Factors that influence Mathematics teachers' use of dynamic software for instruction

by

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Submitted in fulfilment of the requirements for the degree
Master of Education (Science, Mathematics and Technology)
in the Faculty of Education
University of Pretoria

Supervisor: Professor G.H. Stols

January 2015

"Be anxious for nothing, but in everything by prayer and supplication, with thanksgiving, let your requests be made known to God; and the peace of God, which surpasses all understanding, will guard your hearts and minds through Christ Jesus. I can do all things through Christ who strengthens me." (Phil. 4:6-7, 13, NKJV)

Acknowledgements

First of all, I would like to honour my Heavenly Father for giving me the strength to complete my study to the best of my ability.

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

I would also like to thank the following people and institutions for supporting me during my study:

- My supervisor, Professor Gerrit Stols. Thank you for your guidance throughout my study.
- The V.A.W. for allowing me to collect data among their members. I would like to thank Dr. Danie Brink and especially Mr. Valentyn van der Merwe for his assistance with handing out and collecting my questionnaires.
- All the respondents who took the time to complete the questionnaires.
- The Internal Statistical Consultation Service of the University of Pretoria. Ms. Jaqui Sommerville, thank you for your friendliness and help in importing the data into SAS and for the output provided. Dr. Liebie Louw, thank you for your guidance with regards to the statistical analysis of the data.
- The University of Pretoria for providing me with a post graduate bursary.
- The most important people in my life – my family. Thank you for all your support and encouragement throughout my study. Without your support it would have been a lot tougher to complete my study.

Abstract

This study investigated factors that influence mathematics teachers' use of dynamic mathematics software (specifically GeoGebra) for teaching and learning. Since society is so intertwined with technology, Keitel (1997) argues that it is becoming easier to find technological solutions for problems rather than to search for non-technological solutions. This could also hold true for teachers who need to adjust to teaching mathematics with the aid of resources such as Information and Communication Technology (ICT) in a changing society. One of the key trends reported on in the 2013 Higher Education edition of the 2013 NMC report is that the teacher's role keeps on changing because of the ever increasing amount of resources available to students via the Internet (Johnson, Adams Becker, Cummins, Estrada, Freeman & Ludgate, 2013). In order to explore factors that influence mathematics teachers' use of GeoGebra for instruction, a quantitative research design was used. Participants in the study were members of the V.A.W. These participants were purposefully selected since the organisation regularly has training workshops on GeoGebra and most of the organisation's members were therefore familiar with GeoGebra. In order to obtain as large a response as possible, a website link to an e-survey, as well as an invitation to participate in the study were e-mailed in addition to hard copies of the survey which were distributed and collected. Multiple regression analysis was used to investigate the influence of the four UTAUT (Unified Theory of Acceptance and Use of Technology) constructs, namely Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC) (independent variables) on teachers' intention to use GeoGebra (dependent variable). Correlation statistics was used to establish whether correlations between the four UTAUT constructs and teachers' intention to use GeoGebra existed, and if it did, how significant the correlations were – between each item on the survey as well as each UTAUT construct on teachers' intention to use GeoGebra. This study found that the combination of Performance Expectancy, Effort Expectancy and Social Influence explained 30% of the variance in respondents' *intention* to use GeoGebra. On its own however, only Social Influence was found to be a direct determinant of a respondent's *intention* to use GeoGebra, with Performance Expectancy and Effort Expectancy not being significant predictors by themselves of respondents' *intention* to use GeoGebra. Facilitating Conditions were not found to directly influence whether or not people actually used GeoGebra. Teachers' *intention* to use GeoGebra was found to predict the *actual* use of GeoGebra for teaching and learning.

Key words: ICT integration; technology acceptance; Unified Theory of Acceptance and Use of Technology; UTAUT; Dynamic Geometry Software; DGS; GeoGebra; Mathematics

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DEPARTMENT	Science, Mathematics and Technology Education
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List of Acronyms

AECT	Association for Educational Communication and Technology
BI	Behavioural Intention
CAPS	Curriculum and Assessment Policy Statement
C-TAM-TPB	Combined Technology Acceptance Model and Theory of Planned Behaviour
DoE	Department of Education
DGS	Dynamic Geometry Software (DGS)
EE	Effort Expectancy
FC	Facilitating Conditions

FET	Further Education and Training
ICT	Information and Communication Technology
IDT	Theory of Innovation Diffusion
ILS	Interactive Learning System
IT	Information Technology
ITU	International Telecommunications Union
MM	Motivational Model
MPCU	Model of PC (Personal Computer) Utilization
NCTM	National Council of Teachers of Mathematics
NMC	New Media Consortium
PE	Performance Expectancy
SCT	Social Cognitive Theory
SI	Social Influence
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UTAUT	Unified Theory of Acceptance and Use of Technology
V.A.W.	Vereniging vir Afrikaanse Wiskunde-onderwysers (Association for Afrikaans Teachers of Mathematics)

