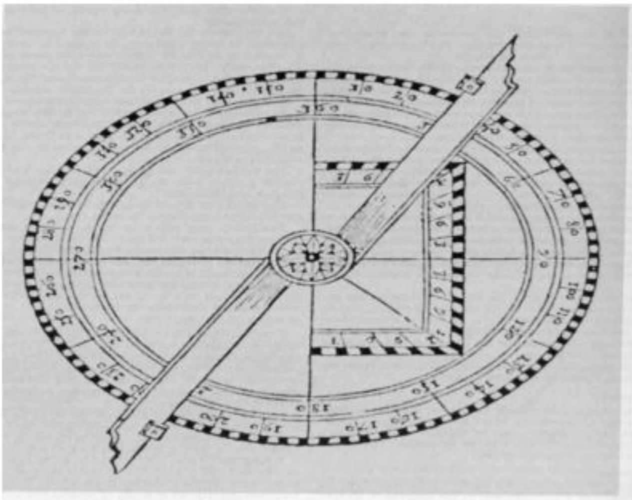
The Chinese also used an instrument similar to the Egyptian groma (Dilke, 1962). The Chinese used a combination of the compass and an instrument known as the gnomon to accomplish similar tasks as the Egyptian groma, providing angles and distances for surveying tasks (Lay-Yong and Kangsheng, 1986). A gnomon was a device that marked out the path of the sun by creating shadows, and this was vital for establishing direction. (Deumlich, 1982),

The Greeks developed the dioptre (Figure 2) which was an improvement of the Egyptian groma (Professional Land Surveyor, 2012). Around 2000 years ago, the Greeks further developed the science of geometry and were using it for precise land division.

Figure 2. The dioptra developed by the Greek (Wallis, 2005)

The Romans modernised the Greek dioptra (also known as the diopter) (Wallis, 2005a), (McCague, 2007). Heron of Alexandria has been credited with the invention of the diopter (Rossi, Russo and Russo, 2009). In his work entitled Diopter, Heron of Alexandria describes it as a portable instrument, an application of the cogwheel, screw, and water level, for taking terrestrial and astronomical measurements. Because of some similarities, Heron's diopter is usually recognized as the predecessor of the modern theodolite (Wallis, 2005a).

Subsequent to the collapse of Roman Empire, several of the surveying instruments and techniques continued and were further improved upon in Europe (Richeson, 1966). The modern theodolite inherited its basic design from the ancient dioptra developed by the Greeks and later improved upon by the Romans. This basic structure was intended to measure and set-out basic geometry necessary for civil intrastructure.



2. *The Digges theodolitus.*

Drawing of Digges Theolitus

Figure 3. Model of the First Theodolite (Wallis, 2005)

In his 1571 book, Leonard Digges made mention of an instrument that he called a Theodolite (figure 3) (Oxford, 2003); (Wallis, 2005a). These theodolites preceded the optical theodolites that emerged at the end of the 16th century (Venkatramaiah, 1996). The theodolite developed further throughout the centuries, due to other inventions and discoveries from other related and non-related disciplines of each particular era (Wallace, 2003). The first industrial revolution contributed to the development of surveying equipment due to the invention of precision tools, allowing for more accurate surveying (Logan, 1965), (Shi, 2010).

The theodolite that has evolved throughout the different eras, from ancient to modern times is best illustrated in Figure 4 (Staiger, 2009). This development can be divided into four different phases and included other surveying instruments (Staiger, 2009). The ancient or archaic phase lasted thousands of years from the predecessor of the theodolite (the groma) to the first optical theodolite in 1590 (Henze, Heine and Siedler, 2009).

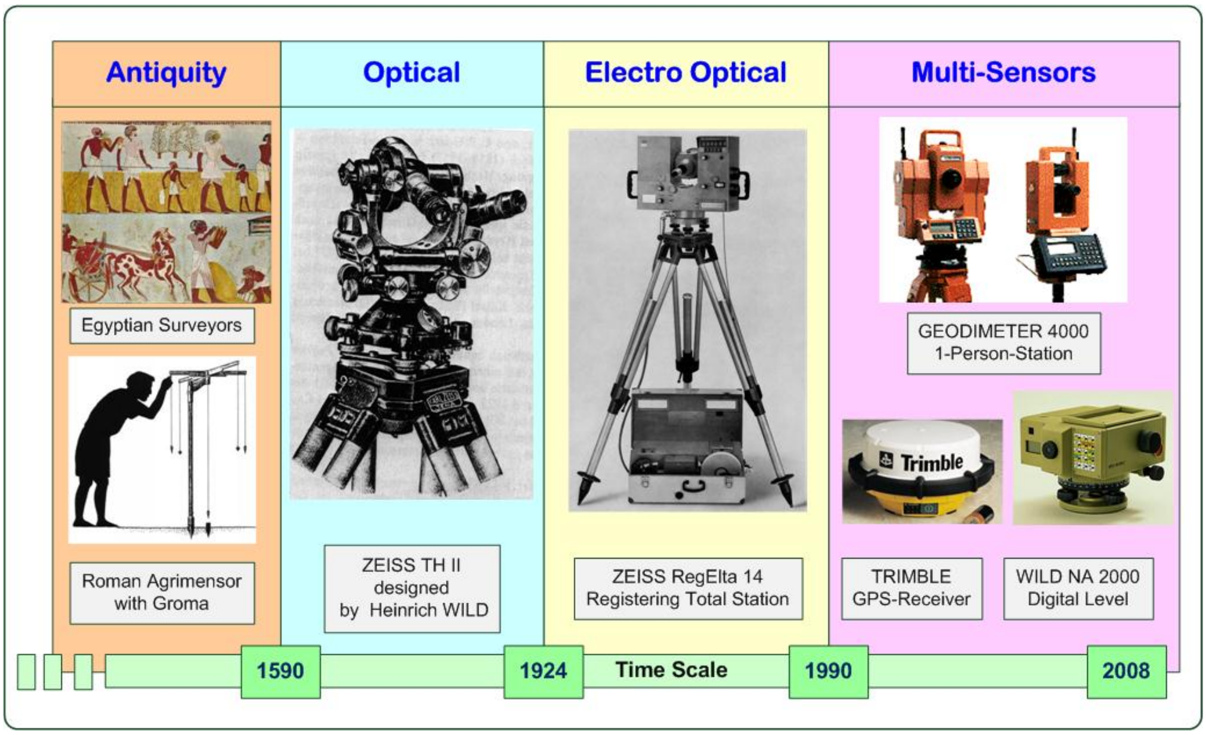


Figure 4. The Theodolite from the various era (Staiger, 2009)

The optical theodolite preceded the first modern theodolite by more than three centuries until the introduction of the Zeis TH II (Deumlich, 1982). This new theodolite was the beginning of the electro-optical phase that continued until the 1980s. This new era resulted in the emergence of the total station, equipping theodolites with on-board distance measurement capabilities and storage (Wolf, 2002). This involved hand-held or on-board collectors and electronic field-books that resulted in the theodolite evolving into total station (Coiner, Bruno and San Ramon, 2002).

In 1990 the first motorised total station (GEODIMETER 4000) was presented, spearheading the Multi-Sensor-Systems available in today's theodolite (Hennes, 1992). Concurrently GPS was announced as the new common positioning system (Carlson, 2000), so much so that today's total stations have built-in GPS receivers (Balodimos *et al.*,, 2003).

2.2.2.2 The Level

In ancient times levelling instruments were very basic, but ingenious, using the properties of water when subjected to gravity (Lewis, 2001). Figure 5 shows an example of a 20 feet long levelling instrument, was known as a chorobates (Aicher, 1995); (Adam, 2005). This apparatus was similar to an ancient instrument in China (Dilke, 1962). The Chinese are credited with the invention of the world's first compass (Lay-Yong and Kangsheng, 1986), and this instrument was used in conjunction with a leveller and plumb-line, for surveying applications. In ancient China, evidence exists of basic levelling instruments used by the surveyors of that time to manage the flow of water (Lay-Yong and Kangsheng, 1986).

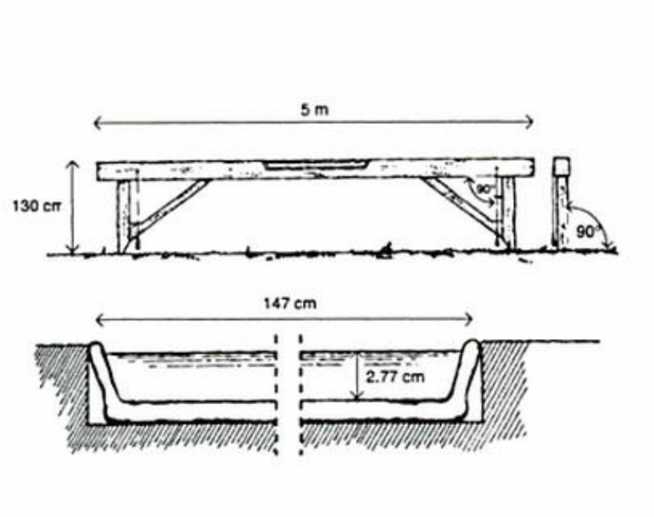


Figure 5. The ancient Roman Chorobates (Aicher, 1995)

Modern levels used the same basic principles of ancient instruments, where the properties of water were exploited to set-out civil infrastructure (Kreisle, 1988). The most common level is the dumpy level that was originally designed by Gravall (Venkatramaiah, 1996). Végső, (2010) refers to the dumpy, builders (tilting), and automatic level as one and the same instrument. However, Field, (2011) makes a clear distinction between the dumpy and automatic levels. The automatic level is physically similar to and based upon the dumpy level and emerged in the 19th century (Wolf, 2002). The dumpy level requires the centering of two bubbles (circular and plate); whereas the automatic level as the name suggests, automatically levels the instrument after a circular bubble is centred by the operator (University of New South Wales, 2014).

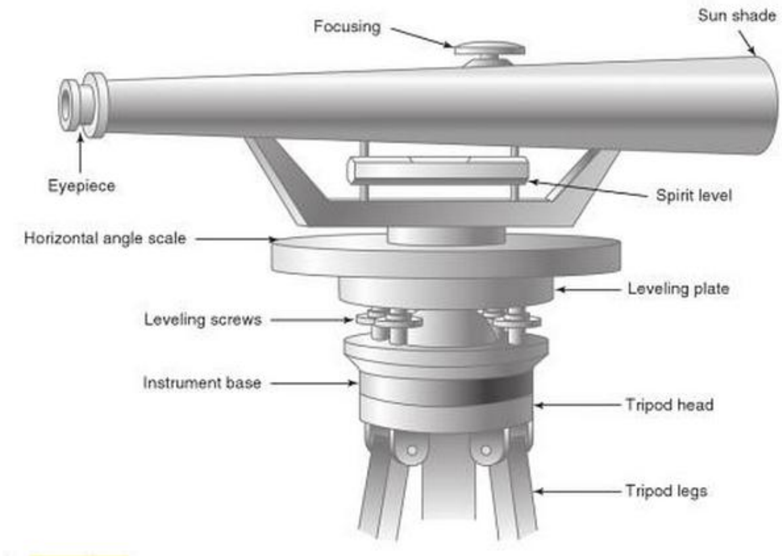


Figure 6. The Dumpy Level (Field, 2011)

Further advancements in technology allowed the digital level to automatically read the levelling staff using bar-code technology (Johnson, 2004). In1990 the first digital level (WILD NA 2000) was introduced allowing for faster and more accurate height determination surveys (Staiger, 2009). The levelling instrument has become digital, and have the capabilities of being connected to a hand-held data collector, ensuring data integrity (Chandra, 2007); (Elhassan and Ali, 2011). Later laser levels were developed for visually establishing the line-of-site even more precision levelling (Field, 2011).

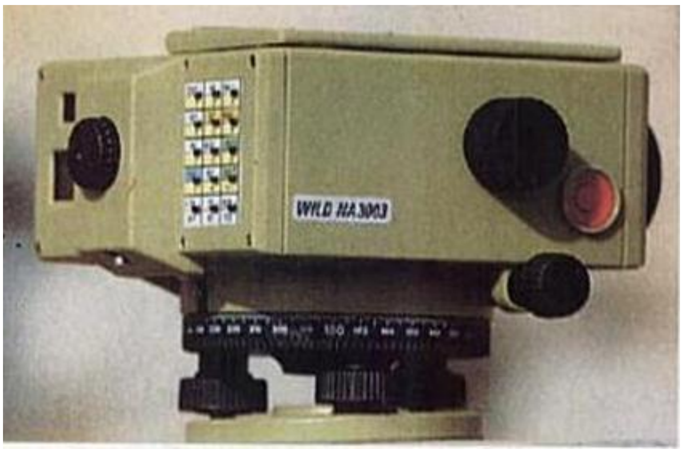


Figure 7. The Digital Level (Chandra, 2007)

2.2.2.3 Modern Surveying Equipment

A variety of new technologies has had a widespread effect upon the surveying profession, (Trinder and Han, 1999). Advancements in electronic and computer technology have been credited for the development of surveying equipment, in particular the theodolite and level. Distances could now be measured more accurately with built-in EDM devices now available for theodolites (Rüeger, 1990). The collection of field data became automated resulting in the reduction of errors, provided the surveyor was familiar with more complicated equipment.

Other technological advancements in particular technology developed by the military known as Global Positioning Systems (GPS), used for navigation became useful to the surveying industry (Carlson, 2000). Today's theodolites are even equipped with built-in GPS receivers and digital scanning technology (Balodimos *et al.,*, 2003). Additionally total stations have become automated allowing the surveyor to be more involved in data collection.

The emergence of geomatics, resulted in the explosion of new technologies for data collection and storage. The integration of a number of geospatial technologies such as GPS, GIS and Lidar (Remote Sensing) are now common place. The mundane tasks of measurement have been taken out the realm of the surveyor (Staiger, 2009). However the surveyor needs to equipped with more skill than ever before if he\she wants to compete in a global market (Simmons, 2012). Educational interventions developed in this study can also be adapted for use in the latest surveying technologies training to ensure that surveying graduates are globally competitive.

Terrestrial laser scanning (TLS) has recently been used in topographic surveying for the rapid and accurate production of digital elevation models (DEM) (Tarolli, Arrowsmith and Vivoni, 2009). Other uses of laser scanning technology include reconstruction, monitoring, as-built, archeology, and topographic surveying (Luh *et al.,*, 2014). These tasks were traditionally accomplished with the total station and modern level; however, the total station and modern level are still relevant today. The surveys produced by the latest surveying technology are randomly checked using surveying principles embedded in basic geometry. These basic geometry techniques are practised by having a full understanding of vertical, horizontal angles and distances evident in the modern theodolite and level. Although new technology must be embraced, professionals in the surveying field must not disregard first principles.

2.3 Engineering Surveying and Civil Engineering

2.3.1 Civil Engineering

In 1828 Thomas Tredgold defined civil engineering as a great value to mankind; because of the skill we possess to guide the abundant sources of power in our natural surroundings for our benefit (Chartered Institution of Civil Engineering, 2013). A more modern definition of civil engineering is the design and maintenance of public works such as roads, bridges, water and energy systems as well as public facilities like ports, railways and airports (American Society of Civil Engineers, 2013). These definitions clearly map out the goal of civil engineering as providing infrastructure to service humans for present and future quality of life. The provision of this infrastructure became possible with the support of engineering surveying (Ghosh, 2010).

2.3.1.1 The Importance of Engineering Surveying in Civil Engineering

Engineering surveying has an important function in civil engineering infrastructure projects, and these developments will not succeed or deliver the intended benefit without accurate surveys (Lam, 2008). Cuomo, (2003), also emphasizes the important function that surveying plays at both the beginning and end of civil engineering infrastructure projects. Competent surveyors or civil engineering technicians, who are confident at using surveying equipment, produce reliable surveys. The knowledge of how to effectively use surveying instruments plays a critical part in eliminating observational errors introduced by the observer if he\she lacks the requisite competencies. The consequence of incompetence is erroneous surveying data, resulting in the negative impact on the entire civil engineering project (Johnson, 2004).

2.3.1.2 The Implications of Inaccurate Engineering Survey Data

One of the most common causes for claims for additional costs incurred during a construction project is the provision of incorrect survey data resulting in subsequent rework (Speirs, 1999). Inaccurate engineering surveying data often impacts on the actual project execution, resulting in costly delays (Bandyopadhyay, 2011). Incorrect survey data was recorded as one of the major reasons for construction project delays, in a study done amongst contractors in India (Bhamre and Kambekar, 2013). According to (Soler, 2013), William Bowie, who was ASCE's first chairman of the Surveying and Mapping Division, was a great promoter of accurate surveying and mapping in civil engineering.

2.4 Engineering Surveying Competence

Operators of the surveying instruments used during the era of the early Egyptians had a high level of competence to have accomplished such great civil engineering feats. Evidence of competency testing for surveyors can be traced back to Roman time (Glasscock, 1974) ;(Dilke, 1971); (Fuller, 1973). A high level of competence was necessary by ancient surveyors, with regards to their contribution to infrastructure projects (Campbell, 2000).

Modern surveying and civil engineering graduates must also demonstrate a high level of competency as is expected of industry (Francis, 1993). (Crofton, 2000) further states that civil engineering curricula must be applicable (developed according to) to industry requirements so that graduates are productive (Simmons, 2012). The loss of construction time as well as the potential loss of life could be likely consequences of supplying erroneous surveying data. Where structural monitoring requires timeous correct data, incorrect surveys are sure to result in severe loss of life (Cawood and Stacey, 2006), (Chrzanowski and Wilkins, 2007). Competent surveyors also reduce overall project costs by employing the best surveying technique best for the appropriate situation (Angus-Leppan, 1967).

2.5 Civil Engineering Qualifications

According to Lam, (2008), engineering surveying plays an important role in civil engineering and is therefore important in civil engineering qualifications. A study of 90 institutions offering civil engineering in America revealed that surveying was prevalent in over 60% of these programmes (Russell and Stouffer, 2005). At the Colorado State University, the dedicated surveying course was discontinued, but part of its content was integrated into the first year engineering subject (Grigg *et al.,*, 2004). Surveying should be included in all civil engineering programmes, considering the importance of surveying plays in civil engineering projects.

The curricula of local universities of technology offering civil engineering qualifications also include surveying as an entry level subject for first year students (Central University of Technology, 2013) (Vaal University of Technology, 2013). Traditional South African universities that offer civil engineering also include surveying as part of their curricula (Nelson Mandela Metropolitan University, 2013). The assessment of surveying competencies is part of the subjects offered at academic institutions.

These competency assessments are evident in surveying courses offered in South African (South African Qualifications Authority, 2001) and international academic institutions (Lam, 2008). Similar competencies are evident in civil engineering courses offering surveying. The ability to operate surveying equipment is a DUT academic requirement (Durban University of Technology, 2010), as well as other local and international institutions offering surveying as part of their civil engineering programme (Lam, 2008).

Engineering surveying competence is a key component of the assessment criteria used to gauge students' ability to correctly and safely demonstrate proficient operation of various surveying equipment. These skills are also necessary for their future careers, where accurate surveying data impacts on the success of civil engineering infrastructure projects (Smith, 2008). Surveying practical competence is one of the requirements for obtaining a surveying qualification (South African Qualifications Authority, 2001).

Curriculum content is influenced by international and local professional regulating organisations, so that what students' learn is relevant to industry (Grigg *et al.,*, 2004). These professional establishments also ensure that certain competencies are obtained at various stages of its member's professional development.

Curriculum development takes into account industry standards. This is ensured by the relevant regulatory bodies. Curricula must be designed to better prepare graduates for real life working scenarios. To ensure that standards are kept, accreditation of qualifications is done by the local Engineering Council of South Africa (ECSA) (Government, 2000). Additionally, international agreements between engineering professional organizations such as the Sydney, Washington and Dublin Accords were instituted to ensure accepted quality of academic qualifications (Sweeney, 2005). These are legislated bodies necessary to make sure that standards are kept and protection of consumers from misconduct of professionals (Patil and Codner, 2007).

2.6 Teaching and Learning

2.6.1 Teaching Styles

Felder and Silverman, (1988), state that the majority of engineering students are visual learners and traditional teaching methods are not catering for these learners. In order to engage students the old-fashioned style of teaching must move towards computer technology (Anderl and Vogel, 1999). The normal lecture method is still the dominant method of lecture delivery in the majority of academic institutions, despite the availability of recent technology available to enhance lectures (Deslauriers, Schelew and Wieman, 2011). The popularity of the normal lecture method is due to its advantage to relay large amounts of information to large classes. This traditional transfer of information to students involves a facilitator relaying material to a classroom. The disadvantage is that there is a one way transfer of information with minimum interaction from students (University of the Free State, 2003).

2.6.2 Learning Styles

There are many types of learning styles proposed by different researches (Keefe, 1979), (Kolb, 1981). These theories have been developed and debated over the last few decades without any clear consensus (Nel, 2008). It is beyond the scope of this research to mention the different learning styles theorised over the decades, but conclude that students do learn differently. We live in a visual world, and we are continually being bombarded with visual images and models in 2D and 3D formats (Brogdon, 2007). Humans are visual thinkers; therefore educational interventions where information displayed to students is of a visual nature will be beneficial (Kipp, 2013).

The Science Technology Engineering and Mathematics (STEM) education initiatives encourage that students be exposed to visual simulation (Shirazi and Behzadan, 2013). Laurillard, (2013), agrees that interactive models of reality in computer-based environments can encourage thorough understanding of a subject area and real-world application.

2.7 Teaching Models for Engineering Education

Jianzhong, (2008), discusses the learning by doing strategy to support learning in engineering education, but proposes the exclusion of the lecture-oriented teaching model. As discussed earlier there are disadvantages to the traditional teaching method, however there are advantages that cannot be ignored. The main advantage is that information can be transferred to a large audience; however this is a one way transfer and hinders effective learning. The support of the traditional teaching method with current computer technology ensures that the lecture method is not totally ineffective.

Surveying instruction has primarily been taught using the traditional lecture method where surveying theories and field procedures are explained via 2D diagrams in course notes and chalkboards (Hui-Lung *et al.,*, 2008). The development of the computer changed the way lectures are delivered; however the lecture method has remained fundamentally the same and has been found to be inadequate for teaching certain surveying concepts. These concepts, once understood, allow students to understand more technically demanding subject matter. The ExCEED teaching model has gained popularity in recent years as it has been designed specifically for civil engineering education.

Many theoretical surveying concepts are difficult to understand for the majority of first time students (Shortis *et al.,*, 2004); (Ahmad and Wei, 2006). Additionally, the related field application is linked to the theory so it is vitally important that students understand both the theory and practical segments of surveying. There are spatial relationships between surveying instruments, other surveying equipment (ranging rods, levelling staves), and the area to be surveyed. The operation of surveying equipment demands a certain level of the understanding of how physical and abstract concepts interact in this 3D space. The abstract concepts such as zenith angle, azimuth angle and line of collimation are imaginary lines that form essential components of surveying measurements (Crawford, 2003). These intangible concepts are often difficult for lecturers to describe to first-time civil engineering and surveying students. Abstract reasoning is important for human intellectual development and is accomplished by creating models of geometric spatial relationships (Velichová, 2002).

Technology allowed lecturers to teach using PowerPoint and other visual displays, but instruction remained 2D limiting students' understanding of 3D spatial relationships. Practical explanations are also limited by the traditional 2D lecture method. Class demonstrations of equipment operation are also impractical, especially when dealing with large class numbers. Visually stimulating lectures especially of surveying equipment operation and field application could help students' understanding of the abstract and physical. Additionally, surveying equipment is limited where about six students are allocated a set of surveying equipment per time-tabled practical period. It is also too expensive to purchase a set of surveying equipment for each student. It is practically impossible and time-consuming for the lecturer to demonstrate all practical procedures to individual students in the field. The introduction of electronic teaching aids has assisted many lecturers to address these problems by use of videos and virtual reality technologies (Bai, 2007); (Yeh, 2005).

The increased use of computer technology available today has been found to enhance teaching and learning. Surveying is an important part of the civil engineering curriculum and a closely related discipline to Civil Engineering, an element of the ExCEED teaching model where computer use is recommended, as well as the use of physical models (Estes et al. 2005).

Students are automatically introduced to physical models of surveying equipment during practical periods. The exposure to these models affects learning as not all students have the opportunity to learn how to operate equipment due to the limited sets of equipment and large groups of students. This study will use virtual models of surveying equipment to enhance student learning with in-class and out of class demonstrations of surveying equipment operation.

2.8 Computers in Education

Computers were introduced to education in the 1960's, but the benefits to teaching and learning were not immediately evident (Molnar, 1997). According to (Eng, 2005), computer use in education has equally fascinated and frustrated teachers and researchers, leaving many unanswered questions. According to (Tinio, 2003) computer-based tools are of great benefit to both teaching and learning. Although many disadvantages exist, and amidst all this negativity recent research has shown that computers in education has had many benefits to engineering education (Balamuralithara and Woods, 2007). Computers in education improved the delivery of information to students in the classroom environment and adding another dimension to the normal lecture method. In contrast (Birkenholtz *et al.,*, 1989) says that there is no guarantee that the advantages of computer-based training will always lead to greater learning in a shorter period of time as compared to traditional delivery methods.

Over the years many terms have emerged describing the influence that computers have in education. These terms include Computer Based Instruction (CBI) and Computer Based Teaching (CBT) that best describe computer centred teaching (Opitz, 1998) (Alessi and Trollip, 1991). To further support these technologies, educational advancements steered towards aiding student learning beyond the classroom. CBT and CBI were now supported by computer-aided learning (CAL). Computer-Aided Learning (CAL) and eLearning (via LMS) best describes computer learning technologies that allow students to learn at their own pace in an online environment. Computer Assisted learning (CAL) has become significant especially at the beginning of the 21st century.

Internet technology has made it possible to place educational content in an online environment, accessible from any internet-enabled computer (Muirhead, 2000). The Internet benefits educational endeavours by including many delivery methods in a graphical user interface. Educators could now enhance their lectures via a Learning Management System (LMS) (D'Antoni and Savage, 2009). Other research endorses that multimedia methodology will have maximum effect for the provision of training in technical areas (Mishra, 2009). Furthermore, it has been advocated that ideal student learning happens when an assortment of teaching approaches are used (Bell and Fogler, 1995). Pedagogically, it may be problematic to deliver training on the Internet because of download times, feedback, response times and maintenance (Gibbings and McDougall, 2005).

2.9 3D in Engineering Education

Graphical display of educational materials (images and text) became possible with computers over the years (Adeli and Adeli, 1988). Computer advancements have allowed for multimedia content to be displayed in traditionally 2D to now in 3D format without compromising the quality of the displayed graphics and accompanying text (Chen *et al.,*, 2011). The animation of the 2D and 3D content ultimately became possible as technology progressed, making teaching and learning more visually appealing (Young, Ellobody and Hu, 2011).

Another dimension to the teaching and learning processes is interaction with the visual media (Kim *et al.,*, 2011). The use of 3D animated models, simulated surveys, videos have improved the way surveying lectures are delivered (Ustinova *et al.,*, 2012). These all assist with teaching students and help them to learn.

3D animated models created with various software packages has been used successfully in engineering education (Alnaseeri, Alfalahi and Alzidi, 2014). Lecture delivery and student learning have benefited by the use of 3D technology. With 3D animated models displayed via a computer interface, lectures now have the potential to become more interesting and learning, more interactive (Bieszke, 2011). With advancements in internet and computer technology users can explore and manipulate 3D interactive virtual environments in instantaneously (Kamath and Kamat, 2013). This technology is advantageous because of the degree of realism of rendered objects and the feeling of reality experienced by users (Sampaio *et al.,*, 2010). This study does not propose a fully immersive student experience as exposure is limited to class lessons and online videos created within SketchUp.

A combination of class 3D lessons of equipment animations and field work simulations and hoped to solicit maximum educational benefits. This study will attempt to use a similar approach by developing 3D digital models of surveying equipment, displaying them during lectures, and making these models available online via a LMS.

2.9.1 3D in Civil Engineering Education

Civil engineering education has benefited from the use of the capabilities of 3D software (Widder and Gorsky, 2013). Researchers at the Colorado state University created 3D models to aid students to visualise complex course material in construction management education (Glick, Porter and Smith, 2012). Recent developments in Building Information Modelling (BIM), has allowed civil engineering professionals to visualize and manage projects in a 3D and four-dimensional (4D) environment (Hartmann *et al.,*, 2012). BIM has been successfully implemented in tertiary project management education (Forsythe, Jupp and Sawhney, 2013).

Other developments in civil engineering education include 3D game development to simulate a construction project prompting students to make decisions (Bargst *et al.,*, 2005), (Sherif and Mekkawi, 2010). Simulated game environments can also be developed to teach students about construction site safety (Lin, Son and Rojas, 2011).

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2.9.2 3D in Surveying Education

Video display of surveying field procedures to introduce students to surveying equipment and related field procedures has been documented in research (University of Leeds, 2006), (Lam, 2008). These innovative methods benefited lectures and assisted students understanding of difficult to understand surveying concepts and field procedures (Ustinova *et al.,*, 2012).

To learn how to design survey networks was facilitated by the development of a web-based simulator (Shortis and Woodhouse, 2001). A study done by (Gibbings and McDougall, 2005), proved that equipment simulators improved the competencies of the participants. Researchers at the Tokyo Denki University developed a web-based 3D surveying simulator to teach students how to operate surveying equipment (Yoichi *et al.,*, 2006).

The National Taiwan University developed SimuSurvey to teach students about surveying via virtual surveying instruments (Lu, Kang and Hsieh, 2007). This online software allowed students to manipulate virtual surveying instruments before being exposed to the actual version. Figure 8 is a screenshot of the user interface available for user manipulation. This computer simulated environment allows for users to manipulate models in three-dimensional scenes, so that surveying tasks can be visualised. The navigation through 3D space is provided by a controller manipulated by the user. The different views include top, front, right or perspective view as per user input. The ability to view the surveying equipment from multiple perspectives also assists during class instruction, where difficult surveying concepts can be explained.

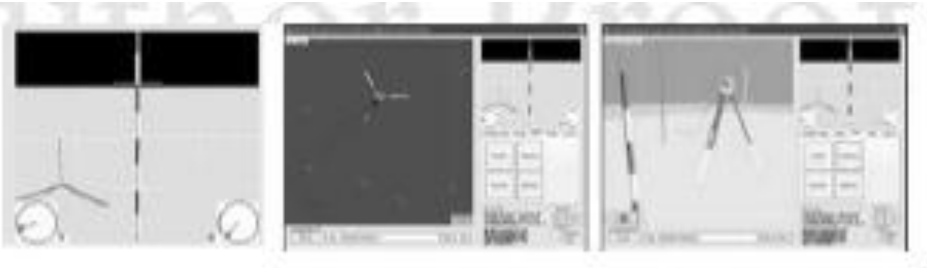


Figure 8. Snapshots of SimuSurvey (Lu et al, 2007)

Figure 9 shows what the user will see through a typical theodolite telescope. This option in SimuSurvey is particularly useful as aiming at a target is one of the most important skills that an observer must master. Additionally, observers must correctly bisect the target so that accurate readings can be booked. The ability of SimuSurvey to mimic actual field procedures assists student learning. This study documented the improvement in student learning, and feedback from students and instructors allowed improvements to be made to the original software.

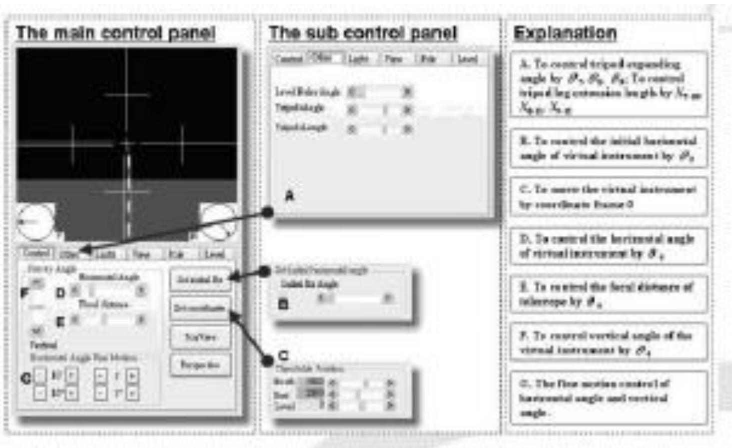


Figure 9. The SimuSurvey user interface (Lu et al, 2007)

Further development of the software based on user and instructor input resulted in the improvement of SimuSurvey and was subsequently renamed SimuSurveyX (Lu *et al.*,, 2009) (Visualization Laboratory, 2011). This software was developed with the Microsoft XNA programming Language (Microsoft Development Network, 2013).

Research at the Nottingham University has shown that first year students generally have difficulty with the operation of surveying equipment, due to the normal lecture method inadequacies and large class numbers (Roberts and Gray, 2009). In response to this they have developed an online computer teaching and learning system to address this problem. In 1999, they originally developed an online learning training system in order to enhance student learning of surveying equipment operation and field procedure. This software was known as SurCal and was developed in-house with the assistance of a dedicated team (Roberts and Gray, 2009). Figure 10 shows the lesson created within their in-house software SurCal showing students the different parts of the theodolite.

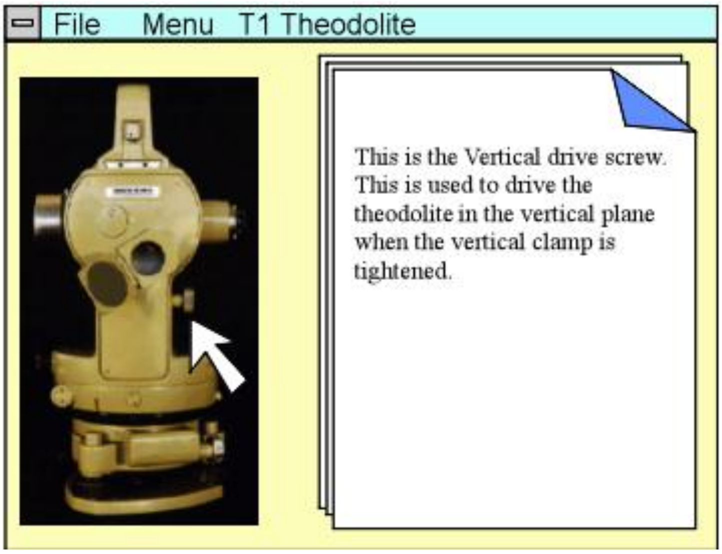


Figure 10. The online SurCAL tutor for learning the theodolite (Roberts and Gray, 2009)

This teaching and learning system used (2D) models of surveying equipment, that were displayed in online environment, mimicking actual practical conditions, is depicted in Figure 11.

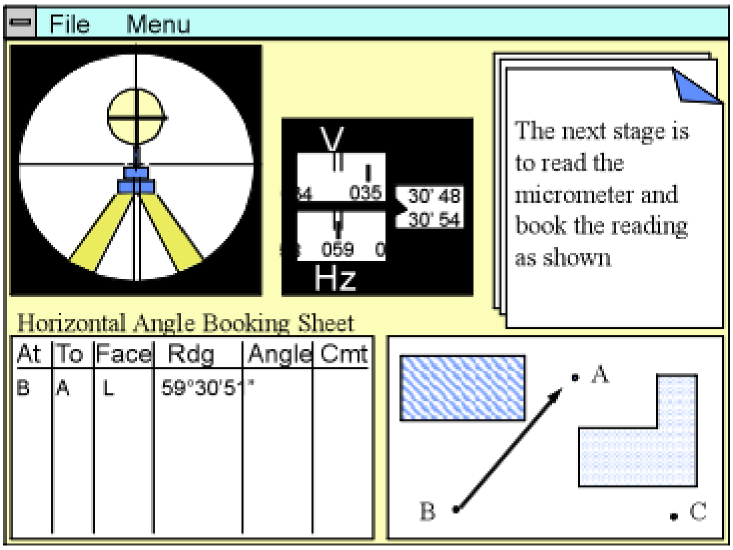


Figure 11. The SurCAL lesson about measuring and reducing angles (Roberts and Gray, 2009)

With further developments in computer and internet technology the original system was improved using Xerte, software developed at the University of Nottingham (University, 2013). Xerte is a content authoring tool, which is Shareable Content Object Reference Model (SCORM) compliant for creating LMS lessons (Wirski, Brownfield and Oliver, 2004). An example lesson about the use of the automatic level that was created with the Xerty software is shown in figure 12.

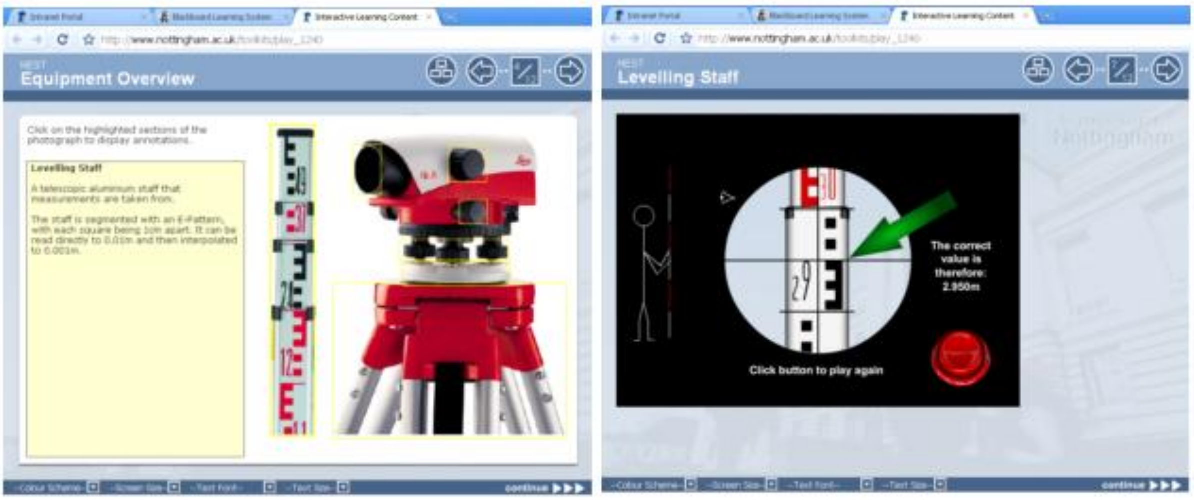


Figure 12. The NEST lesson about using an automatic level (Roberts and Gray, 2009)

These systems are unique to the Taiwan and Nottingham Universities and will not be totally duplicated for this study. They had dedicated programmers and a team of researchers working on their respective projects, not available for this research.

Lessons learnt from the studies above; indicate that the inclusion of 3D models and animation in these teaching environments has met with some success in teaching and learning. However, a similar approach will be used in this research where 3D models of surveying equipment will be created and their operation demonstrated via the 3D modelling and animation capabilities of Sketchup (Sketchup, 2013). The surveying equipment that will be modelled includes theodolites, automatic levels, tripods, levelling staves, ranging rods and tri-stands. These 3D models would then be animated to demonstrate their correct operation via a simulated survey during lectures. These animated models will also be available for students as lessons and videos via Moodle, so that they can learn at their own pace (TechTarget, 2013). Many subjects have benefited from computer aided teaching and learning tools, and these tools have been used successfully in academic institutions both locally (Africa, 2013) and internationally (Costa, Alvelos and Teixeira, 2012).

An important aspect of this research was the development of the 3D animated models. The following chapter documents the development of this teaching tool developed within SketchUp. The choice of SketchUp involved experimenting with a number of other freely available 3D software. Sketchup is a freely available 3D modelling software package that has 3D modelling and animation capabilities.

2.9.3 SketchUp in Engineering Education

SketchUp has been used in other engineering disciplines, such as Mathematics where the spatial ability of student teachers was attempted to be improved by researchers at (Kurtulus and Uygan, 2010). Sketchup is a freely available software that can be used in Mathematics, Physics and Chemistry (Asunda, 2011).

SketchUp has been used in civil engineering education to assist lecturers to explain various civil engineering concepts that would be difficult to explain without visualisations (Hong, Yang and Wang, 2008). The development of a fast remedial course to improve the spatial abilities of civil engineering students was developed within SketchUp software (Martín-Dorta, Saorín and Contero, 2008). 3D models created within SketchUp was successfully implemented to aid students to visualise the construction management process (Glick, Porter and Smith, 2012).

SketchUp has also been used in surveying education to assist with students to understand surveying measurement, especially when applied to site surveying. Researchers at the Northumbria University, developed 3D models from 2D drawings, after realising that students has difficulty understanding the surveying concepts based on 2D plans (Horne and Thompson, 2007). They incorporated the 3D models in their Powerpoint presentations during lectures.

2.10 Summary

Irrespective of the period and the surveying equipment used, the operator had to demonstrate a high level of competency to ensure that the design intent was realised. No matter the time period or equipment used, the operators had to demonstrate the required competencies to produce accurate results.

Advancements in technology have made the life of the surveyor easier, but still require a certain level of competency to use such equipment. These advances in technology require that surveyors are better trained in an extensive field of science than the surveyor in the past. There are disadvantages to technological advancements namely; the replacement of skills, automation of certain tasks reserved for certain qualified surveyors. Today’s professional must be equipped with a wide range of technical skills to compete in this fast growing discipline.

The latest surveying technology has taken the mundane task of field measurements away from the surveyor. However, current surveying equipment requires a professionally registered surveyor to possess more skills and competencies in a wider range than ever before. Although current surveying equipment has almost automated the entire surveying process, the surveyor must still consider all factors that could affect the produced results. The basic surveying principles of independently checking all work, not accepting any result as final until checks have been done must not be lost. The qualities of a competent surveyor must be evident. The principle of working from the “whole to the part” must still be implemented, especially when working over large areas as is possible with today’s technology.

Technology has freed the surveyor of many tasks with regard to field work. The time in the field has also been reduced. A surveyor can now accomplish more in a short space of time. This freeing up of time creates an opportunity to become proficient at more complex computer applications.

To accomplish a surveying job still requires the surveyor to choose the optimal equipment that will be best suited. The amount of data collected in the field has increased tremendously, shaping today's surveyor into export data management professionals. The software available to process this vast amount of information has also become more complicated. There are also multiple configurations of equipment necessary to complete a survey. The understanding of how this integration happens can become demanding upon the surveyor.

Knowledge is power, and is translated into professionally produced surveys by keeping up to date with the latest technology. Technology will only serve its intended purpose if it is used appropriately. All the latest equipment in their apparent simplicity to use can become complicated to maintain. Knowing all potential pitfalls (what can go wrong) has always been the quality of a good surveyor.

Chapter 3: Development of the Teaching Tool

3.1 Introduction

This chapter documents the development of the teaching tool created within SketchUp™ software. Included in this chapter are freely 3D modelling applications tested by the researcher, and the reasons for choosing SketchUp™ software. The development of a teaching tool must take into account the pedagogical concepts deemed essential to provide a benefit to educational outcomes (Salazar, Polat and Almeida, 2003). The teaching tool was evaluated to determine if there indeed was an educational benefit to students, by comparing the competency test results of control and experimental groups. Additionally a Likert-type scale survey was developed to gauge the participating students' attitude towards the educational intervention.

The development of the teaching tool began at the end of 2011 and was completed in the first semester of 2012, so that the teaching tool could be used during the second semester of 2012. The teaching tool remained essentially the same throughout the study period, ensuring consistency in lecture delivery across the experimental semesters.

The development of the teaching tool involved the following stages.

1. Selection of appropriate 3D modelling software
2. Photographed and dimensioned surveying equipment
3. Creation of the 3D models
4. Creation of the DTM from Digital Terrain Model (DTM)
5. Animation of 3D models (Tripod, Theodolite, Automatic Level)

The development of this educational tool involved satisfying a number of educational objectives. When the teaching tool was originally created, the following list of pedagogical goals was envisaged.

1) Virtual 3D models of surveying equipment to resemble actual equipment.
2) Animated 3D models to mimic actual field procedures
3) 3D visualisation within lecture environment
4) Lecturer as facilitator

In addition to the educational objectives, the basic functions of the teaching tool were developed such that actual 3D representations surveying equipment could be developed within SketchUp™ software. The developed 3D models could then be animated so that the replication of field procedures could be mimicked.

3.2 Types of freely available 3D Modelling and Animation Software

There are many open-source, free, and commercially available 3D modelling and animation software packages that have had an impact on civil engineering education (Perdomo *et al.*, , 2005), some purely geared towards 3D modelling and others with a combination of both 3D modelling and animation capabilities. Table 1, lists some of the 3D modelling and animation software that the researcher experimented with to investigate the best software for the development of the teaching tool. All software listed in Table 1, were downloaded and tested by the researcher and evaluated mainly based on their 3D modelling and animation capabilities.

Name	License	Website
K-3D	Free	http://www.k-3d.org/
Blender	Open-Source	http://www.blender.org/
SketchUp	Free\Commercial	http://www.sketchup.com/

Table 1. 3D Modelling and Animation Software Tested by Researcher

The first 3D modelling and animation software tested by the researcher was K-3D. This software is relatively easy software to use with powerful 3D modelling tools; however, the researcher experienced limited animation features. The animation capabilities were not powerful enough to meet the visualisation objectives required for the teaching tool development. Animation was considered as a critical part of the teaching tool development, as the animation of some surveying equipment required complex movements, so the researcher investigated other 3D modelling software to achieve this.

The second 3D modelling and animation software evaluated by the researcher was Blender 3D. Blender 3D is a modern and extremely useful open source 3D modelling and animation software with some advanced features found in commercial packages (Gomide, Flam and Araújo, 2011). These attributes make it also one of the most difficult software to master. To realise the full benefits a user must master the basics and advanced features. The user interface is daunting at first start-up and can become intimidating for the first time user; however with practice the visual interface is easy to use (Bacone, 2012). The researcher experimented with this software (version 2.60) after viewing video tutorials and other online help. After a few days of experimentation, this software was abandoned because of its huge learning curve and complicated user interface.

The third 3D modelling and animation software tested by the researcher which was SketchUp, which was eventually chosen because it had superior 3D modelling and animation capabilities as compared to the other software packages tested. Additionally, its ease of use, small download size and compatibility with a range of operating systems made it the ideal software (Chopra, 2012). Finally, the extensive user community, access to the online 3D warehouse and availability of free plug-ins that were developed by users made it relatively easy to learn in a short space of time. It has frequently won awards for its novel design and flexible implementation (Murdock, 2009). This flexibility is a result of its ability to allow plug-ins that can be added to extend its already extensive tools list (Scarpino, 2010).

3.3 A brief history of SketchUp

SketchUp was developed by @Last Software in 1999 and released in 2000 (Singh and Nieman, 2010). Google bought SketchUp in 2006 (Simpson and De Paor, 2010); (Chopra, 2011a), and later sold it to Trimble in 2012 (Boggs, Dordevic and Shipley, 2012). Trimble subsequently updated SketchUp in 2013, however, this was just a change of ownership exercise as no new functions were added to the then version 8.

During this research, various versions of the software were released since the acquisition by Trimble, however, version 8 was not replaced with the newer version because of compatibility issues with the Proper Animation plug-in. The Proper Animation plugin is available for free download and is compatible with many versions of SkethUp including version 8 used by the researcher (Papasmadov, 2012a); (Chopra, 2011b). The latest version SketchUp was released in 2014 (Sketchup Make), but the researcher decided to remain with Sketchup 8 for feared compatibility issues with the proper animation plugin.

3.4 Development of the 3D Animated Models within SketchUp™

The surveying equipment chosen to be modelled included the tripod, theodolite, ranging rod, levelling staff, and the automatic level. Figure 13 shows the different surveying equipment. The 3D model of the tripod served a dual function (used for both the theodolite and automatic level. Photographs from different perspectives of actual surveying equipment were taken and appropriately dimensioned. The 3D models developed from these dimensioned photographs were drawn to the correct scale within SketchUp. Additionally, a 3D area of the campus where surveying took place was also modeled using SketchUp.

				
Tripod	Thedolite	Ranging Rod	Automatic Level	Levelling Staff

Figure 13. The surveying equipment that were modeled

Appropriate colour was added to all the 3D models so that they could virtually resemble reality. The 3D models were labelled to highlight the important parts necessary for correct operation. Animation to the 3D models was added using a third party add-on called proper animation, to ensure that the operation of the moving parts of the surveying equipment is correctly simulated (Chopra, 2011b). To animate these movements required various rotations about and along defined axes. The defining of the three axes is important when modelling in SketchUp (Brixius, 2010). These axes define 3D space in your model, and are represented by red (X), green (Y) and blue (Z) drawing axes shown in Figure 14. (Chopra, 2012). These axes can be oriented after 3D models are converted into components to specific user requirements.

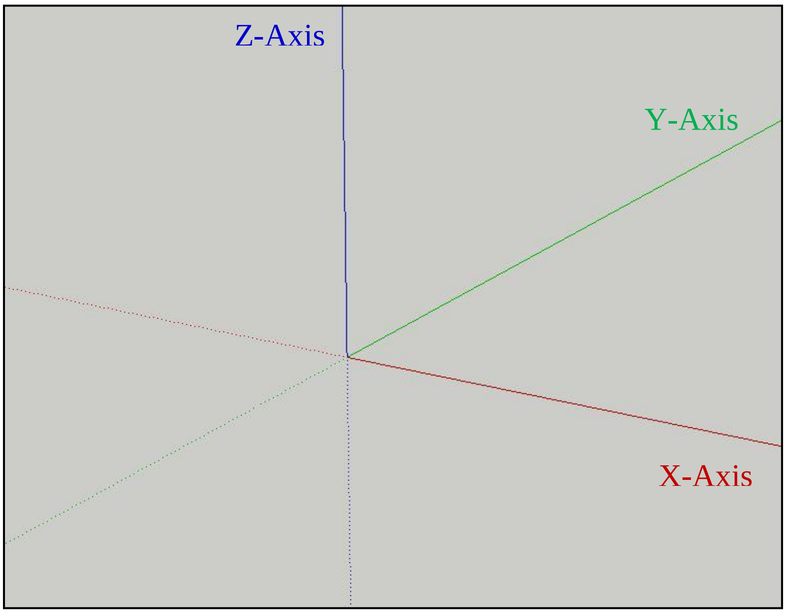


Figure 14. The axes within SketchUp

Additionally, animation added to the surveying equipment ensured that their correct operation could be replicated. Timing and scene transitions were deemed critically important, so tests were done to ensure that the animations behaved in a predictable manner. The 3D models were kept as basic as possible to prevent stagnant animations limited by computer processor speed. The basic 3D model was developed so that no obvious omissions could result in students not recognising the equipment during field practicals.

The modelling of all the 3D models involved the following important steps;

1) Layers used where necessary (organising complex projects)
2) Objects converted to components (prevent object merging and ability to define coordinate (X,Y,Z)

3.4.1 Setting the SketchUp units

The welcome screen of SketchUp (Figure 15), allows the user to choose an appropriate drawing template. The choice of template is important as this will determine the accuracy of 3D models that are developed. The drawing template chosen for this research was the "*Simple Template – Meters*". Although this template is in metres, it was possible to ensure millimetre accuracy when developing the models, as the possibility exists to work to 3 decimal places.