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CHAPTER 1

Introduction

1.1 Problem Statement

Worldwide new technological developments seem to be the order of the day and technology has a profound impact on our lives on a daily basis. The younger generation grows up with computer related technology at their fingertips. As can be seen in the K-12 edition of the 2013 New Media Consortium (NMC) Horizon report, for example, learners spend a considerable time on the Internet on especially social networks to share their views and interests (Johnson, Adams Becker, Cummins, Estrada, Freeman & Ludgate, 2013). Furthermore, in excess of one billion people use Facebook alone, raising the number to a third of the entire world's population if other social networking platforms are included (ibid.). The International Telecommunications Union, a UN agency collecting data from 200 countries, estimates that there will be approximately 3 billion Internet users by the end of 2014 with two thirds of those users residing in developing countries (ITU, 2014; Stephens & SLIS, 2014). These 3 billion Internet users account for 40% of the world's population with more or less one out of three people from developing countries that are connected to the Internet (ITU, 2014). Worldwide Internet usage increased dramatically. In 1993 the number of Internet users worldwide was only 14 million or 0,3% of the world population and by 2009 it increased to 1, 75 billion or 25,6% of the world population (Internet Live Stats, 2014a). Developing countries' Internet users are estimated to have doubled in 5 years from 0,974 billion in 2009 to 1, 9 billion in 2014 (ITU, 2014). South Africa, which is also a developing country, has seen a great increase in the number of Internet users as well – using either personal computers or cell phones to connect to the Internet. Table 1.1 illustrates the increase in Internet users in South Africa.

Year	Number of Internet Users	Population	% Penetration of the Population
2000	2 400 000	43 690 000	5,5 %
2001	2 750 000	44 409 700	6,2 %
2002	3 100 000	45 129 400	6,8 %
2003	3 283 000	45 919 200	7,1 %
2004	3 523 000	47 556 900	7,4 %
2005	3 600 000	48 861 805	7,4 %
2008	4 590 000	43 786 115	10,5 %
2012	8 500 000	48 375 645	17,6%
2014	24 909 854	53 139 528	46,88%

Table 1.1: Internet usage in South Africa (Internet Live Stats, 2014b; Internet World Stats, n.d.a; Internet World Stats, n.d.b).

One of the key trends reported on in the 2013 Higher Education edition of the 2013 NMC report is that the teacher's role keeps on changing because of the ever increasing amount of resources available to learners via the Internet (Johnson et al., 2013). Since society is so intertwined with technology, Keitel (1997) argues that it is becoming easier to find technological solutions for problems rather than to search for non-technological solutions. Learners are also more motivated to learn when Information and Communication Technology (ICT) is used in the classroom since it relates to their interests and way of life (Birch, 2009). One could therefore argue that teachers should re-evaluate their methods of teaching and learning by utilising resources such as ICT in a changing society.

Despite technology being increasingly available to learners, teachers are not using it optimally for teaching and learning. Research points out that "although teachers in schools show great interest and motivation to learn about the potential of ICT, in practice, use of ICT is relatively low and it is focused on a narrow range of applications" (Sime & Priestly, 2005, p. 131). The integration of ICT by mathematics teachers in South Africa are also very low as reported upon their findings by Howie and Blignaut (2009) based on the International Association for the Evaluation of Educational Achievement's (IEA) Second Information in Technology in Education Study 2006 (SITES). Howie and Blignaut (2009) reported that only 18% of grade 8 mathematics teachers used ICT in teaching and learning activities with the main use of ICT being administration and secondly for monitoring learners' feedback. Mathematics teachers' integration of ICT into their classroom practice was still lower, with only 46% of the teachers responding to questions on their frequency of ICT use, of which 5% indicated that they use ICT once a week and an additional 5% of teachers indicated that they use ICT rigorously for a limited time (Howie & Blignaut, 2009). Seeing that mathematics teachers' integration of ICT (particularly in South Africa) is so low, it raises the following question: If technology is so widely used among society in general and learners in particular, why don't South African mathematics teachers make use of ICT optimally for teaching and learning? This study focuses on mathematics teachers' use of dynamic software – specifically GeoGebra – for teaching and learning since the population under study received training in GeoGebra via workshops and since GeoGebra's is also very popular worldwide. By 2013 the number of languages that GeoGebra has been translated into increased to 50 and the official GeoGebra website's visitors increased from 7 000 per month in 2004 to more than one million unique visitors from 190 countries monthly with 500 000 copies of the free GeoGebra software downloaded monthly (Hohenwarter, 2013). Currently GeoGebra are translated into 62 languages with 180 official International GeoGebra Institutes (IGIs) in 80 countries (Botana & Abánades, 2014).

1.2 Rationale for and Purpose of the Study

As a Mathematics and Information Technology (IT) teacher I am interested in the integration of ICT for the teaching and learning of mathematics. Since ICT is a very broad term, I decided to focus my study on factors that influence mathematics teachers' use of dynamic mathematics software.