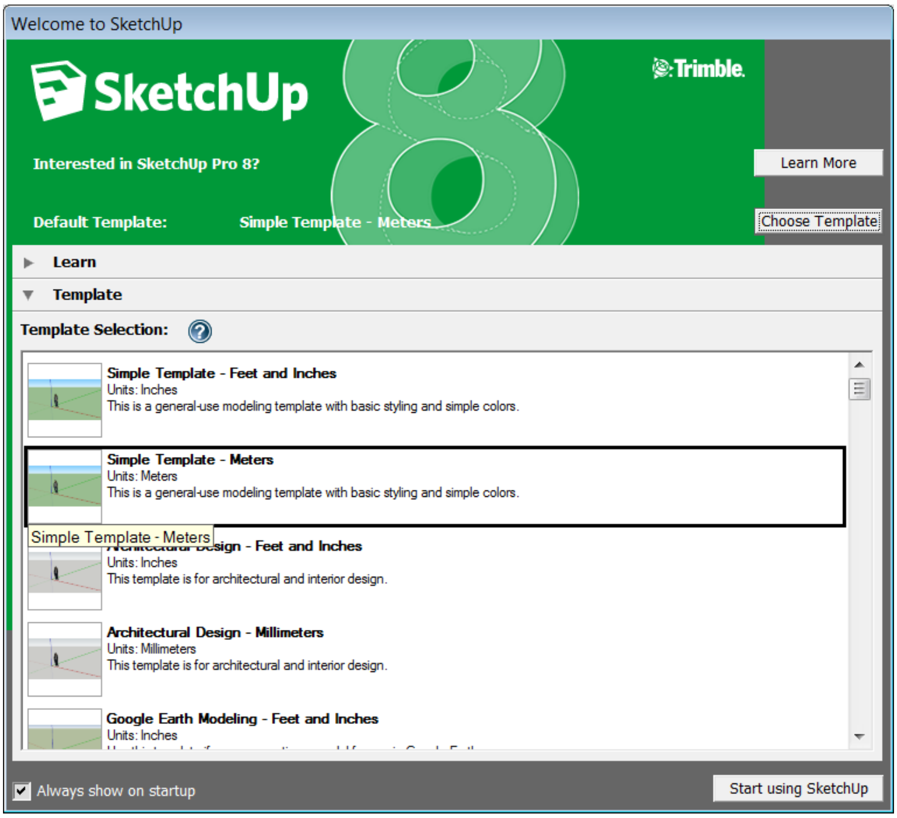


Figure 15. The welcome screen of SketchUp

Sketchup™ software has built-in drawing utilities such as the creation of solid 3D objects that can easily be manipulated to shape according to the users requirements (Haque and Mishra, 2007). The conversion of each of the 3D models into components is regarded as important and has many benefits (Chopra, 2011a). Each modeled 3D object in this research was converted into a component for easy manipulation and for the prevention of 3D objects merging especially in projects with numerous 3D models.

There are also a myriad of viewing options available with regards to viewing the created 3D models from different perspectives and styles. The perspectives that are available from the easy to access view toolbar include isometric, top, front, right back and left views (Stine, 2012). In addition, styles such as x-ray, back edges, wireframe, hidden line, shaded, shaded with textures and monochrome are viewing options, so that the 3D model can be edited easily (Tal, 2010).

3.4.2 The 3D Modelling of the Tripod

The planning started with the development of the tripod. A clear outcome was envisaged where the tripod was to visually resemble the actual equipment that students would eventually use in the field. The tripod consists of three identical legs joined together by a triangular base, where each leg pivots individually. As the tripod consists of three identical legs, a triangle was drawn so that the tripod legs could be equally spaced. The outer and inner tripod legs were modelled and saved as separate components.

	
Digital Photograph	Digital 3D Model

Figure 16. The Digital image and created 3D model

3.4.3 The 3D Modelling of the Theodolite

The theodolite consists mainly of a triangular base (tribrach), and a telescope mounted on two standards ultimately constituting the main body. To capture these main parts, digital photographs of the theodolite were taken from different perspectives and dimensioned as per Figure 17.

Front View	Side View 1	Rear View	Side View 2

Figure 17. Digital photographs of the theodolite

The tribrach of the theodolite was first modelled based on the appropriate dimensions, and also to create a defined geometric centre that the other parts of the theodolite could be centred. This central geometry is critically important for correct rotation about various axes. Each part of the theodolite was modelled as different components and saved on different layers. The establishment of the axis of each component was based on the central location of a vertical line that all components' vertical axes were aligned to.

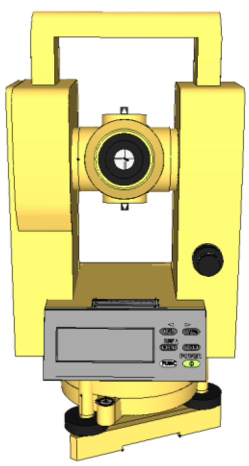
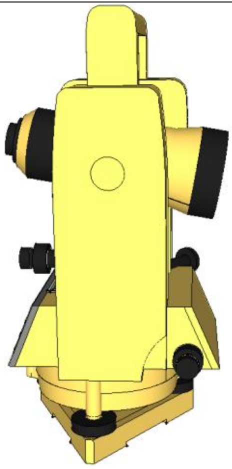
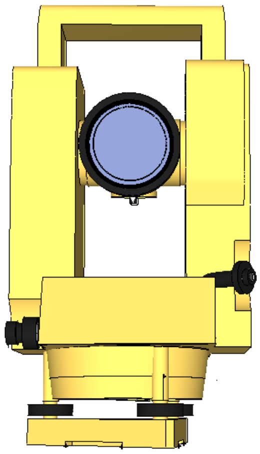
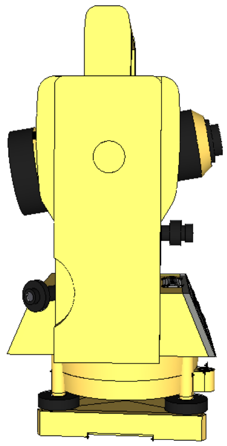
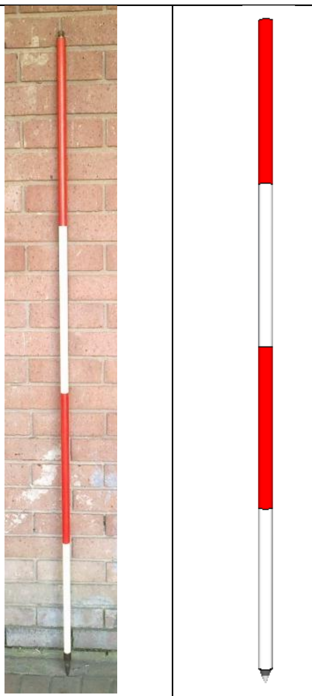
			
Front View	Side View 1	Rear View	Side View 2

Figure 18. 3D models of the theodolite

When viewing objects through an actual theodolite, the observer sees cross hairs. These cross-hairs were also added to the 3D model, to allow for simulated class exercises. Figure 18 shows the final 3D models from different perspectives.

3.4.4 The 3D modelling of the Ranging Rod

The ranging rod is used in surveying for establishing direction when orienting a theodolite (Roy, 2010). A ranging rod is a cylindrical pole consisting of alternative white and red sections for easy visibility when set-up over a control peg (Paul and Whyte, 2012). The bottom (apex) of the ranging rod was first modelled according to the measured dimensions. The alternating white and red sections are 500 millimetres in height and only one section was modelled with the other sections being copies of the first modelled section. The first section after the apex was white, with alternating sections of red and white. The digital image and the final 3D model of the ranging rod are illustrated in Figure 18.



Digital Image	Created 3D model

Figure 19. The Digital image and 3D model of the ranging rod

3.4.5 The 3D modelling of the Automatic Level

The automatic level comprises mainly of a telescope attached to the upper main body, circular bubble, foot-screws, and a triangular base (tribrach) connected to the lower body. The digital photographs of the automatic level are illustrated in Figure 20.

Front View	Side View 1	Rear View	Side View 2

Figure 20. Digital images of the automatic level

These were modelled as separate components so that the telescope and main body could rotate about the vertical axis independent of the lower body and tribrach. Sketchup™ software also has built-in viewing perspectives, allowing the user to view scenes from various angles. The 3D navigation tool also allows the user to manipulate 3D scenes to very intricate degrees. This was especially useful when specific parts of the automatic level were zoomed in. Various automatic parts were labelled. The final 3D model of the automatic level is illustrated in Figure 21. The cross-hairs that are visible when looking through the telescope of an actual automatic level were also added to the 3D model.

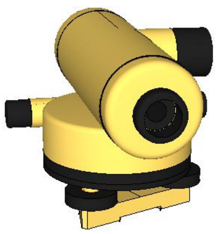
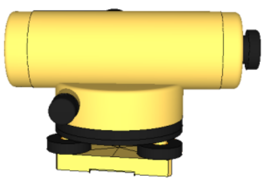
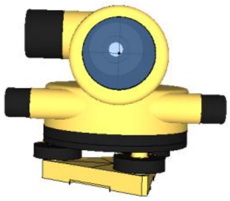
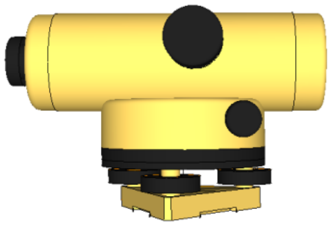
			
Front View	Side View 1	Rear View	Side View 2

Figure 21. 3D models of the automatic level

3.4.6 The 3D modelling of the Levelling Staff

The levelling staff is similar to a ruler which is divided into blocks of centimetres, so that heights can be read to the nearest millimetre (estimated by the observer). The 3D model was created based on the dimensioned digital photograph of the staff. The digital photograph and the final 3D model of the levelling staff is illustrated in Figure 22.

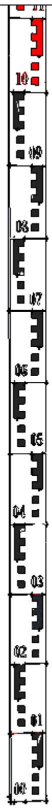
	
Digital Photo	3D Model

Figure 22. Digital image and 3D model of the levelling staff

3.4.7 The creation of the DTM surface

The digital terrain model (DTM) of a portion of the DUT Indumiso Campus was used to create a surface, upon which the surveying equipment was mounted. A DTM is *"simply a statistical representation of continuous surface of the ground by a large number of selected points with known X, Y, Z coordinates in an arbitrary coordinate field"* (Li, Zhu and Gold, 2010).This DTM was imported into AutoCAD Civil 3D 2012 software as a text file and a triangulated irregular network (TIN) surface was created. A TIN model is a variation of a DTM that can visually describe many types of terrestrial information (van Kreveld, 1997). The TIN surface was then exported as a KMZ file that was then imported into SketchUp™ software and placed on a separate layer and an appropriate colour added, as shown by figure 23. Trees were added from Google 3D Warehouse to add further visual aspects (Trimble, 2012).

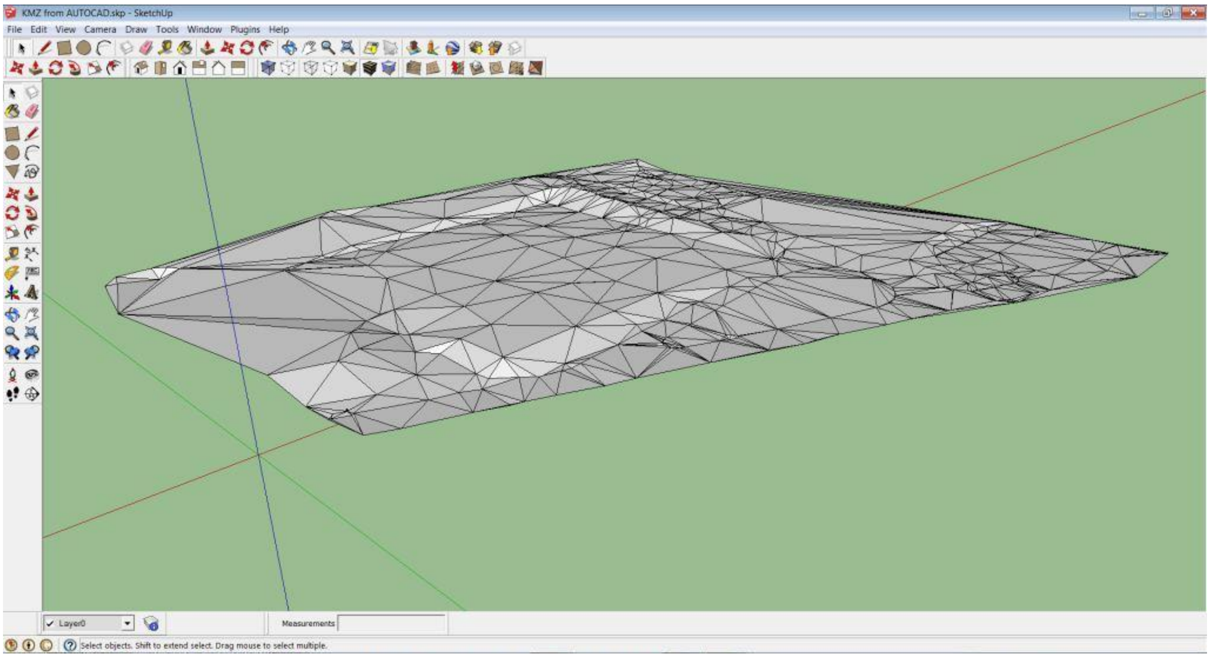


Figure 23. Imported KMZ file from AutoCAD

The DTM surface imported from AutoCAD was then further processed within SketchUp. The triangulated surface was smoothed and an appropriate colour was added. Figure 24 shows the final smoothed DTM surface with tripod, theodolite and tree.

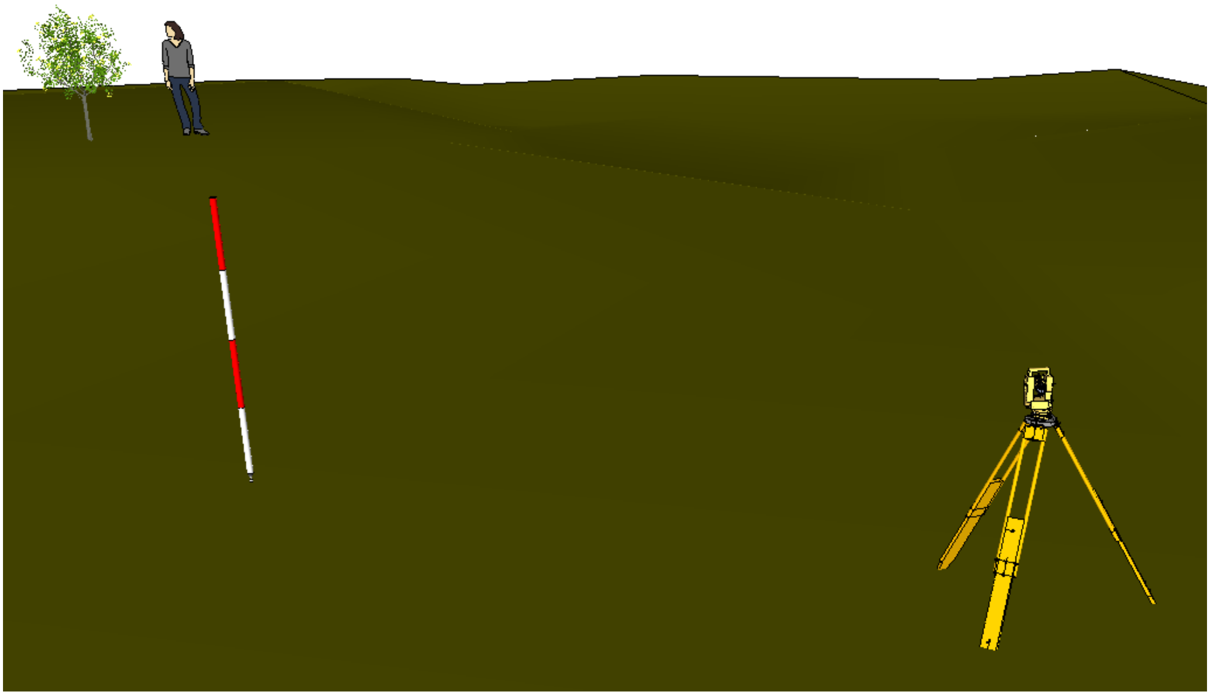


Figure 24. The DTM surface smoothed and colour added

3.5 The Animation of the 3D models

Only the tripod, theodolite and automatic level were animated, with the ranging rod, staff and DTM being static objects. The static objects however, still constitute an important part of the final animation. The ranging rod is used to orient (setting the direction of) the theodolite. Part of the animation includes viewing the models from different visual perspectives. This option adds to the visual dynamics of the animations.

SketchUp has the ability to animate 3D models, and this was initially investigated by the researcher. This animation procedure involves using the scene tabs and layers. This way of animating a 3D model is adequate for simple animation projects, but because the operation of surveying equipment is sometimes very complex, an alternate way was investigated by the researcher. As SketchUp has a huge following, the development of additional functionality such as complex animations is available for download. There are free and commercial options, so the freely available proper animation add-on was chosen after investigating other add-ons. The Proper Animation plugin was chosen as it was easy to install and use.

Proper animation plugin also uses the scenes tabs for animating 3D models, however within each scene complex animations can be done. (Chopra, 2011b). After creating a user account via the sketchUcation website, the Proper Animation plugin was downloaded and enabled within SketchUp (SketchUcation, 2012).

The animation of the 3D models involved the following steps:

1. Selection of all components within the 3D models
2. Save the position of all selected components
3. Individually select component (Isolate component)
4. Move, rotate selected component to desired position
5. Save the manipulated position

The Proper Animation plugin involves the rotation about or movement along a specific axis after the appropriate components are selected. Animation is then added by right-clicking on the selected components and saving this movement within a specific scene (Papasmadov, 2012b).

3.5.1 The Animation of the Tripod

The animation of the tripod involved replicating the movement of each leg along a defined axis. Each leg pivots individually and thus has its own axis and these axes were defined after the individual components were created. The animation was started with selecting the tripod with all legs closed (not extended). The animation involved extending and spreading the legs as required when placing a tripod over a control peg in the field.

3.5.2 The Animation of the Theodolite

The major moving parts of the theodolite after the created components were the telescope and the main body. These major components were all aligned to the Y-axis (green) for horizontal rotations as per Figure 25.

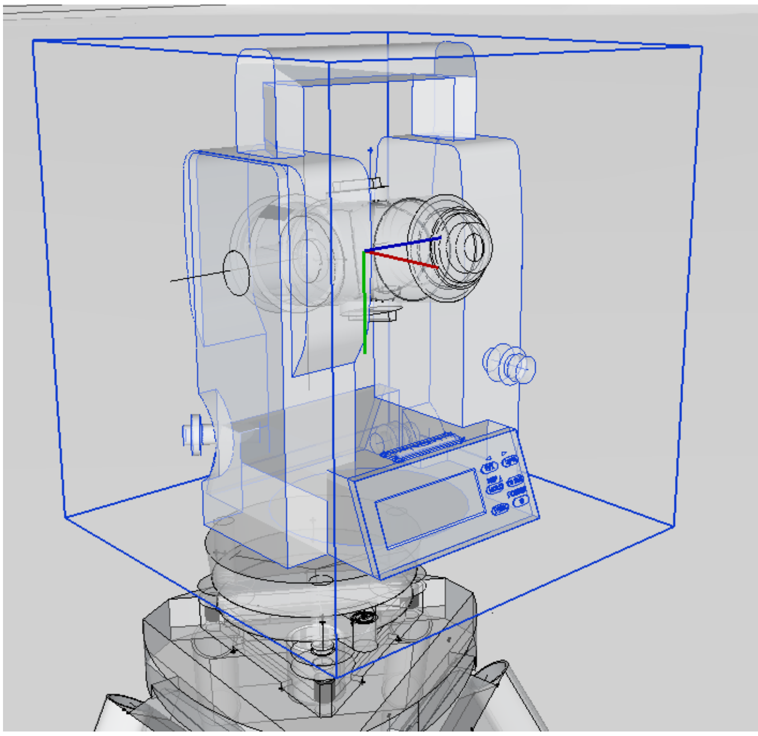


Figure 25. The wire-frame view of the theodolite showing the axes of the main body

After models are converted to components, their axes can be manipulated to suit user requirements. The researcher created a defined centre point of the theodolite main body and vertically oriented the X-axis. The telescope was animated to rotate about the X-axis as shown in Figure 26. Any axis can be chosen as the vertical orientation reference point, as long as there is a defined centre.

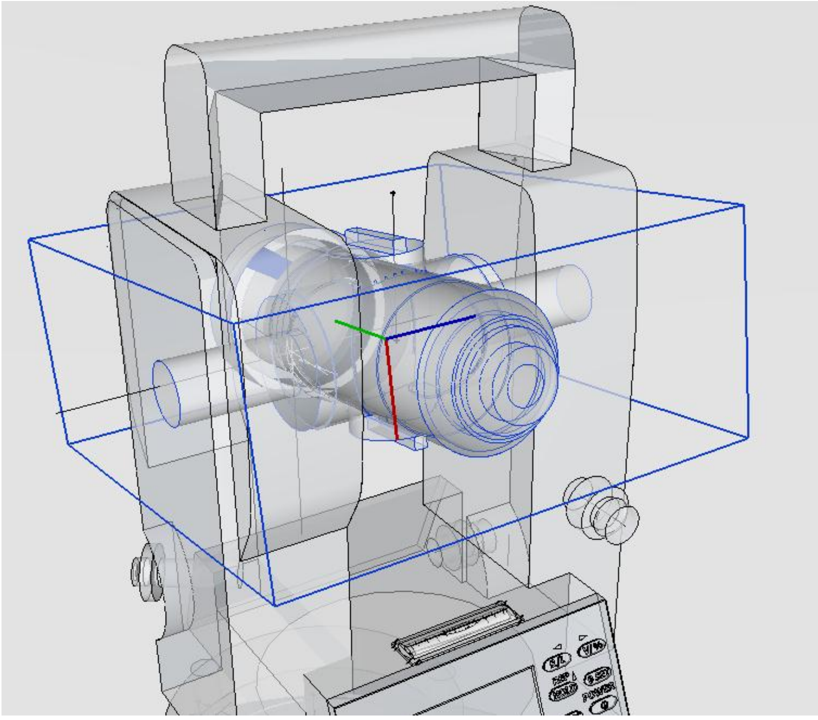


Figure 26. The wire-frame view of the theodolite showing the axes of the telescope

The animation included the actual viewing through the telescope of the theodolite (Figure 27) was made possible to allow students to experience field conditions before they take physical equipment out to the field.

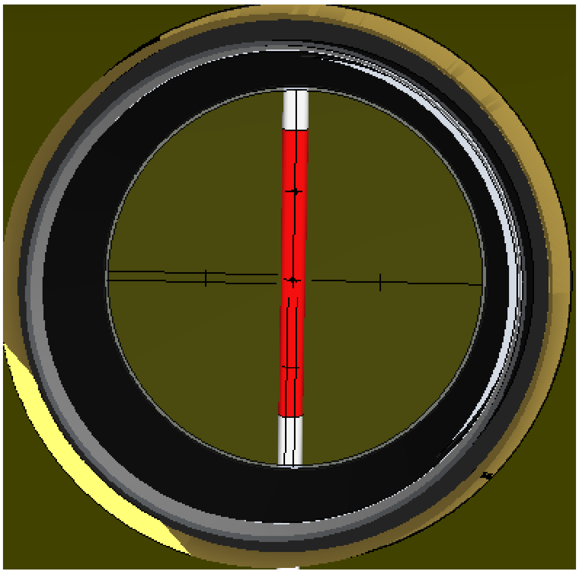


Figure 27. The view through the theodolite telescope

3.5.3 The Animation of the Automatic Level

The major moving part of the automatic level is the telescope that is attached to the main body. This main body rotates horizontally with the pivot point in the centre of the tribrach. The animation therefore ensured that this principle rotation was achieved. Figure 28 shows the wire-frame view, which shows the alignment of the axes to the rotating telescope. This rotation about the vertical axis is important for animations. The telescope was rotated about the X-axis (red).

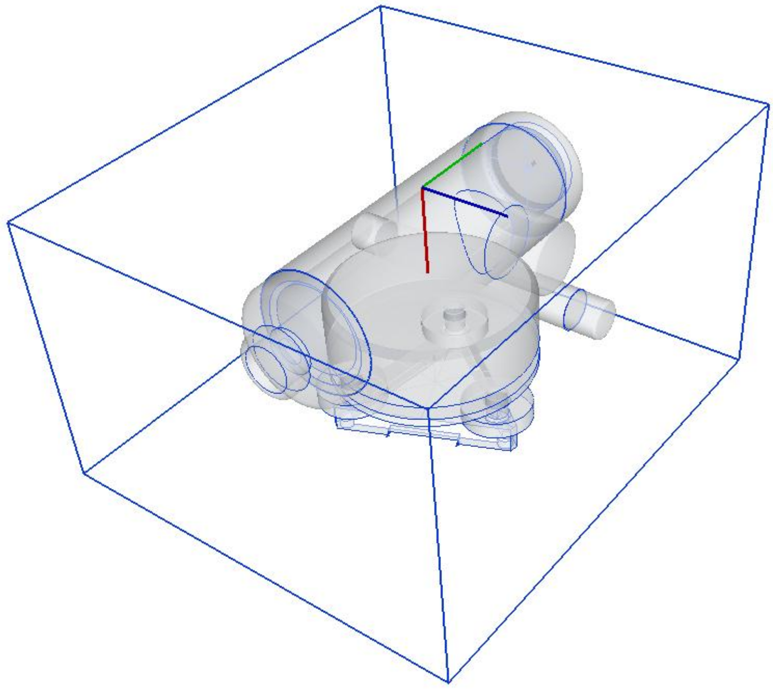


Figure 28. The wire-frame view of the automatic level showing the axes

The animation included the actual viewing through the telescope is shown in Figure 29. Students could then experience field conditions before they take physical equipment out to the field.

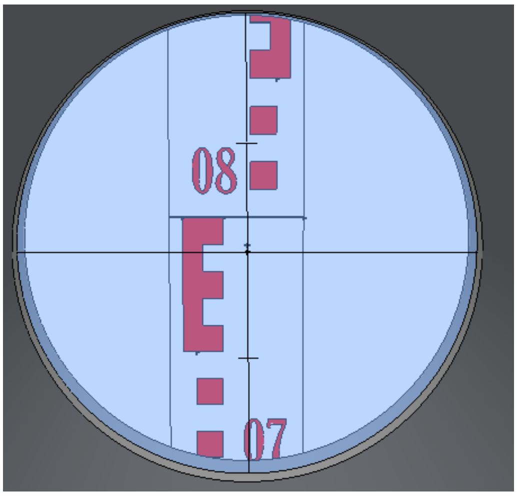


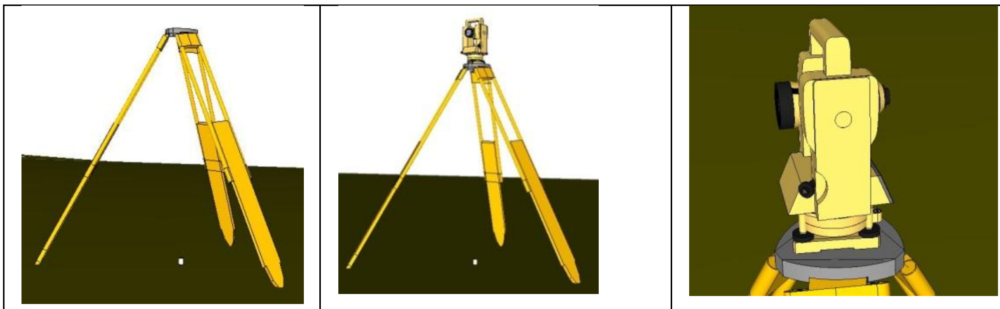
Figure 29. A view through the automatic level telescope

3.6 The use of the Teaching Tool during lectures

The completed 3D models, firstly displayed as static models, were manipulated by the researcher during lectures to teach students the different parts of the surveying equipment. After students became familiar with the different parts of the surveying equipment, they were then taught how to operate the equipment via in-class simulations, with the researcher, demonstrating particular instrument functions. The lessons firstly focused on the 6 skills tests that students are required as part of their assessment. The students were then shown the field application via in-class simulations of field procedures of the 3 practicals that they produce.

3.6.1 The in-class demonstration of the tripod

Firstly the tripod was animated to demonstrate its set-up over a control point. This was animated with text and audio explanations. The set-up of the tripod was then demonstrated in the field during the first week of practical periods. The set-up of the tripod is considered important and was done without securing the theodolite to the tripod. The correct setting-up of the tripod is an important first step to positioning a theodolite over a control peg. The first skills test involves the setting-up of a theodolite, requiring the correct set-up of the tripod. The incorrect positioning of the tripod will negatively affect the final set-up and subsequent data collection. The tripod legs can be extended allowing various height settings based on the height of the observer. Figure 30 shows the major steps involved in setting-up the theodolite.



Extend the legs	Secure theodolite	Centralise and level theodolite

Figure 30. Setting-up of the theodolite (the first skills test)

The other skills tests related to the theodolite include orienting the theodolite, observing an arc of observations and observing vertical angles. All the first four skills test options when linked together, constitute the traverse practical. This link was emphasised during lectures and field applications. Skills tests two, three and four are explained in the next section.

3.6.2 The in-class demonstration of the theodolite for Traverse Surveying

The second skills test involves setting a direction of the theodolite after setting-up of the theodolite. The major steps involved in correctly setting the direction are illustrated in Figure 31.

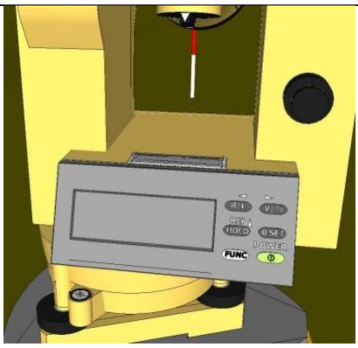
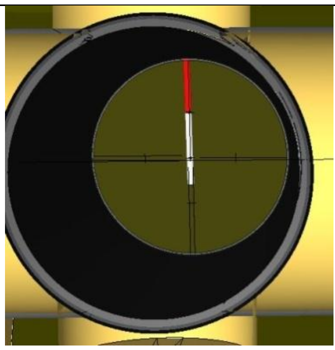
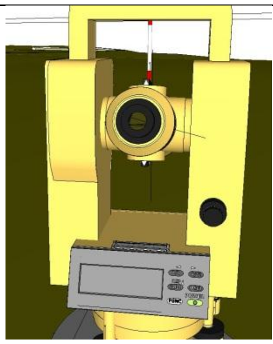
		
Finding the direction on the LCD screen	Bisect the ranging Rod	Setting the Direction by pressing the hold button

Figure 31. The Setting of a Direction (Skills Test 2)

The third skills test involves observing an arc of observations after the direction has been set to the reference ranging rod. Figure 32 illustrates the arc of observations from the plan view perspective.

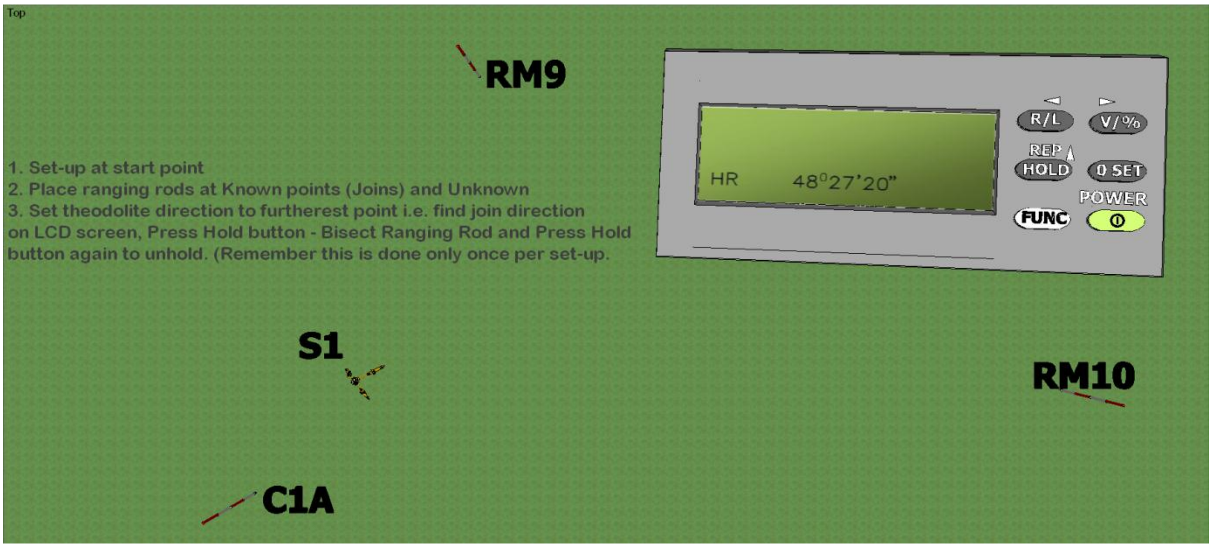


Figure 32. Start of traverse with explanatory text and exaggerated LCD screen

The fourth skills test involves observing vertical angles after the arc of observations were observed at the first set-up. Figure 33 shows the major steps involved with observing vertical angles.

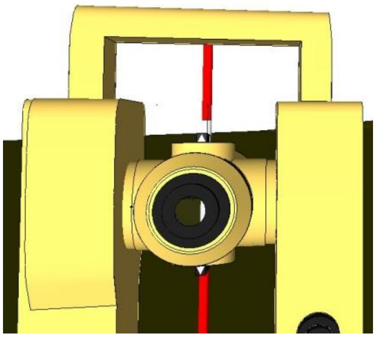
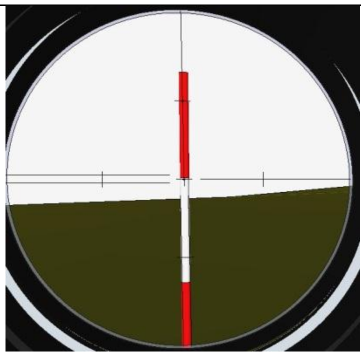
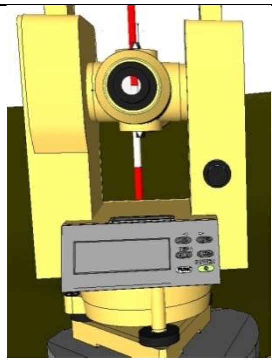
		
Locate Ranging Rod	Bisect the ranging Rod at correct point	Book the first Vertical angle

Figure 33. Observing vertical angles

The first four skills tests are all associated with the initial steps involved in a traverse survey. The setting-up of the theodolite was animated after students learnt about the setting of the tripod both in-class and in the field. Once the setting of the tripod was mastered, students were then taught the various parts of theodolite via 3D models.

The theodolite allows the observer to observe both vertical and horizontal angles whilst looking through the telescope. These observations take place on the horizontal and vertical planes. These two abstract surveying concepts are sometimes difficult to grasp, resulting in the researcher first concentrating on the teaching of the horizontal angles. These lessons were first animated in-class and then demonstrated in the field during practical sessions. Students were then taught via the animations the process followed to orientate the theodolite via horizontal angles.

This involved including the positioning of ranging rods to provide a definite direction and target for sighting. These techniques were demonstrated in-class with students practicing in the field with minimal instruction (conclusion).

The next week of lectures concentrated on teaching students how to securely attach the theodolite to the tripod and centre the instrument of the control peg. All these lessons were demonstrated by the lecture using the virtual 3D animated models. These in-class lectures were followed by practical periods further demonstrating the setting-up of the theodolite with students practising with the researcher.

In addition to the use of the theodolite, a demonstration of the field application of the theodolite was also shown via the virtual 3D animated models. These demonstrations included setting the oriented direction before observations could be booked in a traverse fieldbook. This simulated survey was done as a class exercise with students booking the observations displayed on the virtual image. Animations were paused to allow for such in-class interaction.

3.6.3 The in-class demonstration of the Theodolite for Tacheometry Surveying

The fifth skills test involves collecting information via tacheometric means, for the production of a plan. For these tacheometry observations, the theodolite is also used, in conjunction with the levelling staff. Figure 34 illustrates the major steps involved in observing via tacheometric means.

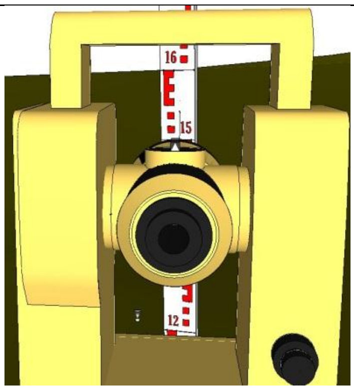
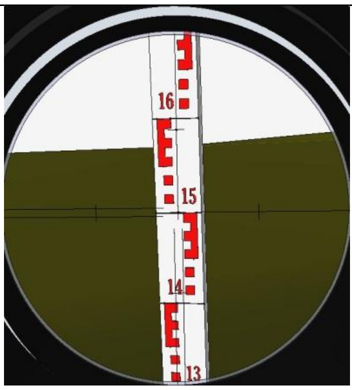
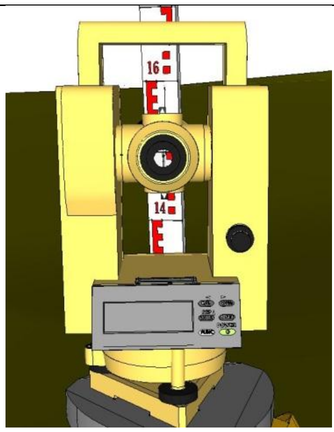
		
Locate the staff	Bisect the staff	Booking the necessary information

Figure 34. A Tacheometry observation

3.6.4 The in-class demonstration of the automatic level

Levelling involves the determination of height difference between two points. The animation of the automatic level involved demonstrating this important aspect. Figure 35 depicts the position of the automatic level in relation to the levelling staves.

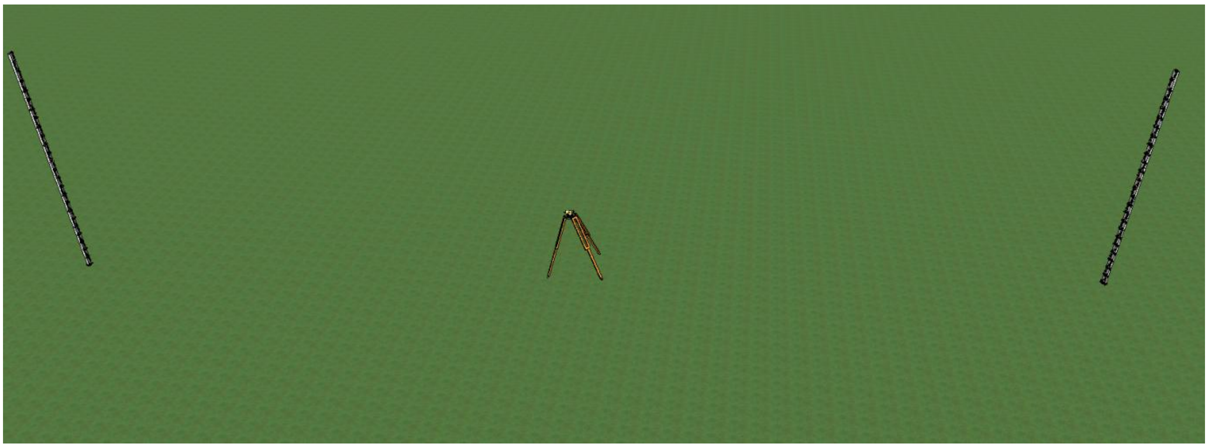


Figure 35. The Automatic level and staves

These in-class lectures of the virtual 3D animated models were repeated for the next levelling project, where the use of the automatic level was demonstrated in class. Firstly, the important parts of the level were shown via labelled 3D static models. These models were manipulated by the researcher to show the automatic level from different visual perspectives. The ability to view 3D models from different visual perspectives is one of the great features of SketchUp^{TM} software. Figure 36 illustrates the major steps involved in observing through an automatic level.

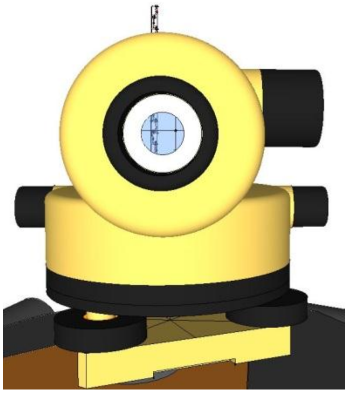
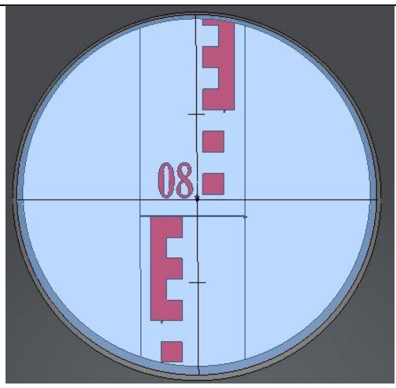
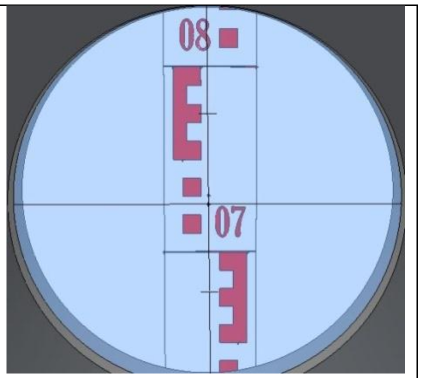
		
Locate the staff	Staff Bisected and First Obseravtion Booked	Staff Bisected and Second Obseravtion Booked

Figure 36. A levelling observation

3.6.5 Summary

This chapter documented the process involved in the development of the 3D animated models used to teach students in a classroom environment, how to use the theodolite and automatic level. The field work was a continuation of what was taught in class, and is thus an important part of this research. It will be investigated if the in-class lessons coupled with the field application contributed to students learning. The next chapter aims to describe how this teaching tool would be tested quantitatively for its effectiveness.

Chapter 4: Research Methodology

4.1 Introduction

Chapter 3 outlined the development of the 3D animated models of the surveying equipment. The development of the teaching tool is also an important element of the research methodology.

This chapter highlights the research design and methodology adopted, to answer the research objectives by reflecting on the basic theories that form the groundwork for educational research. There are numerous philosophical theories about research paradigms; however the most relevant philosophical theories applicable to this research are positivist and constructivist in nature.

Two of the main objectives of the research were to determine if Sketchup software has had an influence on students surveying competence, and whether the created 3D animated models of surveying equipment allowed students to learn faster. Only quantitative paradigms were deemed necessary to satisfy the main research questions.

The first section of this chapter explains the research design and highlights how the research objectives will be answered. The next section outlines the strategy of the chosen research design, with reference to research techniques and instrumentation. The final sections include data collection, ethics and analysis, validity and reliability of the results.

4.2 Research Design

The selection of a research design is extremely significant as it impacts on the total outcomes of the study (Crotty, 1998); (Miller and Salkind, 2002). When a research project is designed, a list of steps to be followed is developed for collection of evidence and the eventual data analysis (Vogt and Johnson, 2011) An appropriate design organises the research in an easy to follow order that guides the researcher to effectively respond to the research problems and the research questions. This makes a properly designed research one of the most vital elements of the research methodology (Creswell, 2012). There other methods to consider in the research design namely; quantifying the variables, data collection, formulating a sampling strategy, and planning the data analysis process (Salkind, 2010).

A researcher is guided by theoretical assumptions where he or she is able to expand on certain occurrences being studied (Kerlinger, 2011). To understand a phenomena and unearth the answers to research questions, the development of a research strategy is essential (Schensul, Schensul and LeCompte, 1999). The research design is the research strategy employed for uncovering the truth and satisfying the research questions (Leedy and Ormrod, 2005). The research strategy outlines the chosen approach, research instruments, sampling procedures and the analysis of the data (Ary *et al.,*, 2010). The first part of outlining a research strategy is to locate a particular research within a research paradigm. In the case of this research both experimental and interpretive designs were used to analyse data quantitative means. The single-phase approach was deemed necessary to answer the objectives of this research.

Yaremko, (1986), stated that an experiment is the manipulation of one or more independent variables so that their influence on one or more dependent variables can be observed. In an experiment the researcher manages how the treatment will be applied (Kelly, 2004). In addition, an experiment can also be referred to as an examination of the effects of a purposefully introduced intervention (Shadish, Cook and Campbell, 2002). This research will embark on a quasi-experimental approach as all students were exposed to the educational intervention in both the experimental and control groups (Shadish, Cook and Campbell, 2002); (Lund, 2005). Experimental research involves the pre-test and pro-test of randomly selected participants from a given population (Truscott *et al.,*, 2009).

The quasi-experimental design used in this study investigated the influence of supporting lectures of surveying equipment operation via three dimensional (3D) animated models. This was done to determine if the 3D system would improve students' academic achievement. The independent (IV) and dependent (DV) variables were the use of 3D animated models during lectures and student achievement, respectively. Quantitative analysis of students' perceptions about the intervention was investigated with the aid of a 19-point Likert-Type Scale questionnaire.

The study investigated two different scenarios where lectures were enhanced by 3D animated models and the control group where the intervention was not used. By default three semesters where the intervention was not used, was selected as the control group to be compared to three semesters where the intervention was used. Additionally the experimental group were also treated to classroom activities related to the collection of field data. This treatment was deemed necessary to add another element to the 3D animated models, booking of field data as is done during actual field application. Furthermore, students were exposed to the 3D animated models a week before the actual skills testing in an intense two hour session where all six skills tests were shown to students.

Students' perceptions related to being exposed to 3D animated models during lectures were collected via a Likert-Type Scale questionnaire. All students exposed to the educational intervention were selected to be part of this study, as prescribed by quasi-experimental research (Creswell, 2013). Before the actual questionnaire was developed, a pilot study was done to refine the research questions to be used in the study.

The impact of two methods of classroom instruction of surveying equipment operation and related field applications, were compared over relevant semesters. This quasi-experimental research was carried out during the following academic semesters; second semester 2010, first and second semester 2011, second semester 2012 and the first and second semester 2013. No intervention was used over the first three semesters and thus formed the control group. Student achievement from the control group comprising of the first three semesters, were compared to the three semesters where the intervention was used. This data contributed to the quantitative data collection.

4.2.1 Basis for Design Choice

The choice of design was guided by the ability to examine an educational phenomenon experimentally (Seidel and Shavelson, 2007). The comparison of two groups of students' achievement is possible via quantitative analysis (Pickard and Childs, 2007). Quantitative analysis is used in education extensively and was the predominant paradigm for many years (Newman, 1998). The use of quantitative data is also used by the researcher to measure the effect that a particular intervention has on educational outcomes (Skene *et al.*,, 2013).

Qualitative methodologies have been useful in the study of how people make sense of their world and how they reflect on their experiences (Bergman, 2010). According to (Patton, 1990) both quantitative and qualitative methodologies have varied advantages. The quantitative approach facilitates the assessment and statistical collection of often limited data from the responses of numerous participants, allowing for economically, but broadly arranging a set of outcomes (Patton, 1990). The difference with qualitative techniques is that they normally produce more in depth information with less data collected and can back the results of the quantitative enquiry (Patton, 1990). This allows for a broader view and increases understanding of the research (Mercer, 2010). This research however, only employs the quantitative research paradigm as this offers the researcher a more scientific enquiry (Mayer, 2000)

4.2.2 Research Paradigm

According to Kuhn, (1962), a paradigm is a theoretical background mutually agreed upon by a community of researchers for investigating problems and discovering answers. Furthermore, Schensul, Schensul and LeCompte, (1999), states that research paradigms form a theoretical background enables researchers to make sense of the social world. It is the researcher's obligation to classify the paradigm to which a particular research area conforms and is critically important as there are various paradigms with numerous assumptions (Cross, 2000).

Positivism or quantitative, interpretivism or qualitative and critical inquiry, are the three broad paradigms that research must be positioned (Charles, 1998). These major research paradigms are best suited for educational research namely: quantitative, qualitative and mixed methods (Reeves and Hedberg, 2003). Various ways of what is reality and knowledge creation is exhibited, where a specific paradigm favours certain research methods over others (Crotty, 1998).

To fulfil the several objectives of this research, a quantitative methodology was adopted. Quantitative research deals with measurement of a phenomenon through quantitative analysis (Firestone, 1987). This research employed only quantitative research techniques used in educational research to quantify achievement test data (Muijs, 2010).

4.2.3 Quantitative Research Paradigm

The quantitative research paradigm is used to test a hypothesis through mathematical analysis (Cohen, Manion and Morrison, 2013). The quantitative approach is sometimes referred to as the positivist research paradigm and collected data is best analysed mathematically Gunderson and Aliagha, (2002). There are dependent and independent variables (Bracht and Glass, 1968). Quantitative research or the positivist paradigm was popularly used in the 1960's in the social sciences, thereby influencing how educational and psychological research was conducted (Quinn, 2002).

Positivists basically believe that the world around us can be observed and understood quantitatively (Schensul, Schensul and LeCompte, 1999). Mertens, (2009), suggests that this objective of reality may be conceptualized, but cannot be constructed in a social context. Schensul, Schensul and LeCompte, (1999) and Mertens, (2009), state that researchers set in a positivist paradigm conceive the world from a pragmatic philosophy. Furthermore, positivists accept that the social world can be isolated and be measured in a similar way that physical scientists experiment with physical phenomena (Johnson and Onwuegbuzie, 2004). This belief system primarily adopts the view that the scientific method is best suited to discover how the world around us functions (Mertens, 2009).

Educational research was always considered to be within the positivist paradigm, where data is quantifiable, and the conclusions are made about the phenomena from the representative sample of a population (Orlikowski and Baroudi, 1991).

The positivist way of conducting research became unpopular amongst educationalists in the early 1970's (Tashakkori and Teddlie, 1998). The main argument being that education problems are very complex and cannot be solved by traditional experimental methods (Tashakkori and Teddlie, 1998); and (Mertens, 2009). Consequently, the constructivist paradigm was suggested by researchers who believed that after experiencing a phenomenon, humans constructed multiple realities (Schensul, Schensul and LeCompte, 1999); (Quinn, 2002); (Mertens, 2009). This research approach became known as the qualitative paradigm.

4.2.4 Qualitative Research Paradigm

The qualitative research paradigm is sometimes referred to as anti-positivist, originated from German philosopher, Edmund Husselain (Groenewald, 2004). The qualitative approach is a descriptive narrative based on the understanding of a phenomenon from the perspective of those experiencing it (Yin, 2009). This type of enquiry is a researcher's interpretation of an educational phenomenon and is essentially a descriptive narrative (Myers, 1997) (Merriam, 2002). (Glesne, 2006) adds that a qualitative research approach aims to expand the understanding of an educational phenomenon with appropriate data collection. In qualitative research, there are no predefined dependent and independent variables, however, the understanding of phenomena is linked to the research questions (Calabrese, 2009).

To determine students' attitudes towards the 3D modelling software as a teaching tool, a quantitative approach was adopted. A satisfaction questionnaire was developed to gauge students' experience after being exposed to 3D models of engineering surveying equipment. This research is hinged on the quantitative research paradigm, and does not use qualitative data analysis more commonly used in educational research (Johnson, Onwuegbuzie and Turner, 2007). The researcher decided to use only quantitative data analysis techniques as this research analyses student achievement data and student attitudes from quantifiable sources.