ICT can be used as an influential educational tool for exploring different topics within the mathematics curriculum. The only reference of the use of ICT in Mathematics in the Curriculum and Assessment Policy Statement (CAPS) of the South African education department can be found in the overview of topics, of specifically functions. This leaves a lot of room for the CAPS for mathematics to be expanded to integrate ICT with the teaching and learning of mathematics to a much greater extent. The following quote from the DoE (2011) refers to grade 10 mathematics:

> *Generate as many graphs as necessary, initially by means of point-by-point plotting, supported by available technology, to make and test conjectures and hence generalize the effect of the parameter which results in a vertical shift and that which results in a vertical stretch and /or a reflection about the x axis (p.14).*

The South African White Paper on e-Education (DoE, 2004) reports that ICT forms a vital part of Government policy to advance teaching and learning in South Africa. The goal of the policy is to improve the teaching of learners born into the technological age, and who are therefore used to technology. The policy has a further objective to broaden and enhance knowledge across the curriculum, besides teaching technical proficiency.

In a study conducted by Fitzallen (2005), teachers claimed that ICT assisted learners' development of critical thinking, problem-solving and analysing skills. The Teacher Training Agency (TTA) in England propose that ICT could considerably contribute to learners' learning of mathematics, since ICT aids them in: (a) practising and strengthening numeral proficiency, (b) investigating, illustrating and explaining number patterns, (c) basic mathematical modelling through investigating data patterns, (d) discussing patterns that occur in numbers, space and shape, (e) advancing rational thinking and gain knowledge from instantaneous feedback, (f) forming links within and over areas of mathematics, (g) creating images in the mind and (h) writing basic procedures (Chrysanthou, 2008). Seeing that the TTA suggests ICT could contribute a great deal to learners' learning of mathematics, new ways should be explored to make mathematics more understandable to learners, which include the use of ICT. In practice, however, various studies nationally (Howie, 2010; Howie & Blignaut, 2009; Mofokeng & Mji, 2010; Varughese, 2011), and internationally (Fitzallen, 2005; Hennessy, Ruthven & Brindley, 2005; Keong, Horani & Daniel, 2005; Williams, Coles, Wilson, Richardson & Tuson, 2000), report on low levels of ICT integration due to various factors. Some of these factors (resources, knowledge and skills of teachers, institutional, attitudes and beliefs of teachers, assessment and subject culture) for not optimally utilising ICT are discussed in the literature review (see section 2.6).

The purpose of my research is to explore what factors influence mathematics teachers' use of dynamic mathematics software – specifically GeoGebra – in their classrooms for the teaching and learning of mathematics.

1.3 Research Question and Objectives

Technology is used increasingly in society and one therefore needs to consider its undisputed impact on education as well. For the purpose of this study, technology will be viewed as ICT (including hardware and software that is limited to dynamic mathematics software in general and GeoGebra specifically). My research questions stems from the aforementioned. The following research question will be addressed:

1. What factors influence mathematics teachers' use of GeoGebra for the teaching and learning of mathematics?

For this quantitative study, I will test and either reject or fail to reject three null hypotheses related to my theoretical framework that is based on Venkatesh, Morris, Davis and Davis (2003) for mathematics teachers' intention towards utilising GeoGebra for teaching and learning as well as their actual use of GeoGebra. The four constructs of Venkatesh et al.'s (2003, p. 447) Unified Theory of Acceptance and Use of Technology (UTAUT) model are: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC) and they claim that these constructs (moderated by gender, age, experience and voluntariness) have a direct influence on whether or not people accept and use ICT (GeoGebra in this study) (refer to section 2.7 and Figure 2.3). In terms of this study, Performance Expectancy is the extent to which mathematics teachers believe that using GeoGebra will assist them in improving their teaching and learning of mathematics. Effort Expectancy in this study is a mathematics teacher's perceived ease of use of GeoGebra for the teaching and learning of mathematics. Social Influence in this study is a mathematics teacher's opinion on what people who are significant to them (namely their principal, HOD or subject head, colleagues and the school governing body) think about their use of GeoGebra for the teaching and learning of mathematics. Facilitating Conditions in this study are the level of a mathematics teacher's perception that organisational and technical infrastructure (such as resources, knowledge/skills and technical support regarding the use of GeoGebra) exists to support the use of GeoGebra for the teaching and learning of mathematics.

Performance Expectancy, Effort Expectancy and Social Influence might influence a teacher's intention to use GeoGebra for teaching and learning, while Facilitating Conditions might influence his/her actual use of GeoGebra for teaching and learning.

In this study, the UTAUT model is adapted to test three hypotheses via three different models (refer to Figure 2.4).

Model 1 (testing whether or not teachers' Performance Expectancy, Effort Expectancy and Social Influence will have an influence on teachers' intention to use GeoGebra for the teaching and learning of mathematics):

H_0: No relationship between teachers' intention to use GeoGebra and their Performance Expectancy, Effort Expectancy and Social Influence exist.

H_1: There is a relationship between teachers' intention to use GeoGebra and their Performance Expectancy, Effort Expectancy and Social Influence.

Model 2 (testing whether or not Facilitating Conditions will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics):

H_0: Facilitating Conditions' means (FC's means) are the same.

H_1: Facilitating Conditions' means (FC's means) are different.

Model 3 (testing whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics):

H_0: Behavioural intention's means (BI's means) for teachers' *intention* to use GeoGebra are the same.

H_1: Behavioural intention's means (BI's means) for teachers' *intention* to use GeoGebra are different.

The latest South African secondary school curriculum for grades 10-12 (i.e. CAPS for the Further Education and Training phase – FET) for mathematics covers the following topics in paper 1: (a) Algebra and Equations (and inequalities), (b) Patterns and Sequences (c) Finance (growth and decay), (d) Functions and Graphs, (e) Differential Calculus and (f) Probability. The CAPS for the FET phase covers (a) Statistics, (b) Analytical Geometry, (c) Trigonometry and (d) Euclidean Geometry and Measurement in paper 2 (DoE, 2011). The FET phase constitutes grades 10-12. GeoGebra could be used for various topics covered in the South African secondary school curriculum (namely CAPS), since GeoGebra could be used for graphs, statistics, calculus, transformation geometry, geometry and analytical geometry. Teachers' use and beliefs about the use of GeoGebra for teaching and learning and their actual of GeoGebra could differ too. It is therefore worthwhile to consider the following additional hypotheses (stated below) concerning teachers' actual use of GeoGebra for these specific mathematics topics.

Additional Hypotheses concerning the actual use of GeoGebra for various Mathematics Topics:

Concerning Performance Expectancy and *graphs*:

H_0: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *graphs* is independent of their *actual use* of GeoGebra for the teaching and learning of *graphs*.

H_1: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *graphs* is associated with their *actual use* of GeoGebra for teaching and learning *graphs*.

Concerning Effort Expectancy and *graphs*:

H_0: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *graphs* is independent of their *actual use* of GeoGebra for the teaching and learning of *graphs*.

H_1: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *graphs* is associated with their *actual use* of GeoGebra for teaching and learning *graphs*.

Concerning Performance Expectancy and *statistics*:

H_0: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *statistics* is independent of their *actual use* of GeoGebra for the teaching and learning of *statistics*.

H_1: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *statistics* is associated with their *actual use* of GeoGebra for teaching and learning *statistics*.

Concerning Effort Expectancy and *statistics*:

H_0: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *statistics* is independent of their *actual use* of GeoGebra for the teaching and learning of *statistics*.

H_1: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *statistics* is associated with their *actual use* of GeoGebra for teaching and learning *statistics*.

Concerning Performance Expectancy and *calculus*:

H_0: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *calculus* is independent of their *actual use* of GeoGebra for the teaching and learning of *calculus*.

H_1: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *calculus* is associated with their *actual use* of GeoGebra for teaching and learning *calculus*.

Concerning Effort Expectancy and *calculus*:

H_0: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *calculus* is independent of their *actual use* of GeoGebra for the teaching and learning of *calculus*.

H_1: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *calculus* is associated with their *actual use* of GeoGebra for teaching and learning *calculus*.

Concerning Performance Expectancy and *transformation geometry*:

H_0: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *transformation geometry* is independent of their *actual use* of GeoGebra for the teaching and learning of *transformation geometry*.

H_1: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *transformation geometry* is associated with their *actual use* of GeoGebra for teaching and learning *transformation geometry*.

Concerning Effort Expectancy and *transformation geometry*:

H_0: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *transformation geometry* is independent of their *actual use* of GeoGebra for the teaching and learning of *transformation geometry*.

H_1: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *transformation geometry* is associated with their *actual use* of GeoGebra for teaching and learning *transformation geometry*.

Concerning Performance Expectancy and *geometry*:

H_0: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *geometry* is independent of their *actual use* of GeoGebra for the teaching and learning of *geometry*.

H_1: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *geometry* is associated with their *actual use* of GeoGebra for teaching and learning *geometry*.

Concerning Effort Expectancy and *geometry*:

H_0: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *geometry* is independent of their *actual use* of GeoGebra for the teaching and learning of *geometry*.

H_1: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *geometry* is associated with their *actual use* of GeoGebra for teaching and learning *geometry*.

Concerning Performance Expectancy and *analytical geometry*:

H_0: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *analytical geometry* is independent of their *actual use* of GeoGebra for the teaching and learning of *analytical geometry*.

H_1: Teachers' Performance Expectancy (PE) of GeoGebra's usefulness of *analytical geometry* is associated with their *actual use* of GeoGebra for teaching and learning *analytical geometry*.

Concerning Effort Expectancy and *analytical geometry*:

H_0: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *analytical geometry* is independent of their *actual use* of GeoGebra for the teaching and learning of *analytical geometry*.

H_1: Teachers' Effort Expectancy (EE) of GeoGebra's ease of use of *analytical geometry* is associated with their *actual use* of GeoGebra for teaching and learning *analytical geometry*.