4.3 Population and Sampling

According to Brynard and Hanekom, (1997), the objects, subjects, phenomena, cases, events and activities, which the researcher can investigate and find information, is referred to as the population. A sample can therefore be selected from the over-all group that constitutes the total population. A population is a group of possible participants or conditions from which the researcher can gather a sample and the conclusions from the selected sample, can be deduced (Sage Publications, 2003).

4.3.1 Population

Students from the Durban University of Technology Indumiso campus were selected to participate in the study. Although the Durban University of Technology has two campuses, the Indumiso campus was selected because of the access to the previous semesters' information. The consideration of other possible factors that could influence the results was taken into account.

For quantitative analysis this research will include the entire population\cohort of students in each semester pre and post intervention. All potential participants in this study were selected within the chosen population within the study by the researcher, by sourcing the achievement data from the ITS database. Students that were directly taught by the researcher formed the main population from which quantitative data were extracted.

4.3.2 Sample Size and Selection

Quantitative data collection, the participants in this intervention study was the full cohort of students per applicable semesters. Data was collected from six cohorts of students over six semesters. Several cohorts were deemed necessary to achieve validity. The overall achievement test score was the main determining criteria, from the entire cohort of students. The entire cohort of students constituted 333 and 250, consisting of the control group and experimental group respectively.

The objective of this research was to evaluate the effect of teaching surveying equipment operation by the use of Sketchup software on student achievement and attitudes toward this intervention.

4.4 Pilot Study

A pilot study was conducted on a sample of students to refine the developed questions to be used on the final population group. A pilot study with students not used in actual study was used to fine-tune questions for actual participants. This pilot study allowed the researcher also to gain more insights into students' experiences. The students used in the pilot study were not included in the data analysis. The final group of students used were chosen randomly.

Following the pilot study, a randomly selected sample of students who were taught via Sketchup, were asked to participate in an interview. The introductory questions were designed to put the students at ease (Arksey and Knight, 1999). Follow up questions became more specific, but solicited more than just yes or no answers.

A set of semi-structured interview questions was used as the measuring instrument. The venue where the interviews take place must be neutral to ensure that the setting is calm and non-intimidating (Wilkinson and Birmingham, 2003). A brief explanation of study is given to the respondents to put them at ease (Williams, 2002) (Fink and Oishi, 2003). Anonymity of the respondents must be assured, so that they feel comfortable with giving answers (Bradburn *et al.*,, 1992). Interview time must be designed so that the interview sessions are not long, to avoid distraction (Kelly, 1999).

4.5 Data Collection

This research employed a quantitative research methodology, where student achievement data was collected experimentally and a perception survey via a Likert-Type Scale Questionnaire. Quantitative data is collected through observation or experiment and/or reliable measurement (Schensul, Schensul and LeCompte, 1999).

Data was collected in the following semesters where the intervention was not used and the assessment rubric (Appendix A) remained the same.
Data was gathered using the following methods:

1. All previous students skills test achievement where no intervention was used
2. All previous students skills test achievement where the intervention was used
3. Likert-Type scale data about students' attitude towards the intervention collected via developed 5-point, 19 question questionnaire
4. Open-ended questions to gauge the perceptions that students have regarding the educational intervention gathered as part of the questionnaire

Two data collection instruments; were compared to see if the exposure to 3D animated models had a significant influence on the overall competency. The first measuring instrument involved the comparison of student achievement from 6 cohorts of students. Three cohorts were the control group and the other three cohorts where the intervention was applied.

The second measuring instrument was a group interview consisting of semi-structured, open-ended questions. The questions were developed to address one of the research objectives regarding the usefulness of the intervention as a teaching tool, and the effect on students' understanding. The first two data collection methods served to provide quantitative data and the third data collection method provided qualitative data.

Quantitative data collection and analysis techniques formed the basis of how educational research was conducted to reveal a phenomenon and answer the research questions. This research approach has dominated educational research for decades (Elliott, 1996). However, the qualitative paradigm has also been considered an alternative, but not a replacement for the quantitative paradigm (McMillan and Parker, 2005). Recent studies have advocated a combination of these approaches, known as a mixed methods approach. This study however uses the quantitative approach as this has been the main research paradigm used in educational research, before qualitative research emerged in the 1970's.

4.5.1 Experimental Quantitative Data

The key data collection method was the pre and post student achievement. The collection of this data was for quantitative data analysis of student achievement compared over 3 semesters where the educational intervention was not used in subsequent semesters where the educational intervention was employed. All students who were tested in the control and experimental groups were included in the quantitative analysis. There were 281 and 219 in the control and experimental groups respectively. A total of 3 and 6 zero values were removed from the control and experimental groups respectively. These zero values constituted students who were registered, but were not assessed. The removal of these zero values result in 278 and 213 students' competency test data the control and experimental groups respectively.

Additionally a 5-point, 19 question Likert-scale questionnaire was also administered and analysed quantitatively to determine students' attitudes towards the educational intervention. This questionnaire was developed by the researcher from a pilot study and in consultation with five staff members' who were asked to comment on the format of the questions. The basic questions were developed by the researcher with input from the pilot study and fellow lecturers. Only 89 of the 213 questionnaires were returned totalling a return rate of 42%, but 6 of these questionnaires were not included in the analysis due to incompleteness. This resulted in a total of 83 completed questionnaires that was used for analysis.

4.6 Data Analysis and Interpretation of results

The collection of data is just the beginning of research. According to Vithal and Jansen, (2012), the systematic organisation of the collected data into easy to deal with sections, the researcher can then make sense of the data. What follows is the processing of the information to answer the research questions. To effectively process the data, coding is necessary by sorting into comprehensive manageable segments.

The collected student achievement scores pre- and post the intervention were gathered and entered into a spreadsheet for further quantitative analysis. Before the interpretation of the results, statistical confidence levels to prove or disprove a hypothesis, were formulated.

According to Babbie, (2007), quantitative data analysis is the mathematical description and manipulation of interpretations for the explanation of a phenomenon. The student achievement data was analysed using the statistical capabilities of SPSS version 22.

An essential element of data analysis is the methodical quest for significance in the collected data (Hatch, 2002). The researcher condenses, arranges and examines data which ultimately leads to further explanation and interpretation (Hatch, 2002). In this study quantitative data of student achievement before and after an intervention and open-ended questions were collected; and thus two methods of data analyses were used.

4.6.1 Statistical Analysis of Research Questions

The first research question investigated the influence that the 3D animated models of surveying equipment had on student competency results. To answer this, the developed null-hypotheses aimed to compare overall competency results. To answer this hypothesis, the comparison involved comparing the combined results of control group versus the combined results of the experimental group. The null hypothesis was tested statistically using the Mann-Whitney U test, as the competency test results were independent and nonparametric (Corder and Foreman, 2009). This test was chosen because the data distribution was not normal according to the Kolmogorov-Smirnov and Shapiro-Wilk tests (Hollander, Wolfe and Chicken, 2013).

To answer the second research question that investigated if individual competency tasks (task 1 to 6) showed an improvement between the control and experimental groups. Six sub-hypotheses were developed to attempt to answer this research question. The data was tested for normal distribution using the Shapiro-Wilk test. All the developed sub-hypotheses were tested statistically using the Mann-Whitney U test.

The third research question investigated the influence that student characteristics (gender and age) had on overall student competency results. The first sub null-hypothesis investigated whether gender has influenced academic performance. To test if gender had an influence on competency test results, a Chi-Square test was used (Hedges and Olkin, 2014). The second sub null-hypothesis investigated whether age had an influence on competency test results. The influence of age was tested using the Mann-Whitney U test. Although race was included in the data, the researcher decided not to use them in the analysis as there was no variability amongst the race groups, with Africans constituting 91.7% and 95.8% in the control and experimental groups respectively.

The fourth research regarding students' perception about being taught via the 3D animated models of surveying equipment was first tested for reliability using the Cronbach's Alpha test. (Lehman *et al.,*, 2013), states that *"Cronbach's Alpha is a general formula for scale reliability based on internal consistency".* Likert-type data is analysed for central tendency via median or mode as compared to Likert scale data which are analysed via the mean (Boone and Boone, 2012).

4.7 Limitation of the Study

This study is limited to first semester Surveying 1 students at Indumiso campus. It is a deliberate attempt not to limit this study to only one task (aspect) of the competency test, as they are all associated with each other. Additionally, it is dreaded that students will not grasp the full understanding of their practicals and thus fail to see the significance of surveying to civil engineering, which is the main area of their qualification. Students are given a random task from the six standard tasks to assess their surveying competence at the assessors' discretion, however, one single task cannot be isolated from the six tasks that a student must perform, therefore students' must know all tasks as an arbitrary task will be chosen by the assessor.

The purpose of the skills test is for a student to be deemed competent for progression into next semester in six areas of surveying tasks. However, the student is required to competently complete a single randomly selected task at the discretion of the assessor. Each task is divided into various components including time, quality and accuracy, but the overall percentage achievement was used as a measure of competency and in the quantitative analysis. If students did not complete a task according to the assessment criteria, they could fail the assessment. There are other factors that can determine a student's success, but overall test scores were chosen as the dependent variable to be compared in this experimental study.

4.8 Ethical Considerations

The selection of which data to analyse gives rise to ethical issues, and to avoid this dilemma, analyses should be done according to the original design (Simons and Usher, 2000). Only test scores were analysed and student information such as names, gender, age and other personal student information were not used in this study, ensuring that students remained anonymous. The test score information from all semesters was used in the quantitative data analysis.

For the collection of quantitative data no student information such as names, gender, age and other personal student information were recorded. Students interviewed in the focus groups were chosen randomly and were given an explanation of the purpose of the research. They were assured of their anonymity and their consent was obtained to conduct research (Cohen, Manion and Morrison, 2013). Fogelman and Comber, (2002), further highlighted the importance of exact and comprehensive data so that the respondents can make an informed decision about potential involvement in a particular study. For ethical considerations the interviewees were given the opportunity not to partake in this study. Leedy and Ormrod, (2005), stated that all the participants have a right to privacy, and must be respected by the researcher. The researcher made it clear that information gathered from respondents will be used responsibly and their identities would remain confidential. The researcher did not use his status as lecturer to influence the results of this study. The students involved in the focus group open-ended interviews were accommodated in a non-threatening environment so that the setting did not resemble a formal lecture.

They were free to respond without any consequences for negative comments. They were advised to respond as honestly as possible and it was explicitly explained that there were no wrong or right answers.

4.9 Validity and Reliability

The extent to which empirical evidence and underlying theoretical principles support the suitability of analyses is what informs research and makes it valid (Messick, 1990). Validity is mainly involved with assessing the significance that an evaluating instrument has on a certain study, where both internal and external validity can be determined (Lavrakas, 2008). Quantitative research frequently consists of a few variables that allow the researcher to quantify research data, allowing measureable data using appropriate procedures to ensure validity (Moskal, Leydens and Pavelich, 2002).

It is important that threats to internal, external, construct, and statistical conclusion validity of quantitative data are identified in research (Taylor, 2013). To ensure the internal validity of student achievement data, a standard marking rubric was used throughout the study. The student achievement data was also sourced directly from the ITS system with permission from departmental head of department. Additionally data was checked against original document for any errors after being imported into Excel, and sorted for statistical analysis. The statistical conclusion validity was ensured by the inclusion of the full cohort of students in the control and experimental groups (Shadish, Cook and Campbell, 2002).

Validity will be in question if there are concerns related to the choice of the research instrument. A pilot study to test the Likert-Type questions was done on students not involved in the final data collection and analyses, to ensure internal validity. The feedback from the pilot study allowed for better question structure to solicit valuable answers, and thus ensuring relevance and validity. The Likert-Type scale data was entered into an Excel 2010 spreadsheet using the data validation option ensuring that only whole numbers from 0 to 5 were entered. Additionally, the construct validity of the Likert-Type Scale questionnaire was tested statistically using correlations and factor analysis. Correlation coefficients were first calculated to determine if the questionnaire could be analysed via factor analysis (Wallen and Fraenkel, 2001). According to Hair *et al.,*, (2006), a correlation coefficient of 0.4 and 0.5 are considered important and very significant respectively.

Reliability is concerned with the repeatability and dependability of the results derived from a sample (Fraenkel, Wallen and Hyun, 1993). The Likert-Type scale questionnaire was checked for reliability using the Cronbach's Alpha reliability test.

4.10 Conclusion

To answer the research questions the quantitative research approach was deemed necessary by the researcher. Quantitative data collection and analysis was the predominant method used in education, however, qualitative analysis gained prominence in the 1970's as another alternative or supportive paradigm to make educational research valid. Validity can also be ensured within the quantitative enquiry without qualitative analysis to support the findings (Onwuegbuzie, 2000). Some research questions are best answered using a specific research paradigm (Truscott *et al.,*, 2009).

Chapter 5: Data Analysis and Findings

5.1 Introduction

This Chapter presents a summary of the collected data that was used to determine the effectiveness of SketchUp™ software as a surveying teaching tool. The main aim of this study is to determine the impact that SketchUp™ has had on student competency in the field. This is to be achieved through the collection and analysis of pertinent data. Being experimental in nature, this study used quantitative methods of data collection for the analysis of both student achievement and student attitudes. Using quantitative analysis, this research compared the test scores of students before and after the educational intervention. The dependent variable was the gathered competency test results. The variable was measured quantitatively to test the researcher's hypotheses (Cross and Sproull, 2004). Additionally, a 5-point 19 question Likert-type scale measuring instrument to ascertain students' attitudes towards SketchUp™ software as a teaching tool was developed and used to reinforce the competency test data. The Likert-type scale survey was tested for reliability using Cronbach's alpha.

5.2 Demographics

Test results from 278 and 213 students, formed part of the control group and experimental group, respectively. Figure 37, shows the participants from the various semesters. The student competency test data from the first and second semesters of 2011, and second semester of 2012, was collected and constituted the control group. The students in the control group were subjected to the normal lecture method when being exposed to surveying equipment before practicals. These test scores were compared to the experimental group, consisting of semester 2 of 2012, and the first and second semester of 2013.

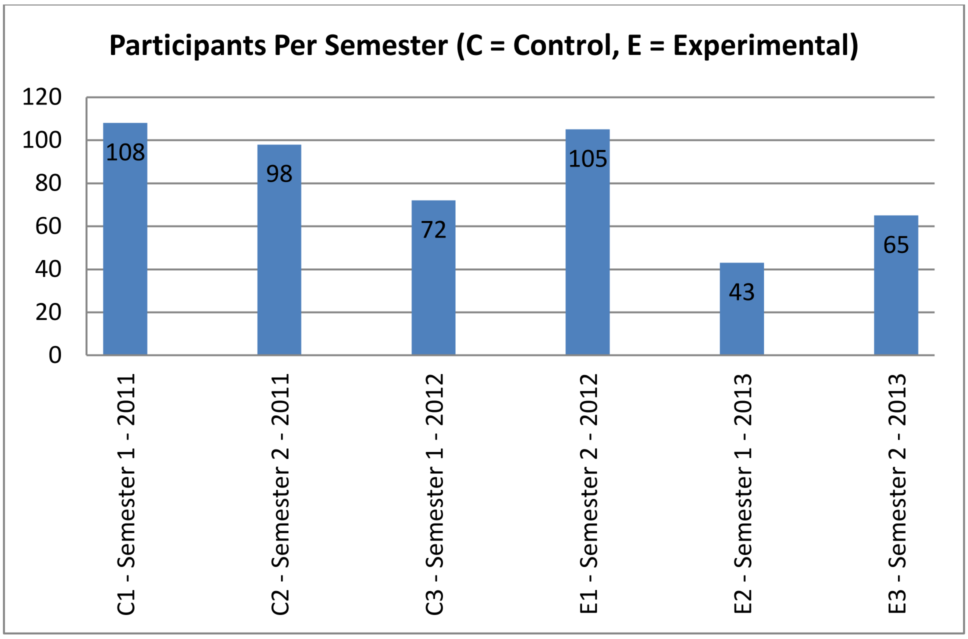


Figure 37. Summary of Control and Experimental group Participants per semester

A summary of the collected control and experimental groups information is shown in Table 2 and Table 3, respectively. The experimental group was exposed to 3D animated models of surveying equipment developed with SketchUp™ software, before practicals. All data received from DUT Integrated Tertiary Software (ITS) was imported and used in a Microsoft Excel 2010 spreadsheet. Students that registered for the subject and those that left without de-registering, were part of the initial import. However, those students that registered and achieved a final mark of zero, were not tested and consequently removed from the study.

Age		**Gender**			**Race**				
Range	Total	Male	Female	Total	African	Indian	Coloured	White	Total
17-18	17	10	7	17	15	2	0	0	*17*
19-20	143	102	41	143	128	12	1	2	*143*
21-22	82	65	17	82	77	3	0	2	*82*
23-24	22	13	9	22	22	0	0	0	*22*
25-26	9	7	2	9	9	0	0	0	*9*
27-28	5	3	2	5	4	1	0	0	*5*
Total	278	200	78	278	255	18	1	4	278

Table 2. Summary of Control group Participants

Age		Gender			Race				
Range	Total	Male	Female	Total	African	Indian	Coloured	White	Total
17-18	8	7	1	8	8	0	0	0	8
19-20	106	67	39	106	103	1	0	2	106
21-22	60	44	16	60	57	2	0	1	60
23-24	23	18	5	23	21	0	0	2	23
25-26	8	5	3	8	8	0	0	0	8
27-28	5	3	2	5	4	0	1	0	5
29-30	1	1	0	1	1	0	0	0	1
31-32	1	1	0	1	1	0	0	0	1
33-34	1	1	0	1	1	0	0	0	1
Total	213	147	66	213	204	3	1	5	213

Table 3. Summary of Experimental group Participants

5.3 Likert-Type Scale Data

A 19 question, five-point Likert-scale consisting of strongly agree, agree, neutral, disagree and totally disagree, were coded numerically as per Table 4. These were then entered into Microsoft Excel 2010 spreadsheet for analysis in SPSS version 2.2. Two hundred and thirteen questionnaires were sent out and ninety were returned, yielding a 42% response rate and 6 questionnaires that were rejected due to incomplete information. The Likert-Type scale questionnaire is shown in Appendix C.

Response	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Code	5	4	3	2	1

Table 4. Coding of Likert-scale questionnaire responses

5.4 Research Questions and Null-Hypotheses

The influence SketchUp™ has had as a teaching tool required the comparison of competency test scores, quantitatively. To answer the first research question, student achievement was compared quantitatively for any significant difference, before and after the educational intervention. The second research question checked for any significant difference in competency test results by comparing each individual task. The third research question investigated the influence that student characteristics have had on competency test results. The fourth research question, gauged the students' attitudes towards the intervention. The student competency test data and the educational intervention constituted the dependent and independent variables respectively. This quasi-experimental research includes quantitative data collection and analysis techniques. Quantitative data includes historical student competency test data and a developed Likert-scale questionnaire. The questions developed for the Likert-Type Scale were developed with the assistance of lecturers as well as a pilot study comprising of randomly selected students not forming part of this research.

The semesters from the control group were combined and compared statistically against the combined experimental group. The main objective of this study is to determine the effects of SketchUp™ software as a teaching tool on student skills test results. The research objectives outlined in chapter 1 resulted in the following research questions. The research questions were answered using the following statistical tests:

5.4.1 Research Question 1

The first research question explored the effect that 3D animation had on student competency test results, by testing the following null hypothesis. *H_{01}: There is no significant difference between the control and experimental groups competency test results at a* 5% level of significance. To answer this, the quantitative data had to be first tested for normality to determine the appropriate statistical method to be used.

The Kolmogorov-Smirnov and Shapiro-Wilk goodness-of-fit tests were used to test for normality (Table 5), and revealed that the distributions were not normal, due to the p-values (Sig.) of both the tests being less than 0.05. As a result, non-parametric statistical methods such, as the Mann-Whitney U test, was chosen to analyse the competency test results, shown in Tables 6.

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Mark	Control	.159	278	.000	.883	278	.000
	Experimental	.224	213	.000	.874	213	.000

a. Lilliefors Significance Correction

Table 5. Test for Normality

The Mann-Whitney U and Wilcoxon W tests (Table 6), revealed that there was a significant difference between the control and experimental test scores, as the p-value (0.028) is less than the level of significance of 0.05. Further statistical analyses shown in table 8, was necessary to determine the direction of the difference.

Ranks

	Group	N	Mean Rank	Sum of Ranks
Mark	Control	278	258.02	71730.00
	Experimental	213	230.31	49056.00
	Total	491		

Test Statistics[a]

	Mark
Mann-Whitney U	26265.000
Wilcoxon W	49056.000
Z	-2.195
Asymp. Sig. (2-tailed)	.028

a. Grouping Variable: Group

Table 6. Mann-Whitney U test to determine competency test results

The direction of the difference infers that the control group has performed better with a higher mean score (81.0396) as compared to the experimental group (79.3005), shown in Table 7. This is also true for the median; however, the standard deviation for the control group is larger than that for the experimental group giving a wider range. The range indicates that the spread about the mean was nearly twice that for the Control group than for the Experimental group. With very similar central scores, it implies that marks clustered closer to the central value for the experimental group than the control group. This implies that the experimental group has performed better than the control group, as the experimental group's scores were closer to the mean value. The null-hypothesis was therefore rejected that there was no significant difference in results.

Group	N	Mean	Std. Deviation	Median	Minimum	Maximum	Range
Control	278	81.0396	13.89343	81.0000	20.00	100.00	80.00
Experimental	213	79.3005	10.13000	80.0000	55.00	100.00	45.00
Total	491	80.2851	12.42020	80.0000	20.00	100.00	80.00

Table 7. Mean scores, standard deviation, median and range

5.4.2 Research Question 2

The data was tested for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests shown in Table 8. The Kolmogorov-Smirnov and Shapiro-Wilk p-values of all the tasks were below 0.05 revealing that none of the distributions was normal. The control and experimental student achievement data per competency test task was thus tested using the Mann-Whitney U and Wilcoxon W tests.

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Task	Statistic	df	Sig.	Statistic	df	Sig.
Score	Task 1	.161	154	.000	.857	154	.000
	Task 2	.130	50	.034	.916	50	.002
	Task 3	.213	28	.002	.872	28	.003
	Task 4	.240	62	.000	.827	62	.000
	Task 5	.155	65	.001	.884	65	.000
	Task 6	.215	132	.000	.888	132	.000

a. Lilliefors Significance Correction

Table 8. Normality Test for Individual Tasks

Statistical analysis of each task is summarised in Table 9, and the direction of these differences is shown in Table 10. The second research question dealt with comparing the control and experimental groups performance when comparing the individual competency test results between the control and experimental groups. This question was answered by the following developed sub-hypotheses.

$H_{02.1}$*: There is no significant difference in competency test results when setting up a theodolite (task 1), at a 95% confidence interval.* As per table 9, there was no significant difference (p = 0.332) in the central measures between the control and experimental groups in task 1 at a 5% level of significance. As per Table 10, the mean scores between the control (83.8972) and experimental (82.5319) group for task 1 indicates a difference in mean scores of 1.37%. This implies that neither group performed significantly better than the other.

$H_{02.2}$*: There is no significant difference in competency test scores when orienting a theodolite (task 2), at a 95% confidence interval.* As per table 9, task 2 showed no significant difference (p = 0.244) with a level of significance of 0.05. As per table 10, the mean scores between the control (81.2581) and experimental (85.2632) group for task 2 indicates a difference in the mean scores of more than 4%. This implies that neither group performed significantly better than the other.

$H_{02.3}$*: There is no significant difference in competency test scores when observing an arc of observations using a theodolite (task 3), at a 95% confidence interval.* Table 9 shows that for task 3, that there was a significance of p = 0.001 less than the level of significance of 0.05, between the control and experimental groups. The mean scores in table 10 between the control (88.6154) and experimental (73.2667) group for task 3 indicates a difference of more than 15%. This implies that the control group achieved higher marks.

$H_{02.4}$*: There is no significant difference in competency test scores when observing vertical angles using a theodolite (task 4), at a 95% confidence interval.* As per table 9, task 4, showed no significance (p = 0.211) with a 5 % level of significance. The mean scores in table 10, between the control (77.8250) and experimental (76.1364) group for task 4 indicates no significant difference between the means, as this variation is 1.69%. This implies that neither group performed significantly better than the other.

$H_{02.5}$: There is no significant difference in competency test scores when observing and booking a tacheometry shot using a theodolite (task 5) at a 95% confidence interval. As per table 9, task 5, shows a significance of p = 0.001 less than the level of significance of 0.05. The mean scores between the control (85.3824) and experimental (77.0323) group for task 5 indicates a significant difference of more than 8%. This implies that the control group achieved better scores for task 5?

$H_{02.6}$: There is no significant difference in competency test scores when observing and booking the height difference between points using an automatic level (task 6) at a 95% confidence interval. As per table 9, task 6, shows a significance of p= 0.001 less than the level of significance of 0.05. The mean scores between the control (72.9245) and experimental (78.8608) group for task 6 indicates a significant difference of more than 5.94%. This implies that the control group achieved better scores for task 6.