Limitations of the Study

This study is limited to South African mathematics teachers with V.A.W. membership and may not be representative of all mathematics teachers in general. Another limitation is that teacher perceptions and attitudes towards GeoGebra integration may be altered in the future by various factors that might be addressed, such as gaining more experience in utilising ICT for teaching and learning, positive social feedback, etcetera and therefore a longitudinal study would have better informed the research question, but time limitation on a Master's study does not allow for a longitudinal study which is too time-consuming for the scope of this study. A related limitation to the study not being longitudinal is that the "actual use" of GeoGebra that is measured, is teachers' actual use before the V.A.W. workshop on GeoGebra. The "actual behaviour" of some of the teachers who were not familiar with GeoGebra before this course might therefore be altered in the future (and the measurement of this future "actual use" is beyond the scope of the study).

Delimitations of the Study enforced by the Researcher

The study is limited to V.A.W. members.

Researcher Assumptions

Respondents will (a) provide sincere feedback when answering the survey questionnaires and (b) respondents will furthermore be clear on and perform survey instructions correctly or ask the researcher if anything is unclear.

Defining ICT in this Study

The term ICT will be used in this study to refer to technology or educational technology as the combination of hardware and software utilised by mathematics teachers for teaching and learning.

1.4 Significance of the Study

The effective incorporation of ICT in education should "advance high order thinking skills such as comprehension, reasoning, problem solving and creative thinking and enhance employability… (and) productivity" (DoE, 2004, p.14). Since the integration of ICT in education forms an integral part of governments' educational policies and goals worldwide – including

South Africa – it could contribute to decision makers' pool of knowledge if they know how and why teachers use ICT in their classrooms and what factors determine teachers' attitudes towards the use of ICT for teaching and learning.

The UTAUT model was used as theoretical framework (refer to Figure 2.3) since the UTAUT model performed significantly better than other models measuring attitude and behaviour (refer to section 2.7). The UTAUT model is applied widely in literature with close to 9 000 hits in Google Scholar, but considerably less in South African studies with just over 900 hits in Google Scholar. Only 71 search results were found for the following search string: (UTAUT OR "Unified Theory of Acceptance and Use of Technology") AND (dynamic geometry software OR GeoGebra). When searching Google Scholar for South Africa AND the previous search string, only 13 search results were displayed. Since the UTAUT model has not been applied in many South African studies where the integration of dynamic mathematics software (especially GeoGebra) is concerned, there is a huge gap in the literature for applying the UTAUT model to explain South African mathematics teachers' integration of specifically GeoGebra for teaching and learning.
Another component of this study which adds to its significance is that it also explores teachers' use of GeoGebra for different mathematical topics. This could be informative to GeoGebra developers in order for them to make certain GeoGebra topics more user-friendly if it were found not to be used optimally. There seems to be a gap in the research regarding the utilisation of GeoGebra for specific mathematics school curriculum topics, since no study was found to specifically explore teachers' use of GeoGebra for the various mathematical topics, but only their use of GeoGebra in general.

1.5 Brief Overview of the Chapters

This dissertation consists of the following chapters (excluding the reference list and appendixes):

Chapter One serves as introduction for the dissertation. In this chapter the problem statement, rationale for the study and purpose of the study is laid out. Additionally the research question and hypotheses are presented on which the dissertation is based. Chapter one furthermore provides the limitations to and significance of the study.

Chapter Two lays out the literature review and the theoretic framework of the study and connects the theoretical framework with the literature review. In this chapter the concept of ICT in education is discussed, paying special attention to technical and conceptual mathematics activity, cognitive computer tools for mathematics education, constructs for mathematical activities and ICT's role in mathematics education. Subsequently, factors or barriers for the integration of ICT for the teaching and learning of mathematics (resources, knowledge and skills of teachers, institutional barriers, attitudes and beliefs of teachers, assessment, subject culture and internal and external factors), are discussed. The literature review ends with a discussion of the use of dynamic mathematics software for the teaching and learning of mathematics in general and GeoGebra specifically. Concerning the theoretical framework, many models in the literature that aim to explain human behaviour exist. Some are refined to explain the acceptance of ICT. The Unified Theory of Acceptance and Use of Technology (UTAUT) model was selected to base the theoretical framework on, since it performed considerably better than other models for explaining human behaviour. The four main constructs of the UTAUT model, namely Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI) and Facilitating Conditions (FC), are discussed. Additionally, Behavioural Intention which is hypothesised to influence teachers' Actual Use (AU) of GeoGebra and which is also hypothesised to be influenced by the aforementioned constructs, is discussed.

Chapter Three describes and substantiates the chosen research design and method. Critical realism as the researcher's paradigmatic perspective is discussed. Subsequently, the research design and justification for using a quantitative design is discussed. Thereafter the research methods, including the sample and study participants, the participant profile, data collection strategies, surveys as instrument and data analysis procedures for quantitative data analysis, are discussed. Next the validity (including construct, internal, statistical inference and external validity) and reliability issues for quantitative research are discussed and finally ethical issues are considered.

Chapter Four presents the findings of the study. The chapter starts off with a presentation of the demographic information of the respondents. This is followed by providing a background to the respondents' use of GeoGebra. The chapter ends with a discussion of the findings concerning the measured UTAUT constructs, including the findings on models 1, 2 and 3 as well as the findings on the additional hypotheses (stated in section 1.3).

Chapter Five presents a discussion of the findings. Furthermore, implications of the study are stated and future research to be conducted is pointed out, recommendations are made, and conclusions are drawn.

1.6 Chapter Summary

In Chapter One, the problem statement was discussed first of all. Worldwide new technological developments seem to be the order of the day with the learners spending a considerable time on the Internet on especially social networks to share their views and interests (Johnson et al., 2013). Statistics regarding Internet use worldwide as well as in South Africa were presented, since one of the key trends reported on in the 2013 Higher Education edition of the 2013 NMC Report is that the teacher's role keeps on changing because of the ever increasing amount of resources available to learners via the Internet (Johnson et al., 2013). Despite technology being increasingly available to learners, teachers are not using it optimally for teaching and learning. The question that arises is: If technology is so widely used among society in general and learners in particular, why don't South African mathematics teachers make use of ICT optimally for teaching and learning? Hypotheses related to my theoretical framework that were based on Venkatesh et al. (2003) for mathematics teachers' attitudes towards utilising GeoGebra in their classrooms and their actual use of GeoGebra, and the hypotheses were set to answer the research question: What factors influence mathematics teachers' use of GeoGebra in their classrooms? Limitations of the study such as being limited to V.A.W. members as well as the significance of the study, namely the fact that the UTAUT model has not been applied in many South African studies where the integration of dynamic mathematics software (especially GeoGebra) is concerned, were also discussed. Finally a brief overview of the chapters was given.

CHAPTER 2

Literature Review and Theoretical Framework

In this study the literature is reviewed in order to guide the researcher in selecting and applying an appropriate model (refer to section 2.1) to understand mathematics teachers' use of ICT for the teaching and learning of mathematics. The chapter starts off with a discussion of the concept of ICT in education, followed by reviewing ICT's role in teaching and learning mathematics. Next, the use of dynamic mathematics software for the teaching and learning of mathematics in general and GeoGebra specifically is discussed. Finally, factors or barriers for the utilisation of ICT for the teaching and learning of mathematics are discussed.

2.1 Information and Communications Technology (ICT) in Education

In order to investigate how ICT is used in teaching and learning mathematics and what factors constitute as barriers for the integration of ICT in teacher practice, one must have a clear understanding of what is meant by ICT. ICT may include older technology such as overhead projectors and basic hand-held calculators as well as newer technology, such as data projectors, electronic interactive whiteboards, and computer software. Information Technology (IT), computer technology and ICT are regularly used reciprocally (Draper, 2010) to refer to the same thing. Draper (2010) defines ICT as referring to "all technologies used for processing information and for communicating" (p. 24). ICT has been defined and redefined from various perspectives over the last few decades as it keeps on developing. Three approaches towards ICT, are ICT seen as (a) hardware, (b) software and (c) systems (Anekwe & Williams, 2014). As ICT develops, definitions of ICT are required to be updated as well. Sabry and Barker (2009) state that ICT include the awareness of the latest media whereby course material can be conveyed, as well as multimedia representation that matches various teaching and learning styles and interactivity.

ICT is dynamic, for the latest ICT is always sought after in order to achieve the learning system's goals of versatility and interactive learning amongst others (ibid.).

The Association for Educational Communication and Technology (AECT) in the United States of America is concerned with standardising definitions of ICT (Anekwe & Williams, 2014). The Board of Directors of the AECT has endorsed a definition (and the sixth since 1963) of ICT (Richey, Silber & Ely, 2008). A definition by Janusewski and Molenda reads as follows: ICT "is the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources" (Richey et al., 2008, p. 24). In this definition, instructional design is downplayed but not ignored and current understanding of the learning process is considered (Richey et al., 2008). Facilitating learning implies the supplying and arrangement of resources and tools in such a way that learning is meaningful instead of superficial while also assessing the performance (Anekwe & Williams, 2014).

In the South African White Paper on e-Education (DoE, 2004), a distinction is made between IT and ICT. The white paper defines ICT as the combination of IT (hardware and software) and communication technology, allowing the processing, handling and exchanging of data, information and knowledge, thereby increasing what is humanly possible. The term ICT will be used in this study to refer to technology or educational technology as the combination of hardware and software utilised by mathematics teachers for teaching and learning.