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Task 1	2270.500	3398.500	-0.969	0.332
Task 2	237.000	733.000	-1.165	0.244
Task 3	25.000	145.000	-3.453	0.001
Task 4	359.500	612.500	-1.251	0.211
Task 5	273.500	769.500	-3.388	0.001
Task 6	1424.000	2855.000	-3.239	0.001

Table 9. Mann Whitney Test scores for comparison between the groups

Group	Task	N	Mean	Median	Std. Deviation
Control	Task 1	107	83.8972	89.0000	12.83490
	Task 2	31	81.2581	80.0000	13.64055
	Task 3	13	88.6154	95.0000	13.86566
	Task 4	40	77.8250	75.0000	15.71850
	Task 5	34	85.3824	89.0000	13.59370
	Task 6	53	72.9245	70.0000	10.93486
	Total	278	81.0396	81.0000	13.89343
Experimental	Task 1	47	82.5319	80.0000	10.11424
	Task 2	19	85.2632	85.0000	9.64274
	Task 3	15	73.2667	70.0000	7.28469
	Task 4	22	76.1364	70.0000	10.90345
	Task 5	31	77.0323	70.0000	10.05148
	Task 6	79	78.8608	80.0000	9.47160
	Total	213	79.3005	80.0000	10.13000
Total	Task 1	154	83.4805	85.0000	12.05338
	Task 2	50	82.7800	80.0000	12.32600
	Task 3	28	80.3929	76.5000	13.18062
	Task 4	62	77.2258	70.0000	14.12638
	Task 5	65	81.4000	80.0000	12.66121
	Task 6	132	76.4773	75.0000	10.46000
	Total	491	80.2851	80.0000	12.42020

Table 10. Means, Medians and Standard Deviations

This implies that the majority of the marks' improvement occurred in the control group. The null hypothesis is thus rejected that there is no significant difference in marks between the control and experimental groups. The inspection of the total means and standard deviations indicate that most of the improvements in competency test results were in the experimental group. However for all six tasks the standard deviations for the experimental group are smaller than for the control group. This indicates that there is greater clustering of scores around the mean in the experimental group than in the control.

5.4.3 Research Question 3

The third research question is concerned with the influence that student characteristics (gender and age) has had on student performance. Table 11 shows the number of male and female participants in both the control and experimental groups.

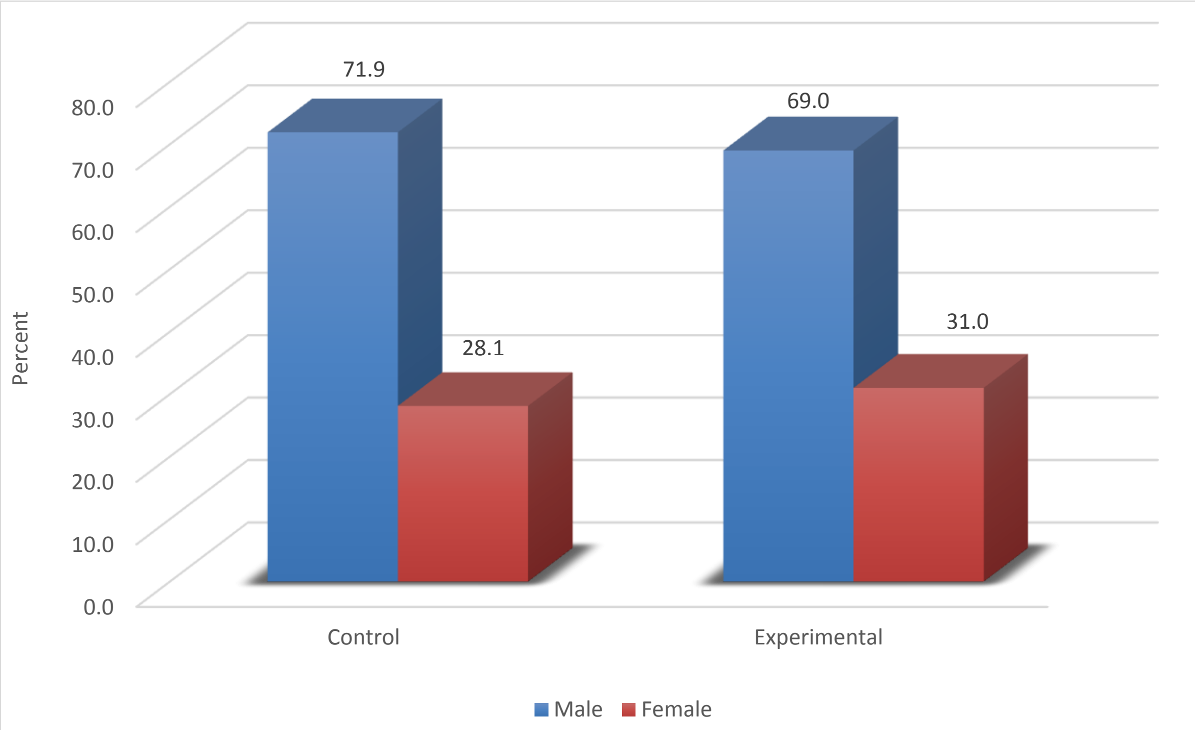


Figure 38. Summary of male and female participants

The following developed sub-hypotheses attempted to determine the influence that gender has had on student performance.

$H_{03.1}$: *There is no significant difference in competency test results at a 95% confidence interval between the male and female test results.* This was answered using Chi-Square test. Chi-Square tests are used when frequency data is used. Table 11 shows a summary of the male and female students control and experimental groups. A Chi-square test was used to measure if there is a significant difference in competency test marks between male and female students. This analysis shows that there is no significant difference (Table 11). Since the Fisher's

Exact test value (p = 0.486) is greater than the level of significance (α = 0.05), it implies that there is no significant difference between the two groups by gender.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	.499[a]	1	.480	.486	.272	
Continuity Correction[b]	.368	1	.544			
Likelihood Ratio	.498	1	.480	.486	.272	
Fisher's Exact Test				.486	.272	
Linear-by-Linear Association	.498[c]	1	.480	.486	.272	.062
N of Valid Cases	491					

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 62.47.

b. Computed only for a 2x2 table

c. The standardized statistic is .706.

Table 11. Chi-square test to determine if gender influenced test results

$H_{03.2}$: There is no significant difference in competency test results at a 95% confidence interval between the various age groups. As Age and marks were scale variable, the relationships were obtained using the Mann-Whitney U Test shown in Table 12. The p-value (0.581) indicates that there is no significant difference in the age, between the control and experimental groups.

Ranks

	Group	N	Mean Rank	Sum of Ranks
Age	Control	278	242.91	67529.00
	Experimental	213	250.03	53257.00
	Total	491		

Test Statistics[a]

	Age
Mann-Whitney U	28748.000
Wilcoxon W	67529.000
Z	-.551
Asymp. Sig. (2-tailed)	.581

a. Grouping Variable: Group

Table 12. Mann-Whitney U test to determine if age influenced test results

5.4.4 Research Question 4

To answer the fourth research question, the following hypothesis was tested. *H_{04}: The student's perceptions regarding the 3D animated models of surveying equipment were positive*. To test for this, quantitative analysis of the Likert-scale responses were verified statistically. The first approach was to test for reliability using Cronbach's Alpha reliability coefficient.

5.4.4.1 Reliability Statistics

Cronbach's Alpha reliability coefficient was used to determine the internal consistency reliability of the instrument. Cronbach alpha of 0.7 or greater is an indication of internal consistency of responses, recommended in most social science research situations (Santos, 1999). Cook and Beckman, (2006), further substantiates that the validity and reliability indices of Cronbach's alpha coefficients of 0.700 or higher is required for Likert-type scale. The calculated Cronbach Alpha for the Likert-type scale questionnaire was 0.901 (Table 13), exceeding the recommended minimum requirement of 0.700.

The two most important aspects of precision are reliability and validity. Reliability is computed by taking several measurements on the same subjects. A reliability coefficient of 0.70 or higher is considered as "acceptable". Table 13 below reflects the Cronbach's alpha score for all the items that constituted the questionnaire. The reliability score for the construct exceeds the recommended value of 0.700. This indicates a high (overall) degree of acceptable, consistent scoring for the various sections of the research.

Case Processing Summary

		N	%
Cases	Valid	83	100.0
	Excluded[a]	0	.0
	Total	83	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.901	19

Table 13. Cronbach Alpha Statistics for Likert-Type Scale Data

5.4.4.2 Correlations and Factor Analysis of the Likert-Type Scale Questionnaire

To test for validity of the Likert-Type questionnaire correlation and factor analysis testing was done. Correlation analysis is done to check whether the information is suitable for factor analysis testing. The results in Appendix D showed that factor analysis was suitable for the questions in the instrument as the correlation coefficients were mostly greater than 0.4 and is considered significant.

Principal component factor analysis of the questionnaire was conducted and common themes were identified amongst the questions. Appendix E shows the three highlighted major themes that emerged, (1)-Yellow, (2)-green and (3)-red. These were appropriately named by the researcher as: (1) virtual surveying equipment, (2) the competency tasks (1-6), (3) overall learning experience. The intention however was not to reduce the number of questions, but to show that the items were related to each other and theoretically illustrate common themes.

5.4.4.3 Statistical Analysis of Likert-Type Scale

A participant's response to any item, ranged from the highest possible score of five and the lowest score of one. After all the items were coded, the average scores per question were statistically analysed for central tendency (median and mode) as well as variability (frequencies). Median score however does not necessarily reflect a neutral attitude (Oppenheim, 2001). Student attitudes towards SketchUp as a teaching tool, were compared using the median, mode and frequency tests.

Table 14 shows the frequencies of likert-scale responses and the frequency distribution from the 83 responses.

Questions	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
1	28 34%	50 60%	5 6%	0 0%	0 0%	83 100%
2	27 33%	50 60%	6 7%	0 0%	0 0%	83 100%
3	20 24%	47 57%	16 19%	0 0%	0 0%	83 100%
4	20 24%	49 59%	12 14%	1 1%	1 1%	83 100%
5	32 39%	37 45%	14 17%	0 0%	0 0%	83 100%
6	23 28%	49 59%	11 13%	0 0%	0 0%	83 100%
7	25 30%	42 51%	15 18%	1 1%	0 0%	83 100%
8	31 37%	34 41%	15 18%	3 4%	0 0%	83 100%
9	31 37%	30 36%	19 23%	3 4%	0 0%	83 100%
10	18 22%	42 51%	20 24%	3 4%	0 0%	83 100%
11	21 25%	45 54%	13 16%	4 5%	0 0%	83 100%
12	18 22%	43 52%	19 23%	3 4%	0 0%	83 100%
13	15 18%	46 55%	18 22%	4 5%	0 0%	83 100%
14	20 24%	41 49%	20 24%	2 2%	0 0%	83 100%
15	22 27%	47 57%	11 13%	2 2%	1 1%	83 100%
16	24 29%	48 58%	9 11%	1 1%	1 1%	83 100%
17	28 34%	36 43%	18 22%	1 1%	0 0%	83 100%
18	29 35%	41 49%	11 13%	2 2%	0 0%	83 100%
19	42 51%	27 33%	14 17%	0 0%	0 0%	83 100%

Table 14. Frequency Responses of Likert Scale Questionnaire

Likert-type data is analysed for central tendency via the median and mode. Each Likert-type question was analysed individually to test for central tendency (median or mode) (Table 15), as well as frequency distribution (variability) (Table 14). The median for all questions was 4, except for question 19 with a median of 5, revealing a generally positive student attitude towards the 3D animated models of surveying equipment.

	Questions	Median	Mode
1	The SketchUp 3D model of the theodolite visually resembled an actual theodolite	4	4
2	The SketchUp 3D model of the theodolite assisted my understanding of the basic structure of the theodolite	4	4
3	The SketchUp 3D model of the automatic level visually resembled an actual automatic level	4	4
4	The SketchUp 3D model of the automatic level assisted my understanding of the basic structure of the automatic level	4	4
5	The SketchUp 3D models of the tripod, staff and ranging rod visually resembled an actual tripod, staff and ranging rod	4	4
6	The exposure to the 3D animated models of surveying equipment prepared me sufficiently for all traversing, levelling and tacheometry surveying practicals	4	4
7	The 3D animated models of surveying equipment operation improved my understanding of difficult to understand surveying practical concepts	4	4
8	The SketchUp 3D animated models of the theodolite assisted me to understand how to set-up and operate the theodolite	4	4
9	The 3D animated models assisted me with orienting a theodolite (finding a direction)	4	5
10	The 3D animated models assisted me with observing and booking an Arc of Observations	4	4
11	The 3D animated models assisted me with observing and booking vertical angles	4	4
12	The 3D animated models assisted me with observing and booking a tacheometry point	4	4
13	The SketchUp 3D animated model of the automatic level assisted me to understand how to operate the automatic level	4	4
14	The 3D animated models assisted me with observing and booking the height difference between two points	4	4
15	The SketchUp in-class lessons of equipment operation assisted my understanding of the proper field procedure	4	4
16	The SketchUp in-class lessons of 3D animated models of surveying equipment assisted my overall learning experience	4	4
17	The exposure to the 3D animated models of surveying equipment prepared me sufficiently for the end of semester competency test	4	4
18	The SketchUp in-class lessons of 3D animated models of surveying equipment were visually stimulating and interesting	4	4
19	I would recommend the use of SketchUp software in other Civil Engineering subjects	5	5

Table 15. Median and Mode of Likert-Type Scale Questionnaire

5.5 Summary

The results from the quantitative analysis of student achievement, student characteristics and the Likert-Type Scale questionnaire will be expanded upon in the following chapter.

Chapter 6: Conclusions and Recommendations

6.1 Introduction

This study investigated the impact that a teaching tool developed with SketchUp software, has had on student competency test scores. Test scores were compared between control and experimental groups before and after the educational intervention. This educational intervention used SketchUp software as a teaching tool after 3D models of surveying equipment were developed. Literature has shown that SketchUp has been used in other educational disciplines such as Mathematics and Physics. Other similar software that can display 3D virtual models has been documented as being beneficial to educational endeavours.

Research has shown that surveying is an important dimension of most civil engineering projects, thereby emphasising the importance that graduates have a full understanding of surveying equipment operation (Lam, 2008). A lack of such competence has the potential of resulting in negative consequences for the civil engineering projects. Although the majority of surveying work is carried out by registered surveyors, civil engineering practitioners also are required to perform basic surveying tasks. These technical abilities must be demonstrated during students' studies, that is an indication of their future abilities. These skills are taught at tertiary level, but certain restrictions hamper the effective teaching and learning process. Large class numbers and the limited availability of survey equipment have been experienced at the local and international educational institutions (Roberts and Gray, 2009). This research has attempted to address these barriers to teaching and learning, based on educational interventions of other higher education institutions teaching and learning interventions. The development of other institutions' teaching tools was studied and a similar intervention was proposed for this study based on the unique circumstances at the DUT (Shortis and Woodhouse, 2001); (Gibbings and McDougall, 2005); (Yoichi *et al.,*, 2006); (Hui-Lung *et al.,*, 2008); (Roberts and Gray, 2009).

Research has also shown that surveying and civil engineering are closely related disciplines, with surveying evolving from civil engineering from antiquity (Shields, 1972). This synergy has resulted in successful civil engineering feats throughout the millennia.

6.1.1 Surveying Competence

The relevance of surveying is also emphasised by the inclusion in most civil engineering qualifications both internationally and locally. The governing of surveying and civil engineering practitioners also highlights the importance of the production of accurate surveying information. It has been documented that negative consequences result from inaccurate surveys, including loss of life and the impact on project cost and delivery. This research has attempted to show that competent graduates and practitioners are, therefore, critically important. This competence was evident from ancient times with records of Egyptian, Roman and Chinese surveyors using surveying equipment to assist with civil engineering infrastructure projects. It is evident in recent literature that operators of surveying equipment must possess the necessary skills (Fourie, 1994).

6.1.2 Teaching of Surveying

Computers have played a vital role in education, with educators having many options to display educational content to aid student learning. The traditional talk and chalk lecture method was slowly being replaced by the display of information via digital projectors. This digital display employed software packages such as Microsoft PowerPoint. As computer technology progressed, more visually appealing content became possible. Engineering subjects benefited from these technologies as complex concepts could now be explained with the aid of visualisations. Text could now be combined with graphics, making lectures more interesting and appealing. These 2D visualisations were beneficial, but limited, resulting in the development of 3D content for lectures. This study employed the use of 3D animated models of surveying equipment to teach students about surveying equipment and their use, attempting to enhance their competence.

6.2 Summary of Findings

The quantitative data analysis of student achievement data revealed that there was no significant difference between the control and experimental groups. This apparent insignificance could be attributed to the pass requirement of 70%.

6.2.1 Research Question 1

Statistical analysis of research question 1, revealed that there was a significant difference in the competency test scores between the control and experimental groups. However, further inspection indicated that the control group had a higher overall mean than the experimental group, and thus the null hypothesis was accepted. Further inspection of the means indicated that the control group performed better, however the standard deviation for the experimental group was smaller implying that the experimental group achieved better results.

6.2.2 Research Question 2

Statistical analysis of the individual tasks, showed competency tests results for tasks 1, 2 and 4 were not significantly different. However, there was a significant difference between the test scores when comparing tasks, 3, 5 and 6. For tasks 3 and 5, the control group performed better. The experimental group performed better in the experimental group for task 6. The inspection of the overall means and standard deviations indicated that the experimental group performed better.

6.2.3 Research Question 3

Statistical analysis proved that gender did not influence the student performance between the control and experimental groups. This was also true for age.

6.2.4 Research Question 4

Additional quantitative analysis of the Likert-type scale questionnaire revealed that there was a positive attitude of students towards the educational intervention, where the median and mode consistently averaged a score of 4. This indicates that the teaching tool has had some impact on students' learning experience.

6.3 Limitations

This research is based on the introduction of a teaching tool developed in SketchUp software for first semester Surveying 1 students, studying civil engineering at the Durban University of Technology, Indumiso campus. This study is not limited to only one mandatory skills test eventually chosen by the assessor at the time of assessments, as students must be proficient in all tasks.

The majority of student's lack of computer skills limited this study to in-class demonstrations facilitated by the lecturer. Although this study did not utilize other educational interventions such as LMS systems, their inclusion in this study has significance for future development of the developed teaching tool.

6.4 Recommendations

SketchUp has educational benefits as documented by other educational institutions including this research. SketchUp has been used as a teaching tool in many STEM educational subjects and therefore can be applied to other subjects taught at the DUT, such as Mathematics, Drawing, Physics, and other civil engineering related subjects. Lessons learnt from this research can be used to benefit other educational initiatives embarking on improving student engagement during lectures.

This research has the potential to be more beneficial to education if developed further by including options for student interaction with the developed teaching tool. Variations of the teaching tool could be expanded as a teaching tool where students can learn to a certain extent, at their own pace. Other visualisation environments such as fully-immersive 3D simulations and augmented reality are other possibilities available within SketchUp software.

The researcher investigated other freely available 3D modelling animation software, with potentially more capabilities than the free version of SketchUp can provide. Further research into the use of Blender 3D software as an alternative to SketchUp software will be investigated further. Commercial software such as AutoCAD can also be investigated for educational ventures, especially the availability of educational licenses for educational institutions.

Other research areas closely related to the use of 3D models in education include a fourth and fifth dimension to visualisations. These extra dimensions involve the inclusion of time (fourth dimension) and cost (fifth dimension) to the developed 3D models, allowing educators and students alike to visualise all aspects of a technical process especially in civil engineering. This type of visualisation is referred to as Building Information Management (BIM). These BIM principles could also be incorporated into the education of students studying surveying, further emphasising the importance of surveying in civil engineering projects.

Finally, the developed 3D models and animation could be included as part of the Surveying 1 syllabus. The current course notes and practical manual could include the developed images and explanations, allowing students to prepare themselves fully for the mandatory skills test at the end of each semester. As surveying equipment gets more complex, 3D animated models can play a vital role in teaching and learning process.

References

Adam, J.-P. 2005. *Roman building: materials and techniques*. Routledge.

Adeli, H. and Adeli, H. 1988. An overview of expert systems in civil engineering. *Expert systems in construction and structural engineering*: 45-83.

Africa, O. 2013. *Unit 1: Case studies - Delivering e-learning in South Africa*. Available: http://www.oerafrica.org/supportinglearners/Unit1/CasestudiesdeliveringelearninginSouthAfrica/tabid/1039/Default.aspx (Accessed 12 October 2013).

Ahmad, M. A. and Wei, L. 2006. Development of essol-v2 for engineering survey calculations. *International Journal of Engineering and Technology*, 3 (1): 54-60.

Aicher, P. J. 1995. *Guide to the aqueducts of ancient Rome*. Bolchazy-Carducci Publishers.

Alessi, S. M. and Trollip, S. R. 1991. *Computer-based instruction: Methods and development*. Prentice Hall Professional Technical Reference.

Alnaseeri, T. M., Alfalahi, H. A. and Alzidi, A. M. 2014. 3d Model to Educational Multimedia Approach for Simulate Parts of Shock Tunnel. *Australian Journal of Basic & Applied Sciences*, 8 (9)

American Society of Civil Engineers. 2013. *What is Civil Engineering*. Available: http://www.asce.org/What-Is-Civil-Engineering-/ (Accessed 10 May 2013).

Anderl, R. and Vogel, U. R. 1999. Teaching Environment for the Education of Engineering Students. *Interactive Learning Environments*, 7 (2-3): 195-208.

Angus-Leppan, P. 1967. Land system reforms in Canada and their possible application in Australia. *Australian Surveyor*, 21 (7): 213-222.

Arksey, H. and Knight, P. T. 1999. *Interviewing for social scientists: An introductory resource with examples*. Sage.

Ary, D., Jacobs, L. C., Razavieh, A. and Sorensen, C. 2010. *Introduction to research in education*. Cengage Learning.

Asunda, P. A. 2011. Open courseware and STEM initiatives in career and technical education.

Babbie, E. 2007. The Practice of Social Research. Belmont: Thomson Wadsworth.

Bacone, V. K. 2012. *Blender Game Engine: Beginner's Guide*. Packt Publishing Ltd.

Bai, J. 2007. The teaching video of the theodolite setting procedure, Taiwan.

Balamuralithara, B. and Woods, P. C. 2007. Virtual laboratories in engineering education: The simulation lab and remote lab. *Computer Applications in Engineering Education*, 17 (1): 108-118.

Balodimos, D., Korakitis, R., Lambrou, E. and Pantazis, G. 2003. Fast And Accurate Determination Of Astronomical Coordinates Φ, Λ. and azimuth, using a total station and gps receiver. *Survey Review*, 37 (290): 269-275.

Bandyopadhyay, S. 2011. *JnNURM - Rapid Training Programme - Preparation of DPRs*. Available: http://spcept.ac.in/profile_saswat.aspx?pg=fac&sub=fac&prof=saswat (Accessed 29 September 2013).

Bargst, H.-J., #228, dt and Blickling, A. 2005. Determination of process durations on virtual construction sites. Paper presented at the *Proceedings of the 37th conference on Winter simulation*. Orlando, Florida.1162979: Winter Simulation Conference, 1549-1558.

Bell, J. T. and Fogler, H. S. 1995. The investigation and application of virtual reality as an educational tool. In: Proceedings of *Proc. American Society for Engineering Education Annual Conference, Session*.

Bergman, M. M. 2010. On concepts and paradigms in mixed methods research. *Journal of Mixed Methods Research*, 4 (3): 171.

Bhamre, P. and Kambekar, A. 2013. Impact of Geo-Environmental Parameters and economics of delay in Construction Projects. In: Proceedings of *Indian Geotechnical Conference*. Roorkee,

Bieszke, E. 2011. What is the Future of Augmented Reality Technology on Smartphones. *Bachelor Thesis, Bournemouth University*,

Birkenholtz, R. J., Stewart, R., McCaskey, M., Ogle, T. and Lindardt, R. 1989. Using microcomputers in education: Assessment of three teaching strategies. *Journal of the American Association of Teacher Educators in Agriculture*, 30 (1): 51-69.

Boggs, K. J., Dordevic, M. M. and Shipley, S. T. 2012. Google Earth® Models with COLLADA and WxAzygy® Transparent Interface: An example from Grotto Creek, Front Ranges, Canadian Cordillera. *Geoscience Canada*, 39 (2)

Boone, H. N. and Boone, D. A. 2012. Analyzing likert data. *Journal of extension*, 50 (2): 1-5.

Bracht, G. H. and Glass, G. V. 1968. The external validity of experiments. *American Educational Research Journal*: 437-474.

Bradburn, N. M., Sudman, S., Blair, E., Locander, W., Miles, C., Singer, E. and Stocking, C. 1992. *Improving interview method and questionnaire design: Response effects to threatening questions in survey research*. University Microfilms.

Brixius, L. 2010. *Google SketchUp Workshop: Modeling, Visualizing, and Illustrating*. Taylor & Francis.

Brogdon, G. 2007. Education, Constructivism and Virtual Reality. *Retrieved July*, 10: 2010.

Brynard, P. and Hanekom, S. 1997. *Introduction to research in Public Administration and related academic disciplines*. JL van Schaik Academic.

Calabrese, R. L. 2009. *The dissertation desk reference: the doctoral student's manual to writing the dissertation*. R&L Education.

Campbell, B. 2000. *The writings of the Roman land surveyors: introduction, text, translation and commentary*. Society for the Promotion of Roman Studies.

Carlson, T. P. 2000. The impact of Global Positioning Systems (g.p.s.) in Land Surveying and the related competencies needed by land surveying graduates in the state of Wisconsin. Master of Science, University of Wisconsin-Stout.

Cawood, F. and Stacey, T. 2006. Survey and geotechnical slope monitoring considerations. *Journal-South African Institute of Mining and Metallurgy*, 106 (7): 495.

Central University of Technology. 2013. *National Diploma: Engineering: Civil ISNDLS*. Available: http://cut.hive.couxd.com/faculty_pages/national-diploma-engineering-civil-isndls/ (Accessed 11 October 2013).

Chandra, A. 2007. *Higher Surveying*. New Age International.

Charles, C. M. 1998. *Introduction to educational research*. ERIC.