2.2 Teaching and Learning using ICT

In the previous section the term ICT was discussed and this section subsequently looks at the teaching and learning of Mathematics using ICT. The use of ICT in education is endorsed by the South African Department of Education:

> *Learning through the use of ICTs is arguably one of the most powerful means of supporting students to achieve the nationally-stated curriculum goals. It must however be very thoughtfully selected and integrated into educational planning and management. In particular, the use of ICTs for learning encourages: learner-centred learning; active, exploratory, inquiry-based learning; collaborative work among students and teachers; and creativity, analytical skills, critical thinking and informed decision-making (DoE, 2004, p. 19).*

Seeing that ICT's use in education is endorsed by the South African Department of Education, methods or approaches in education should be investigated to integrate ICT for teaching and learning. Anekwe and Williams (2014) provide a list of objectives of ICT in terms of teaching in the classroom:

- Classify and scrutinise learners' traits and educational requirements;
- Shaping classroom goals and declaring them in terms of behaviour;
- Investigating the substance of instruction and putting it in an appropriate order;
- Recognising obtainable teaching and learning materials;
- Getting familiarised with the type of learner and teacher interactions;
- Assessing the efficiency of instruction in the classroom in terms of learner achievement;
- Offering suitable assessment to both learners and teachers for adapting the teaching-learning method as needed.

An educational method refers to a coordination of approaches of educational cooperation between teachers and learners, with learners gaining new knowledge and skills while simultaneously advancing their cognitive skills (Cunska & Savicka, 2012). There are various classifications of educational methods according to the: (a) way knowledge and perception are presented, (b) learners' cognitive activity and the level of independent learning, (c) methods of teaching and learning, (d) educational aims of a lesson and (e) interrelationship of teaching methods (Cunska & Savicka, 2012). Albrecht (1998, cited in Cunska & Savicka, 2012) believes the best classification is the classification that is consistent with learners' cognitive activity and the level of independent learning, "because this approach respects the relationship that each element of the curriculum meets the specific way of learning" (Cunska & Savicka, 2012, p. 1483). A learner's role in the learning process can be categorised as (a) passive, (b) active and (c) interactive (Cunska & Savicka, 2012) and it is summarised in Table 2.1, together with the main teaching methods associated with each role.

Classification of Methods	Description	Main educational Methods applied
Passive	Learners are seen as not co-operative educational "objects" that need to understand the learning material.	Lectures, reading, demonstrations, learners' answers in front of the class.
Active	Learners are seen as educational "subjects" doing creative tasks and participating in dialogue with the teacher.	Creative tasks, dialogue with the teacher.
Interactive	All learners as well as the teacher are involved in the educational process. The teacher is only the organiser (and facilitator) of the educational process who provides a qualitative educational environment.	Co-operative educational methods such as projects, problems, discussions and games.

Table 2.1: Classification of methods according to learner's role in the educational process (Cunska & Savicka, 2012, p.1484).

An interactive approach could be more easily adopted with the advent of ICT creating opportunities for learners, for instance making conjectures about mathematical properties for themselves when using dynamic mathematics software. As stated by Cunska and Savicka (2012, p.1485): with the arrival of ICT "our attention should be paid to (the) paradigm of modern pedagogy – student is in the centre of practical educational process, he can learn independently in (a) suitable place, (at a suitable) time and speed." Interactive Learning Systems could be used by teachers to support learners in their learning (Baldwin & Sabry, 2003).

An Interactive Learning System (as illustrated in Figure 2.1), comprise of the following components: (a) content, (b) learners, (c) technology, (d) pedagogy and (e) interaction (Baldwin & Sabry, 2003). Each component is described by Baldwin and Sabry (2003) as follows: Content consists of subject matter to be taught, development of skills, and aims and objectives to be achieved. For the learners' component, the learners' diversity (e.g. prior knowledge, age, etcetera), as well as their various ways of learning (e.g. visual or verbal, etcetera) need to be considered. Technology concerns the reflection upon the media to be used for conveying information in order to accommodate various interactions, teaching methods, and ways of learning. Pedagogy consists of teaching approaches which are appropriate to the subject matter to be taught. Interaction is concerned with learners' interaction with the computer system, interactivity level and teaching methods used by considering the content and learners.