Chartered Institution of Civil Engineering. 2013. *What is civil engineering*. Available: http://www.ice.org.uk/nearyou/UK-Regions/Northern-Ireland/Education, http://ces.digitalpc.co.uk (Accessed 28 September).

Chen, Y.-C., Chi, H.-L., Hung, W.-H. and Kang, S.-C. 2011. Use of tangible and augmented reality models in engineering graphics courses. *Journal of Professional Issues in Engineering Education & Practice*, 137 (4): 267-276.

Chopra, A. 2011a. *Google SketchUp 8 for dummies* (Text). Hoboken, N.J.: Wiley Pub.,.

Chopra, A. 2011b. Proper Animation is a very cool plugin. Available: http://sketchupdate.blogspot.com/2011/02/proper-animation-is-very-cool-plugin.html (Accessed 17 November 2011).

Chopra, A. 2012. *Introduction to Google SketchUp*. John Wiley & Sons.

Chrzanowski, A. and Wilkins, R. 2007. Fully automatic and reliable real time monitoring systems for steep slopes, embankments, and structures. In: Proceedings of *Computer Applications In Geotechnical Engineering*. ASCE, 1-10.

Cohen, L., Manion, L. and Morrison, K. 2013. *Research methods in education*. Routledge.

Coiner, C. M., Bruno, P. A. P. and San Ramon, C. 2002. 3D Laser Scanning for Common Surveying Applications.

Cook, D. A. and Beckman, T. J. 2006. Current concepts in validity and reliability for psychometric instruments: theory and application. *The American journal of medicine*, 119 (2): 166. e167-166. e116.

Corder, G. W. and Foreman, D. I. 2009. *Nonparametric statistics for non-statisticians: a step-by-step approach*. John Wiley & Sons.

Costa, C., Alvelos, H. and Teixeira, L. 2012. The Use of Moodle e-learning Platform: A Study in a Portuguese University. *Procedia Technology*, 5 (0): 334-343.

Coutts, B. and Grant, D. 2009. The New Zealand surveyor—the 21st century. *Journal of Spatial Science*, 54 (2): 49-62.

Crawford, W. G. 2003. Construction surveying and layout. *Safety*, 3: 2.

Creswell, J. W. 2012. *Qualitative inquiry and research design: Choosing among five approaches*. Sage.

Creswell, J. W. 2013. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage.

Crofton, F. S. 2000. Educating for sustainability: opportunities in undergraduate engineering. *Journal of Cleaner Production*, 8 (5): 397-405.

Crone, G. 1953. *Maps and Their Makers: An Introduction to the History of Cartography*. London:: Hutchinson.

Cross, K. P. 2000. The educational role of researchers. *New Directions for Higher Education*, 2000 (110): 63-74.

Cross, R. and Sproull, L. 2004. More than an answer: Information relationships for actionable knowledge. *Organization Science*, 15 (4): 446-462.

Crotty, M. 1998. *The foundations of social research: Meaning and perspective in the research process*. Sage.

Cuomo, P. A. 2003. *Surveying principles for civil engineers : review for the engineering surveying section of the California special civil engineer examination*. 2nd ed. Belmont, Calif.: Professional Publications.

D'Antoni, S. and Savage, C. 2009. *Open educational resources: conversations in cyberspace*. Paris: United Nations Educational, Scientific and Cultural Organization, 2009.

Dauben, J. W. 1998. Ancient Chinese mathematics: the (Jiu Zhang Suan Shu) vs Euclid's Elements. Aspects of proof and the linguistic limits of knowledge. *International Journal of Engineering Science*, 36 (12–14): 1339-1359.

Deslauriers, L., Schelew, E. and Wieman, C. 2011. Improved learning in a large-enrollment physics class. *science*, 332 (6031): 862-864.

Deumlich, F. 1982. *Surveying Instruments*. Berlin: Walter de Gruyter.

Dilke, O. A. W. 1962. The Roman Surveyors. *Greece & Rome*, 9 (2): 170-180.

Dilke, O. A. W. 1971. *The Roman land surveyors: an introduction to the agrimensores*. David and Charles.

Durban University of Technology. 2010. Department of Civil Engineering and Surveying - Handbook for 2011.

Elhassan, I. M. and Ali, A. 2011. Comparative study of accuracy in distance measurement using: Optical and digital levels. *Journal of King Saud University-Engineering Sciences*, 23 (1): 15-19.

Elliott, G. 1996. *Crisis and change in vocational education and training*. Jessica Kingsley Publishers.

Eng, T. S. 2005. The Impact of ICT on Learning: A Review of Research. *International Education Journal*, 6 (5): 635-650.

Estes, A. C., Welch, R. W. and Ressler, S. J. 2005. The ExCEEd Teaching Model. *Journal of Professional Issues in Engineering Education & Practice*, 131 (4): 218-222.

Felder, R. M. and Silverman, L. K. 1988. Learning and teaching styles in engineering education. *Engineering education*, 78 (7): 674-681.

Field, H. L. 2011. *Landscape surveying*. Cengage Learning.

Fink, A. and Oishi, S. M. 2003. *How to conduct in-person interviews for surveys*. Sage.

Firestone, W. A. 1987. Meaning in method: The rhetoric of quantitative and qualitative research. *Educational researcher*, 16 (7): 16-21.

Fogelman, K. and Comber, C. 2002. Surveys and sampling. *Research methods in educational leadership and management*: 93-107.

Forsythe, P., Jupp, J. and Sawhney, A. 2013. Building Information Modelling in Tertiary Construction Project Management Education: A Programme-wide Implementation Strategy. *Journal for Education in the Built Environment*, 8 (1): 16-34.

Forte, E. N. and Ecole polytechnique fédérale de Lausanne. 1991. *CALISCE '91 : proceedings of the International Conference on Computer Aided Learning and Instruction in Science and Engineering, September 9-11, 1991, EPFL, Lausanne, Switzerland*. Lausanne: Presses polytechniques et universitaires romandes.

Fourie, C. 1994. *Options for the cadastre in the new South Africa: Report to the South African Council for Professional and Technical Surveyors*. University of Natal, Department Surveying and Mapping.

Fraenkel, J. R., Wallen, N. E. and Hyun, H. H. 1993. How to design and evaluate research in education.

Francis, R. M. 1993. Civil Engineering Education in Canada. *European Journal of Engineering Education*, 18 (4): 387-395.

Fuller, C. A. 1973. The Roman Land Surveyors: An Introduction to the Agrimensores, O. A. W. Dilke, David and Charles Press, Newton Abbot, 1971. 145 x 225 mm., 260 pages (with bibliography and index), 9 tables (not labelled). 34 photographs. 58 maps and diagrams. £3.90. *Cartography*, 8 (2): 92-93.

Geomatica. 2005. *The Journal of Geospatial Information Science, Technology and Practice*, 59 (2)

Ghosh, J. K. 2010. *Elementary engineering surveying*. New Delhi: Studium Press (India).

Gibbings, P. and McDougall, K. 2005. Are equipment simulators effective when used for technology-based training? *Journal of Spatial Science*, 50 (2): 79-89.

Glasscock, J. T. C. 1974. Education for surveyors. *Australian Surveyor*, 26 (1): 35-43.

Glesne, C. 2006. Making words fly: developing understanding through interviewing. *Becoming qualitative researchers: An introduction*: 79-107.

Glick, S., Porter, D. and Smith, C. 2012. Student Visualization: Using 3-D Models in Undergraduate Construction Management Education. *International Journal of Construction Education and Research*, 8 (1): 26-46.

Godfrey, D. and Brahan, J. 1984. *Computer-aided learning using the NATAL language*. Victoria, B.C.: Press Porcépic.

Gomide, J. V. B., Flam, D. L. and Araújo, A. d. A. 2011. Recent improvements to OpenMoCap and its release to download and to development as free open source software. In: Proceedings of *International Conference Cinema Art, Technology, Communication*. 1317-1324.

Government, S. A. 2000. *Engineering Profession Act 2000*, . Cape Town: Available: https://www.ecsa.co.za/regulation/RegulationDocs/EngProfAct46_2000.pdf (Accessed 13 October 2013).

Grigg, N. S., Criswell, M. E., Fontane, D. G., Saito, L., Siller, T. J. and Sunada, D. K. 2004. Integrated Civil Engineering Curriculum: Five-Year Review. *Journal of Professional Issues in Engineering Education & Practice*, 130 (3): 160-165.

Groenewald, T. 2004. A Phenomenological Research Design Illustrated. *International journal of qualitative methods*, 3 (1)

Gunderson, A. and Aliagha, M. 2002. *Interactive Statistics*.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E. and Tatham, R. L. 2006. *Multivariate data analysis*. Pearson Prentice Hall Upper Saddle River, NJ.

Haque, M. E. and Mishra, R. 2007. 5D virtual constructions: Designer/constructor's perspective. In: Proceedings of *Computer and information technology, 2007. iccit 2007. 10th international conference on*. IEEE, 1-4.

Hartmann, T., Van Meerveld, H., Vossebeld, N. and Adriaanse, A. 2012. Aligning building information model tools and construction management methods. *Automation in Construction*, 22: 605-613.

Hatch, J. A. 2002. *Doing qualitative research in education settings*. SUNY Press.

Hedges, L. V. and Olkin, I. 2014. *Statistical method for meta-analysis*. Academic press.

Hennes, M. 1992. Leistungsmerkmale des One-Man-Systems Geodimeter 4000. *VR*, 4 (5): 1992.

Henze, F., Heine, K. and Siedler, G. 2009. Developments of Surveying Technologies in Construction History. In: Proceedings of *Proceedings of the Third International Congress on Construction History*.

Hollander, M., Wolfe, D. A. and Chicken, E. 2013. *Nonparametric statistical methods*. John Wiley & Sons.

Hong, D.-f., Yang, G.-d. and Wang, Z.-h. 2008. Construction of Virtual Campus Based on ArcScene and SketchUp [J]. *Computer Technology and Development*, 12: 014.

Horne, M. and Thompson, E. M. 2007. Virtual Reality and 3D modelling in built environment education.

Hui-Lung, K., Shih-Chung, K., Cho-Chien, L., Shang-Hsieh, H. and Yong-Huang, L. 2008. Using Virtual Instruments to Teach Surveying Courses_Application and Assessment. *Wiley Periodicals Inc.*,

Jianzhong, Z. 2008. On CDIO Model under Learning by Doing Strategy. *Research in Higher Education of Engineering*, 3: 1-6.

Johnson, A. 2004. *Plane and geodetic surveying : the management of control networks*. London ; New York: Spon Press.

Johnson, R. B. and Onwuegbuzie, A. J. 2004. Mixed methods research: A research paradigm whose time has come. *Educational researcher*, 33 (7): 14-26.

Johnson, R. B., Onwuegbuzie, A. J. and Turner, L. A. 2007. Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, 1 (2): 112-133.

Kamath, R. and Kamat, R. 2013. Development of an Intelligent Virtual Environment for Augmenting Natural Language Processing in Virtual Reality Systems. *International Journal of Emerging Trends & Technology in Computer Science (IJETTCS) Volume*, 2: 198-203.

Kavanagh. 2003. *Geomatics*. Prentice Hall.

Keefe, J. W. 1979. Learning style: An overview. *Student learning styles: Diagnosing and prescribing programs*: 1-17.

Kelly, A. 2004. Design research in education: Yes, but is it methodological? *The journal of the learning sciences*, 13 (1): 115-128.

Kelly, K. 1999. Hermeneutics in action: Empathy and interpretation in qualitative research. *Research in practice: Applied methods for the social sciences*: 398-420.

Kerlinger, F. N. 2011. Foundations of behavioral research, 1986. *New York, NY: Holt, Rinehart, and Winston,*

Kim, Y., Park, S., Kim, H., Jeong, H. and Ryu, J. 2011. Effects of different haptic modalities on students' understanding of physical phenomena. In: Proceedings of *World Haptics Conference (WHC), 2011 IEEE*. IEEE, 379-384.

Kipp, K. 2013. *Teaching on the Education Frontier: Instructional Strategies for Online and Blended Classrooms Grades 5-12*. John Wiley & Sons.

Kolb, D. A. 1981. Learning styles and disciplinary differences. *The modern American college*: 232-255.

Kreisle, W. 1988. History of Engineering Surveying. *Journal of Surveying Engineering*, 3 (114): 3.

Kuhn, T. S. 1962. The Structure of Scientific Revolutions.

Kurtulus, A. and Uygan, C. 2010. The effects of Google Sketchup based geometry activities and projects on spatial visualization ability of student mathematics teachers. *Procedia - Social and Behavioral Sciences,* 9 (0): 384-389.

Lam, S. 2008. Teaching Engineering Surveying in a Civil Engineering Program_Curriculum Pedagogy and Assessment. *Journal of Professional Issues in Engineering Education and Practice*, 134 (2): 6.

Laurillard, D. 2013. *Rethinking university teaching: A conversational framework for the effective use of learning technologies*. Routledge.

Lavrakas, P. J. 2008. *Encyclopedia of survey research methods*. Sage.

Lay-Yong, L. and Kangsheng, S. 1986. Mathematical Problems on Surveying in Ancient China. *Archive for History of Exact Sciences*, 36 (1): 1-20.

Leedy, P. D. and Ormrod, J. E. 2005. *Practical research*. Pearson Merrill Prentice Hall Columbus, OH.

Lehman, A., O'Rourke, N., Hatcher, L. and Stepanski, E. 2013. *JMP for Basic Univariate and Multivariate Statistics: Methods for Researchers and Social Scientists*. SAS Institute.

Lewis, M. J. T. 2001. *Surveying Instruments of Greece and Rome*. United States of America: Cambridge University Press.

Li, Z., Zhu, C. and Gold, C. 2010. *Digital terrain modeling: principles and methodology*. CRC press.

Lin, K.-Y., Son, J. W. and Rojas, E. M. 2011. A pilot study of a 3D game environment for construction safety education. *Journal of Information Technology in Construction*, 16: 69-83.

Logan, W. 1965. Cybernetics and Surveying. *Survey Review*, 18 (135): 34-37.

Lu, C.-C., Kang, S.-C. and Hsieh, S.-H. 2007. SimuSurvey: a computer-based simulator for survey training. In: Proceedings of *Proceedings of CIB 24th W78 Conference Maribor*. 26-29.

Lu, C.-C., Kang, S.-C., Hsieh, S.-H. and Shiu, R.-S. 2009. Improvement of a computer-based surveyor-training tool using a user-centered approach. *Advanced Engineering Informatics*, 23 (1): 81-92.

Luh, L. C., Setan, H., Majid, Z., Chong, A. K. and Tan, Z. 2014. High resolution survey for topographic surveying. In: Proceedings of *IOP Conference Series: Earth and Environmental Science*. IOP Publishing, 012067.

Lund, T. 2005. The Qualitative–Quantitative Distinction: Some comments. *Scandinavian Journal of Educational Research*, 49 (2): 115-132.

Martín-Dorta, N., Saorín, J. L. and Contero, M. 2008. Development of a fast remedial course to improve the spatial abilities of engineering students. *Journal of Engineering Education*, 97 (4): 505-513.

Mayer, R. E. 2000. What is the place of science in educational research? *Educational researcher*, 29 (6): 38-40.

McCague, H. 2007. *Learning from the Roman Land Surveyors: A Mathematical Field Exercise pp. 105-114*. Washington, D.C.: Mathematical Association of America.

McMillan, W. and Parker, M. 2005. 'Quality is Bound Up With Our Values': evaluating the quality of mentoring programmes. *Quality in higher education*, 11 (2): 151-160.

Mercer, N. 2010. The analysis of classroom talk: Methods and methodologies. *British journal of educational psychology*, 80 (1): 1-14.

Merriam, S. B. 2002. Qualitative research in practice: Examples for discussion and analysis.

Mertens, D. M. 2009. *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods*. Sage.

Messick, S. 1990. Validity of test interpretation and use.

Microsoft Development Network. 2013. *XNA*. Available: http://msdn.microsoft.com/en-us/library/bb200104.aspx (Accessed 11 August 2013).

Miller, D. C. and Salkind, N. J. 2002. *Handbook of research design and social measurement*. Sage.

Mishra, R. 2009. *Educational research*. APH Publishing.

Molnar, A. R. 1997. Computers in education: A brief history. *T H E Journal*, 24 (11): 63.

Moskal, B. M., Leydens, J. A. and Pavelich, M. J. 2002. Validity, reliability and the assessment of engineering education. *Journal of Engineering Education*, 91 (3): 351-354.

Muijs, D. 2010. *Doing quantitative research in education with SPSS*. Sage.

Muirhead, W. D. 2000. Online education in schools. *International Journal of Educational Management*, 14 (7): 315-324.

Murdock, K. L. 2009. *Google SketchUp and SketchUp Pro 7 Bible*. John Wiley & Sons.

Myers, M. D. 1997. Qualitative research in information systems. *Management Information Systems Quarterly*, 21: 241-242.

Nel, C. 2008. 3 Learning style and good language learners. *Lessons from good language learners*: 49.

Nelson Mandela Metropolitan University. 2013. *Civil Engineering: What does it entail?* Available: http://civileng.nmmu.ac.za/Home (Accessed 11 October 2013).

Newman, I. 1998. *Qualitative-quantitative research methodology: Exploring the interactive continuum*. SIU Press.

Nicholas, J. 2003. Information literacy evaluation: moving towards virtual learning environments. *Electronic Library*, 21 (4): 322-334.

Onwuegbuzie, A. J. 2000. Expanding the Framework of Internal and External Validity in Quantitative Research.

Opitz, M. 1998. Computer-Based Instruction. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 72 (1): 4-5.

Oppenheim, A. 2001. Attitude scaling. *Questionnaire design, interviewing and attitude measurement. London: Continuum*: 187-209.

Orlikowski, W. J. and Baroudi, J. J. 1991. Studying information technology in organizations: Research approaches and assumptions. *Information systems research*, 2 (1): 1-28.

Oxford. 2003. *The Oxford Companion to The History of Modern Science*. New York: Oxford University Press.

Papasmadov, M. 2012a. *My SketchUp Plugins*. Available: https://sites.google.com/site/morisdov/ (Accessed 17 January 2012).

Papasmadov, M. 2012b. *My SketchUp Plugins*. Available: https://sites.google.com/site/morisdov/ (Accessed 17 January 2012).

Patil, A. and Codner, G. 2007. Accreditation of engineering education: review, observations and proposal for global accreditation. *European Journal of Engineering Education*, 32 (6): 639-651.

Patton, M. Q. 1990. *Qualitative evaluation and research methods*. SAGE Publications, inc.

Paul, R. and Whyte, W. 2012. *Basic Surveying*. Routledge.

Perdomo, J. L., Shiratuddin, M. F., Thabet, W. and Ananth, A. 2005. Interactive 3D visualization as a tool for construction education. In: Proceedings of *Information Technology Based Higher Education and Training, 2005. ITHET 2005. 6th International Conference on*. IEEE, F4B/23-F24B/28.

Pickard, A. J. and Childs, S. 2007. *Research methods in information*. Facet London.

Price, D. J. 1955. Medieval land surveying and topographical maps. *Geographical Journal*: 1-7.

Professional Land Surveyor. 2012. *A brief history of Land Surveying*. Available: http://plsurvey.com/surveyinghistory.htm (Accessed 27 October).

Quinn, P. M. 2002. Qualitative research and evaluation methods. *California EU: Sage Publications Inc*,

Reeves, T. C. and Hedberg, J. G. 2003. *Interactive learning systems evaluation*. Educational Technology.

Richeson, A. W. 1966. *English land measuring to 1800 : Instruments and Practices*. Cambridge (Mass.): The Society for the History of Technology & M.I.T.Press.

Roberts, G. W. and Gray, J. 2009. NEST - A New Web Based Teaching Tool for Engineering Surveying. Paper presented at the *FIG Congress*. Sydney, Australia, 11-16 April 2010. 8.

Rossi, C., Russo, F. and Russo, F. 2009. Measuring Distance. *Ancient Engineers& Inventions*: 13-25.

Roy, S. K. 2010. *Fundamentals of surveying*. PHI Learning Pvt. Ltd.

Rüeger, J. M. 1990. *Electronic distance measurement*. Springer.

Russell, J. S. and Stouffer, W. B. 2005. Survey of the National Civil Engineering Curriculum. *Journal of Professional Issues in Engineering Education & Practice*, 131 (2): 118-128.

Sage Publications, I. 2003. *Target Populations and Samples. How to Sample in Surveys. SAGE Publications, Inc*. Available: http://dx.doi.org/10.4135/9781412984478 (Accessed 18 July 2013).

Salazar, G. F., Polat, I. H. and Almeida, J. C. 2003. The Role of the 3D Parametric Building Model in the Future Education and Practice of Civil Engineering and Construction. *Bridges*, 10 (40704): 39.

Salkind, N. J. 2010. *Encyclopedia of research design*. Sage.

Sampaio, A. Z., Ferreira, M. M., Rosário, D. P. and Martins, O. P. 2010. 3D and VR models in Civil Engineering education: Construction, rehabilitation and maintenance. *Automation in Construction*, 19 (7): 819-828.

Santos, J. R. A. 1999. Cronbach's alpha: A tool for assessing the reliability of scales. *Journal of extension*, 37 (2): 1-5.

Scarpino, M. 2010. Automatic SketchUp: Creating 3-D Models in Ruby.

Schensul, S. L., Schensul, J. J. and LeCompte, M. D. 1999. *Essential ethnographic methods: Observations, interviews, and questionnaires*. Rowman Altamira.

Seidel, T. and Shavelson, R. J. 2007. Teaching effectiveness research in the past decade: The role of theory and research design in disentangling meta-analysis results. *Review of educational research*, 77 (4): 454-499.

Shadish, W. R., Cook, T. D. and Campbell, D. T. 2002. *Experimental and quasi-experimental designs for generalized causal inference*. Wadsworth Cengage learning.

Sherif, A. and Mekkawi, H. 2010. Excavation Game: Computer-Aided-Learning Tool for Teaching Construction Engineering Decision Making. *Journal of Professional Issues in Engineering Education & Practice*, 136 (4): 188-196.

Shi, W. 2010. *Principles of modeling uncertainties in spatial data and spatial analyses*. CRC Press.

Shields, J. M. 1972. Project Planning. *Journal of the Surveying and Mapping Division*, 98 (1): 61-66.

Shirazi, A. and Behzadan, A. H. 2013. Technology-enhanced learning in construction education using mobile context-aware augmented reality visual simulation. In: Proceedings of *Winter Simulation Conference*. 3074-3085.

Shortis, M., Leahy, F., Ogleby, C., Kealy, A. and Ellis, F. 2004. Web-based learning of spatial design and analysis concepts using simulations and visual feedback. *Survey Review*, 37 (291): 344-359.

Shortis, M. and Woodhouse, N. 2001. Learning design of survey networks using a web-based simulator. In: Proceedings of *5th Conference on Optical 3-D Measurement Techniques*. 447-454.

Simmons, S. 2012. The structure of academic surveying and spatial science programs in Australia and New Zealand as an educational pathway to land surveyor registration. *Azimuth*,

Simons, H. and Usher, R. 2000. *Situated ethics in educational research*. Psychology Press.

Simpson, C. and De Paor, D. 2010. Restoring maps and memoirs to four-dimensional space using virtual globe technology: a case study from the Scottish Highlands. *Geological Society, London, Special Publications*, 335 (1): 429-441.

Singh, S. and Nieman, S. 2010. *Beginning Google SketchUp for 3D Printing*. Springer.

Skene, A., King, S., Patterson, J. and Cheng, T. C. K. 2013. Make Your Teaching Innovations Count: A primer on quantitative approaches in educational research.

SketchUcation. 2012. *Sketchup Plugins*.

Sketchup. 2013. *Sketchup\3D for Everyone* (online). Available: http://sketchup.google.com/intl/en/index.html (Accessed 11 January 2013).

Smith, D. 2008. *Surveying, Mapping and GIS: Epic Battles: GIS vs. Surveying* (online). Available: http://surveying-mapping-gis.blogspot.com/2008/07/epic-battle-gis-vs-surveying.htnl?m=1 (Accessed 19 February 2013).

Soler, T. 2013. William Bowie: Eminent Scientist and First Chairman (1926–1940) of ASCE's Surveying and Mapping Division. *Journal of Surveying Engineering*, 140 (1): 2-11.

South African Qualifications Authority. 2001. Criteria and Guidelines for Assessment of NQF Registered Unit standards and Qualifications. 11.

Speirs, N. 1999. *Claims in civil engineering contracts*.

Staiger, R. 2009. Push the Button – or Does the "Art of Measurement" Still Exist? Paper presented at the *FIG Working Week 2009*. Israel, 3-8 May 2009. FIG,

Staples, M. 1998. The illusion of choice in computer-aided learning. *Journal of Information Ethics*, 7 (1): 36-41.

Stine, D. J. 2012. *Google SketchUp 8 for Interior Designers*. SDC Publications.

Sweeney, K. 2005. International Recognition of Engineering Degrees, Programs, and Accreditation Systems. *Educating the Engineer of 2020*,

Tal, D. 2010. *Google SketchUp for Site Design: A Guide to Modeling Site Plans, Terrain and Architecture*. John Wiley & Sons.

Tarolli, P., Arrowsmith, J. R. and Vivoni, E. R. 2009. Understanding earth surface processes from remotely sensed digital terrain models. *Geomorphology*, 113 (1): 1-3.

Tashakkori, A. and Teddlie, C. 1998. *Mixed methodology: Combining qualitative and quantitative approaches*. Sage.

Taylor, C. S. 2013. *Validity and Validation*. Oxford University Press.

TechTarget. 2013. *Learning Management System (LMS)* (online). Available: http://searchcio.techtarget.com/definition/learning-management-system (Accessed 12 October 2013).

Tinio, V. 2003. ICT in Education: e-Primers for the information economy, society and policy. *New York, NY: United Nations Development Programme*,

Trimble. 2012. *3D Warehouse*. Available: https://3dwarehouse.sketchup.com/ (Accessed

Trinder, J. and Han, S. 1999. Impact of New Technologies on Geomatics in 2010. *Australian Surveyor*, 44 (1): 29-34.

Truscott, D. M., Swars, S., Smith, S., Thornton-Reid, F., Zhao, Y., Dooley, C., Williams, B., Hart, L. and Matthews, M. 2009. A cross-disciplinary examination of the prevalence of mixed methods in educational research: 1995–2005. *International Journal of Social Research Methodology*, 13 (4): 317-328.

University, N. 2013. *Xerte Project*. Available: http://www.nottingham.ac.uk/xerte/index.aspx (Accessed 18 October 2013).

University of Leeds. 2006. *Using a theodolite* (videorecording). Leeds [Johannesburg]: University of Leeds ; Dept. of Civil Engineering., University of Leeds. Audio Visual Service., Film & Video Showcase [distributor],.

University of New South Wales. 2014. *Dumpy Level*. Available: http://www.gmat.unsw.edu.au/currentstudents/ug/projects/f_pall/html/l1.html (Accessed 11 August 2014).

University of the Free State. 2003. Open, Blended, and Engaged Learning at the University of the Free State. University of the Free State. Available: http://www.ufs.ac.za/dl/userfiles/Documents/00000/121_eng.pdf (Accessed 12 October 2013).

Ustinova, N., Kala, V., Mill, T. and Ellmann, A. 2012. Geodetic surveying studies for civil engineering students at Tallinn University of Technology. *Geodesy and Cartography*, 38 (2): 86-91.

Vaal University of Technology. 2013. *Courses and Programmes | Faculty of Engineering and Technology*. Available: http://www.vut.ac.za/index.php/faculties/engineering-a-technology/courses-a-programmes (Accessed 12 October 2013).

van Kreveld, M. 1997. Algorithms for triangulated terrains. In: Plášil, F. and Jeffery, K. eds. *SOFSEM'97: Theory and Practice of Informatics*. Springer Berlin Heidelberg, 19-36. Available: http://dx.doi.org/10.1007/3-540-63774-5_95 (Accessed 15 August 2014).

Végső, F. 2010. Data acquisition and integration 2.

Velichová, D. 2002. Geometry in engineering education. *European Journal of Engineering Education*, 27 (3): 289-296.

Venkatramaiah, C. 1996. *Textbook of Surveying*. Second ed. Hyderabad: Sangam Books Ltd.

Visualization Laboratory. 2011. *SimuSurveyX*. Available: http://simusurveyx.caece.net/ (Accessed 15 November 2011).

Vithal, R. and Jansen, J. 2012. *Designing your first research proposal: a manual for researchers in education and the social sciences*. Juta and Company Ltd.

Vogt, W. P. and Johnson, R. B. 2011. *Dictionary of statistics & methodology: A nontechnical guide for the social sciences*. Sage.

Wallace, D. 2003. The Impact of Technology on Surveying: Past, Present, and Future. In: Proceedings of *7th South East Asian Survey Congress*.

Wallen, N. E. and Fraenkel, J. R. 2001. *Educational research: A guide to the process*. Psychology Press.

Wallis, D. A. 2005a. History of Angle Measurement. Paper presented at the *From Pharaohs to Geoinformatics*. Cairo, Egypt, a6-21 April 2005. FIG,

Wallis, D. A. 2005b. History of Angle Measurement. Paper presented at the *From Pharaohs to Geoinformatics*. Cairo, April 2005. FIG, 17.

Widder, M. and Gorsky, P. 2013. How students use a software application for visualizing 3D geometric objects to solve problems. *Journal of Computers in Mathematics and Science Teaching*, 32 (1): 89-120.

Wilkinson, D. and Birmingham, P. 2003. *Using research instruments: A guide for researchers*. Psychology Press.

Williams, M. 2002. *Making sense of social research*. Sage.

Wirski, R., Brownfield, G. and Oliver, R. 2004. Exploring SCORM and the national flexible learning toolboxes. In: Proceedings of *Beyond the comfort zone: Proceedings of the 21st ASCILITE Conference*. 938-947.

Witness Tree Surveying. 2013. *What is Surveying?* Available: https://witnesstreesurveying.com/ (Accessed 12 January 2013).

Wolf, P. R. 2002. Surveying and mapping: History, current status, and future projections. *Journal of Surveying Engineering*, 128 (3): 79-107.

Yaremko, R. M. 1986. *Handbook of research and quantitative methods in psychology: For students and professionals*. Psychology Press.

Yeh, I. 2005. *Virtual reality learning system for surveying practice, National Science Council*. Taiwan, Tech. Rep.

Yin, R. K. 2009. *Case study research: Design and methods*. sage.

Yoichi, K., Hirofumi, C., Tatsuya, O. and Kunihiko, O. 2006. Computer-Assisted Surveying Education Using 3D Simulator. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, XXXVI (Part 6): 5.

Young, B., Ellobody, E. and Hu, T. W. 2011. 3D Visualization of Structures Using Finite-Element Analysis in Teaching. *Journal of Professional Issues in Engineering Education & Practice*, 138 (2): 131-138.

Appendix A – Competency Test Rubric

Note: Student has to obtain 70% minimum in order to pass the skills test

COMPETENCY TO BE EVALUATED	Tolerance	Mark Allocation	Score
Task 1 (Setting-up, centring and levelling of a theodolite)			
1. Centring the instrument over the point (5mm=15, 10mm=10, 15mm=5)	0 - 4mm	20%	
2. Levelling the circular / plate bubble (2 grad=10), (3 grad=0)	1 grad	15%	
3. Instrument set at correct height, setting the legs correctly, tribrach central to tripod head (approx. 7marks each)		15%	
4. Measuring height of instrument	5mm	10%	
5. Time taken to complete the entire task (7½min=30%, 8min=20%, 8½min=10%, 9min=0%)	7 mins	40%	
TIME TAKEN: __________ ***INSTR. HT:*** __________			
Task 2 (Orienting a theodolite to a given direction)			
1. Setting and locking the protractor on a given direction	30"	25%	
2. Sighting the orienting point and bisecting crosshairs on object	30"	25%	
3. Unlocking protractor and re-observing point, reading direction.	Pass/Fail	20%	
4. Time taken to complete the entire task (5½mins=20%) (6mins=10%)	5 mins	30%	
TIME TAKEN: __________			
Task 3 (Observing an arc of observations) - 3 points + R.O.			
1. Accuracy of readings	30"	15%	
2. Bisecting crosshairs on object	Pass/Fail	15%	
3. Correct order and rotation of observations	Pass/Fail	20%	
4. Booking of results (neatness, method & mean)		20%	
5. Time taken to complete the entire task (11min - 20% 12min - 10%)	10mins	30%	
TIME TAKEN: __________			
Task 4 (Observing vertical angles and reducing the observations)			
1. Accuracy of readings	30"	20%	
2. Bisecting crosshairs on object	Pass/Fail	20%	
3. Correctness of booking and checking (add up to 360°)	Pass/Fail	30%	
4. Time taken to complete the entire task (5½min - 20% 6min - 10%)	5 mins	30%	
TIME TAKEN: __________			
Task 5 (Observing and booking a tache spot shot.)			
1. Measure height of instrument (5–7mm=10), (7–10mm=5), (>10mm=0)	< 4mm	15%	
2. Accuracy of the angular readings	30"	15%	
3. Accuracy of the staff readings	2 mm	20%	
4. Booking of results [(neatness (6) & method (14)]		20%	
5. Time taken to complete the entire task (6min - 20% 7min - 10%)	5 mins	30%	
TIME TAKEN: __________			
Task 6 (Set up a level and find the height difference two points.)			
1. Accuracy of the readings (3mm–4mm=10), (5mm=5), (>5mm=0)	2 mm	20%	
2. Setting up the instrument and levelling correctly	Pass/Fail	20%	
3. Bisecting the Crosshairs on the object	Pass/Fail	10%	
4. Booking and reducing of results (layout, neatness & correctness)		20%	
5. Time taken to complete the entire task (6min - 20% 7min - 10%)	5 mins	30%	
TIME TAKEN: __________			

Please note:	*COMMENTS*
• *If instrument is more than 20 mm off the centre of peg then student fails the test.*	
• *If the instrument tripod legs are not pushed into the ground securely then student fails the test.*	
• *If the instrument is setup too high and is not observable, then student fails the test.*	
• *If the instrument is not levelled accordingly, then student fails the test.*	

Appendix B – Summary of Student ITS Information

Test Scores				Test Scores			
No.	Control	No.	Experimental	No.	Control	No.	Experimental
1	0	1	70	49	85	49	70
2	0	2	70	50	85	50	75
3	20	3	70	51	85	51	75
4	65	4	70	52	85	52	80
5	70	5	70	53	86	53	80
6	70	6	70	54	87	54	80
7	70	7	70	55	89	55	80
8	70	8	70	56	89	56	80
9	70	9	70	57	89	57	85
10	70	10	70	58	89	58	90
11	70	11	70	59	90	59	90
12	70	12	70	60	90	60	90
13	70	13	70	61	90	61	90
14	70	14	75	62	90	62	90
15	70	15	75	63	90	63	95
16	70	16	75	64	90	64	100
17	70	17	80	65	91	65	100
18	70	18	80	66	91	66	100
19	70	19	80	67	91	67	70
20	70	20	80	68	91	68	70
21	70	21	80	69	91	69	70
22	70	22	80	70	91	70	70
23	70	23	80	71	92	71	70
24	70	24	80	72	92	72	70
25	70	25	80	73	92	73	70
26	70	26	83	74	92	74	70
27	70	27	85	75	92	75	70
28	70	28	85	76	93	76	70
29	70	29	85	77	93	77	70
30	70	30	90	78	93	78	72
31	70	31	90	79	93	79	77
32	70	32	90	80	93	80	85
33	70	33	90	81	93	81	95
34	70	34	90	82	93	82	70
35	72	35	90	83	94	83	70
36	75	36	90	84	94	84	70
37	75	37	95	85	95	85	70
38	75	38	95	86	95	86	70
39	75	39	95	87	95	87	70
40	75	40	95	88	95	88	70
41	76	41	95	89	95	89	70
42	80	42	95	90	95	90	70
43	80	43	95	91	95	91	70
44	80	44	95	92	95	92	70
45	82	45	98	93	96	93	70
46	83	46	98	94	96	94	70
47	85	47	100	95	97	95	70
48	85	48	70	96	97	96	70

No.	Control	No.	Experimental	No.	Control	No.	Experimental
97	97	97	70	144	85	144	70
98	98	98	80	145	90	145	70
99	99	99	90	146	90	146	70
100	100	100	90	147	95	147	70
101	100	101	95	148	95	148	70
102	100	102	100	149	95	149	70
103	100	103	100	150	96	150	70
104	100	104	55	151	100	151	70
105	100	105	70	152	100	152	70
106	100	106	70	153	100	153	70
107	100	107	70	154	0	154	70
108	100	108	70	155	20	155	70
109	100	109	70	156	50	156	70
110	50	110	70	157	60	157	70
111	65	111	70	158	65	158	70
112	70	112	70	159	70	159	70
113	70	113	70	160	70	160	70
114	70	114	70	161	70	161	70
115	70	115	70	162	70	162	70
116	70	116	70	163	70	163	75
117	70	117	70	164	70	164	75
118	70	118	70	165	70	165	75
119	70	119	70	166	70	166	75
120	70	120	78	167	70	167	75
121	70	121	80	168	70	168	75
122	75	122	80	169	70	169	75
123	75	123	80	170	70	170	75
124	75	124	80	171	70	171	75
125	80	125	80	172	73	172	75
126	80	126	80	173	75	173	80
127	82	127	80	174	75	174	80
128	82	128	85	175	75	175	80
129	87	129	90	176	75	176	80
130	90	130	90	177	77	177	80
131	90	131	90	178	80	178	80
132	95	132	95	179	80	179	80
133	95	133	95	180	83	180	80
134	98	134	100	181	83	181	80
135	100	135	60	182	85	182	80
136	100	136	60	183	85	183	80
137	100	137	70	184	90	184	80
138	100	138	70	185	90	185	80
139	100	139	70	186	93	186	80
140	100	140	70	187	95	187	80
141	50	141	70	188	96	188	80
142	76	142	70	189	98	189	80
143	80	143	70	190	100	190	80

No.	Control	No.	Experimental	No.	Control	No.	Experimental
191	100	191	80	237	70		
192	100	192	85	238	70		
193	100	193	85	239	70		
194	100	194	90	240	70		
195	30	195	90	241	70		
196	70	196	90	242	70		
197	70	197	90	243	70		
198	70	198	90	244	70		
199	70	199	90	245	70		
200	70	200	90	246	70		
201	75	201	90	247	70		
202	80	202	90	248	70		
203	80	203	90	249	70		
204	80	204	90	250	70		
205	82	205	90	251	70		
206	82	206	90	252	70		
207	85	207	95	253	70		
208	87	208	95	254	70		
209	87	209	95	255	70		
210	87	210	95	256	70		
211	88	211	100	257	70		
212	90	212	100	258	70		
213	90	213	100	259	70		
214	92			260	70		
215	92			261	70		
216	93			262	70		
217	94			263	75		
218	94			264	75		
219	94			265	75		
220	95			266	75		
221	95			267	77		
222	95			268	79		
223	95			269	80		
224	96			270	80		
225	97			271	82		
226	98			272	84		
227	100			273	84		
228	100			274	86		
229	35			275	87		
230	40			276	88		
231	56			277	89		
232	60			278	90		
233	60			279	90		
234	70			280	93		
235	70			281	95		
236	70						

Appendix C – Likert-Type Scale Questionnaire

	Questions	Circle your Answer				
1	The SketchUp 3D model of the theodolite visually resembled an actual theodolite	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
2	The SketchUp 3D model of the theodolite assisted my understanding of the basic structure of the theodolite	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
3	The SketchUp 3D model of the automatic level visually resembled an actual automatic level	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
4	The SketchUp 3D model of the automatic level assisted my understanding of the basic structure of the automatic level	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
5	The SketchUp 3D models of the tripod, staff and ranging rod visually resembled an actual tripod, staff and ranging rod	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
6	The exposure to the 3D animated models of surveying equipment prepared me sufficiently for all traversing, levelling and tacheometry surveying practicals	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
7	The 3D animated models of surveying equipment operation improved my understanding of difficult to understand surveying practical concepts	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
8	The SketchUp 3D animated models of the theodolite assisted me to understand how to set-up and operate the theodolite	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
9	The 3D animated models assisted me with orienting a theodolite (finding a direction)	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
10	The 3D animated models assisted me with observing and booking an Arc of Observations	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
11	The 3D animated models assisted me with observing and booking vertical angles	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
12	The 3D animated models assisted me with observing and booking a tacheometry point	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
13	The SketchUp 3D animated model of the automatic level assisted me to understand how to operate the automatic level	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
14	The 3D animated models assisted me with observing and booking the height difference between two points	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
15	The SketchUp in-class lessons of equipment operation assisted my understanding of the proper field procedure	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
16	The SketchUp in-class lessons of 3D animated models of surveying equipment assisted my overall learning experience	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
17	The exposure to the 3D animated models of surveying equipment prepared me sufficiently for the end of semester competency test	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
18	The SketchUp in-class lessons of 3D animated models of surveying equipment were visually stimulating and interesting	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
19	I would recommend the use of SketchUp software in other Civil Engineering subjects	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

Appendix D – Correlation Coefficients

Correlations

ALL VALUES WITH A * or ** ARE SIGNIFICANT

		The SketchUp 3D model of the theodolite visually resembled an actual theodolite	The SketchUp 3D model of the theodolite assisted my understanding of the basic structure of the theodolite	The SketchUp 3D model of the automatic level visually resembled an actual automatic level	The SketchUp 3D model of the automatic level assisted my understanding of the basic structure of the automatic level	The SketchUp 3D models of the tripod, staff and ranging rod visually resembled an actual tripod, staff and ranging rod	The exposure to the 3D animated models of surveying equipment prepared me sufficiently for all traversing, levelling and tacheometry surveying practicals	The 3D animated models of surveying equipment operation improved my understanding of difficult to understand surveying practical concepts	The SketchUp 3D animated models of the theodolite assisted me to understand how to set-up and operate the theodolite	The 3D animated models assisted me with orienting a theodolite (finding a direction)	The 3D animated models assisted me with observing and booking an Arc of Observations	The 3D animated models assisted me with observing and booking vertical angles	The 3D animated models assisted me with observing and booking a tacheometry point	The SketchUp 3D animated model of the automatic level assisted me to understand how to operate the automatic level	The 3D animated models assisted me with observing and booking the height difference between two points	The SketchUp in-class lessons of equipment operation assisted my understanding of the proper field procedure	The SketchUp in-class lessons of 3D animated models of surveying equipment assisted my overall learning experience	The exposure to the 3D animated models of surveying equipment prepared me sufficiently for the end of semester competency test	The SketchUp in-class lessons of 3D animated models of surveying equipment were visually stimulating and interesting	I would recommend the use of SketchUp software in other Civil Engineering subjects
Spearman's rh The SketchUp 3D model of the theodolite visually resembled an actual theodolite	Correlation Co	1000																		
	Sig. (2-tailed)																			
	N	83																		
The SketchUp 3D model of the theodolite assisted my understanding of the basic structure of the theodolite	Correlation Co	.556**	1000																	
	Sig. (2-tailed)	.000																		
	N	83	83																	
The SketchUp 3D model of the automatic level visually resembled an actual automatic level	Correlation Co	.508**	.551**	1000																
	Sig. (2-tailed)	.000	.000																	
	N	83	83	83																
The SketchUp 3D model of the automatic level assisted my understanding of the basic structure of the automatic level	Correlation Co	.525**	.372**	.626**	1000															
	Sig. (2-tailed)	.000	.001	.000																
	N	83	83	83	83															
The SketchUp 3D models of the tripod, staff and ranging rod visually resembled an actual tripod, staff and ranging rod	Correlation Co	.476**	.473**	.406**	.404**	1000														
	Sig. (2-tailed)	.000	.000	.000	.000															
	N	83	83	83	83	83														
The exposure to the 3D animated models of surveying equipment prepared me sufficiently for all traversing, levelling and tacheometry	Correlation Co	.565**	.399**	.432**	.476**	.403**	1000													
	Sig. (2-tailed)	.000	.000	.000	.000	.000														
	N	83	83	83	83	83	83													
The 3D animated models of surveying equipment operation improved my understanding of difficult to understand surveying practical concepts	Correlation Co	.366**	.343**	.389**	.462**	.252*	.348**	1000												
	Sig. (2-tailed)	.001	.001	.000	.000	.022	.001													
	N	83	83	83	83	83	83	83												
The SketchUp 3D animated models of the theodolite assisted me to understand how to set-up and operate the theodolite	Correlation Co	.350**	.263*	.247*	.354**	.223*	.300**	.337**	1000											
	Sig. (2-tailed)	.001	.016	.024	.001	.043	.006	.002												
	N	83	83	83	83	83	83	83	83											
The 3D animated models assisted me with orienting a theodolite (finding a direction)	Correlation Co	.319**	.272*	.267*	.386**	.233*	.216*	.287**	.507**	1000										
	Sig. (2-tailed)	.003	.013	.015	.000	.034	.050	.009	.000											
	N	83	83	83	83	83	83	83	83	83										
The 3D animated models assisted me with observing and booking an Arc of Observations	Correlation Co	.337**	.421**	.235*	.152	.247*	.292**	.329**	.303**	.346**	1000									
	Sig. (2-tailed)	.002	.000	.033	.171	.024	.007	.002	.005	.001										
	N	83	83	83	83	83	83	83	83	83	83									
The 3D animated models assisted me with observing and booking vertical angles	Correlation Co	.454**	.385**	.191	.369**	.309**	.397**	.281*	.467**	.314**	.537**	1000								
	Sig. (2-tailed)	.000	.000	.084	.001	.005	.000	.010	.000	.004	.000									
	N	83	83	83	83	83	83	83	83	83	83	83								
The 3D animated models assisted me with observing and booking a tacheometry point	Correlation Co	.337**	.245*	.130	.214	.298**	.307**	.443**	.450**	.422**	.454**	.565**	1000							
	Sig. (2-tailed)	.002	.025	.242	.052	.006	.005	.000	.000	.000	.000	.000								
	N	83	83	83	83	83	83	83	83	83	83	83	83							
The SketchUp 3D animated model of the automatic level assisted me to understand how to operate the automatic level	Correlation Co	.503**	.422**	.446**	.391**	.427**	.441**	.459**	.512**	.379**	.399**	.499**	.517**	1000						
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000							
	N	83	83	83	83	83	83	83	83	83	83	83	83	83						
The 3D animated models assisted me with observing and booking the height difference between two points	Correlation Co	.436**	.360**	.307**	.393**	.425**	.340**	.437**	.561**	.439**	.509**	.535**	.534**	.566**	1000					
	Sig. (2-tailed)	.000	.001	.005	.000	.000	.002	.000	.000	.000	.000	.000	.000	.000						
	N	83	83	83	83	83	83	83	83	83	83	83	83	83	83					
The SketchUp in-class lessons of equipment operation assisted my understanding of the proper field procedure	Correlation Co	.256*	.172	.261*	.248*	.264*	.351**	.131	.269*	.227*	.173	.313**	.236*	.407**	.374**	1000				
	Sig. (2-tailed)	.020	.121	.017	.024	.016	.001	.239	.014	.039	.119	.004	.032	.000	.000					
	N	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83				
The SketchUp in-class lessons of 3D animated models of surveying equipment assisted my overall learning experience	Correlation Co	.291**	.424**	.131	.138	.304**	.204	.288**	.388**	.315**	.286**	.312**	.273*	.282**	.403**	.330**	1000			
	Sig. (2-tailed)	.008	.000	.237	.214	.005	.064	.008	.000	.004	.009	.004	.012	.010	.000	.002				
	N	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83			
The exposure to the 3D animated models of surveying equipment prepared me sufficiently for the end of semester competency test	Correlation Co	.202	.334**	.217*	.184	.248*	.277*	.271*	.436**	.377**	.335**	.425**	.461**	.469**	.475**	.409**	.406**	1000		
	Sig. (2-tailed)	.066	.002	.049	.096	.024	.011	.013	.000	.000	.002	.000	.000	.000	.000	.000	.000			
	N	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83		
The SketchUp in-class lessons of 3D animated models of surveying equipment were visually stimulating and interesting	Correlation Co	.216*	.288**	.254*	.153	.289**	.158	.215	.368**	.311**	.239*	.346**	.339**	.341**	.253*	.262*	.373**	.433**	1000	
	Sig. (2-tailed)	.050	.008	.021	.166	.008	.153	.051	.001	.004	.030	.001	.002	.002	.021	.017	.001	.000		
	N	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	
I would recommend the use of SketchUp software in other Civil Engineering subjects	Correlation Co	.089	.249*	.195	.129	.241*	.115	.386**	.170	.163	.202	-.035	.141	.072	.129	.142	.397**	.303**	.316**	1000
	Sig. (2-tailed)	.423	.023	.077	.245	.028	.302	.000	.125	.141	.067	.751	.204	.515	.244	.199	.000	.005	.004	
	N	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83

**. Correlation is significant at the 0.01level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix E – Factor Analysis

Rotated Component Matrixa

	Component				
	1	2	3	4	5
The SketchUp 3D model of the theodolite visually resembled an actual theodolite	.724	.268	.234	-.011	.029
The SketchUp 3D model of the theodolite assisted my understanding of the basic structure of the theodolite	.611	.448	-.076	.332	-.052
The SketchUp 3D model of the automatic level visually resembled an actual automatic level	.797	-.020	.150	.158	.014
The SketchUp 3D model of the automatic level assisted my understanding of the basic structure of the automatic level	.702	-.103	.506	.086	.001
The SketchUp 3D models of the tripod, staff and ranging rod visually resembled an actual tripod, staff and ranging rod	.592	.247	-.006	.308	.221
The exposure to the 3D animated models of surveying equipment prepared me sufficiently for all traversing, levelling and tacheometry surveying practicals	.673	.244	.053	-.076	.208
The 3D animated models of surveying equipment operation improved my understanding of difficult to understand surveying practical concepts	.388	.187	.490	.343	-.296
The SketchUp 3D animated models of the theodolite assisted me to understand how to set-up and operate the theodolite	.121	.231	.759	.136	.219
The 3D animated models assisted me with orienting a theodolite (finding a direction)	.107	.267	.635	.122	.067
The 3D animated models assisted me with observing and booking an Arc of Observations	.177	.788	.079	.145	-.116
The 3D animated models assisted me with observing and booking vertical angles	.184	.732	.290	-.044	.227
The 3D animated models assisted me with observing and booking a tacheometry point	.105	.693	.394	.088	.068
The SketchUp 3D animated model of the automatic level assisted me to understand how to operate the automatic level	.440	.506	.393	.059	.228
The 3D animated models assisted me with observing and booking the height difference between two points	.308	.448	.508	.142	.215
The SketchUp in-class lessons of equipment operation assisted my understanding of the proper field procedure	.162	.042	.127	.078	.833
The SketchUp in-class lessons of 3D animated models of surveying equipment assisted my overall learning experience	.157	.161	.310	.622	.297
The exposure to the 3D animated models of surveying equipment prepared me sufficiently for the end of semester competency test	.065	.476	.205	.356	.413
The SketchUp in-class lessons of 3D animated models of surveying equipment were visually stimulating and interesting	.034	.227	.315	.492	.363
I would recommend the use of SketchUp software in other Civil Engineering subjects	.115	-.008	.045	.878	-.069

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization. a.

Rotation converged in 8 iterations.