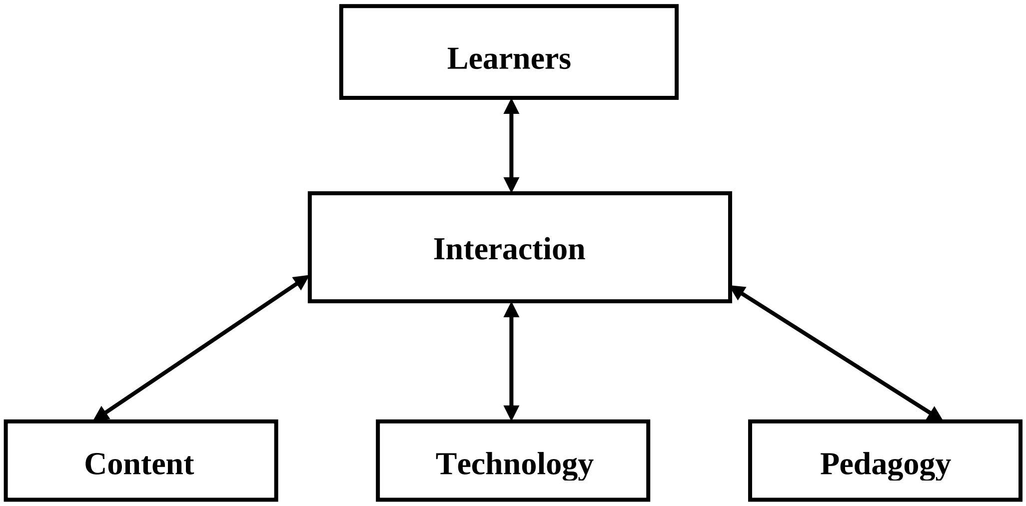

Figure 2.1: Components of an Interactive Learning System (ILS) (Baldwin & Sabry, 2003, p. 327)

In order for learner support to take place when using ICT, Interactive Learning Systems should implement "some basic design principles such as active engagement, active thinking, ... flexibility in expanding interactions beyond the lecture ..., allow for reflection and provide feedback, ... and use of multimedia, including graphics, which may promote discovery and inference" (Sabry & Barker, 2009, p. 187).

2.2.1 Progress and Problems concerning the use of ICT in Education

Although it is highly speculated that ICT would remarkably advance teaching and learning through the inventive use of new technologies, history gives a different account (Spector, 2010). The prediction of the 1980's that intelligent training systems would radically improve teaching and learning that would be comparable to one-to-one human tuition did not materialise. The predictions of the 1990's whereby computer-supported collaboration and distance learning would make teachers teaching in a classroom redundant did not materialise either. A possible reason is that distance learning is complex and the teacher's role is unlikely to be eradicated by ICT (Spector, 2010).

ICT can either support teaching and learning or it could hamper teaching and learning (Spector, 2010). Conducting a review of the literature, in excess of 2 200 studies were reviewed by Kadiyala and Crynes (2000) on the effectiveness of the use of ICT. A large proportion of these studies that they reviewed were also reviews and meta-analysis with more or less 760 studies, including elementary level education that met their criteria (ibid.). Kadiyala and Crynes (2000) found that an amazingly small number of studies reported negative results assumingly because of an unwillingness by researchers to publish negative results regarding the use of ICT. Kadiyala and Crynes' (2000) literature review do however offer compelling support that ICT could improve teaching and learning if the pedagogy is sound and if ICT, techniques and objectives are well-matched. Jonassen, Peck and Wilson claim that significant learning occurs when ICT permit learner engagement in knowledge construction, verbalisation, cooperation, validation and reflection activities (Chen, Hong, Sung & Chang, 2011).

To conclude, ICT is highly invested upon by various schools and Education Departments, but it is merely an instrument for reaching teaching and learning goals and should not be the goal in itself (Ringstaff & Kelley, 2002). As Mann (1999, p. 5) appropriately puts it: "Instructional technology only works for some kids, in some topics, and under some conditions...There is nothing that works for every purpose, for every learner and all the time". Instead of asking whether or not ICT works, one should ask when and in which circumstances ICT will work (Heinecke, Milman, Washington, & Blasi, 2001). ICT could therefore be a great asset for teaching and learning if the pedagogy is sound.

2.3 ICT's Role in Mathematics Education

ICT, including computer algebra systems and interactive geometry software, is deemed to be critical for ensuring first-class mathematics education (NCTM, 2008). Learners, guided by their teachers, can broaden their mathematical reasoning and use technological tools for calculations, identifying problems, making decisions and reflecting on mathematical problems (ibid.).

The National Council of Teachers of Mathematics (NCTM) is an association of mathematics teachers and other role players who have an interest in mathematics education with the majority of its members residing in the United States and Canada (Kilpatrick, 2007). The vision of the NCTM is that learners across the globe are afforded excellent mathematics education, are enthusiastic about mathematics, and are empowered by the opportunities acquired from mathematics (NCTM, 2013). One of the six principles of the NCTM (2000) concerns the use of ICT. The NCTM (2000) suggests that it is vitally important to use ICT for the teaching and learning of mathematics, since learners could better comprehend mathematics if ICT is utilised correctly. ICT aids learners in deciding upon action to be taken, reflection, logical thinking and solving problems (ibid.). The NCTM's position statement entitled "The Role of Technology in the Teaching and Learning of Mathematics" states:

> *Technology is an essential tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology. Effective teachers maximize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics. When technology is used strategically, it can provide access to mathematics for all students. (NCTM, 2008, p. 1)*

The NCTM however holds the view that utilising ICT "cannot replace conceptual understanding, computational fluency, or problem-solving skills" and teachers should therefore make balanced use of ICT in a planned fashion in order to improve the teaching and learning of mathematics (ibid., p.1). Teachers need to be able to make well-informed decisions on the most appropriate incorporation of ICT into their lesson plans and the mathematics curriculum should also make provision for the inclusion of ICT for instruction (NCTM, 2008).

2.3.1 Technical and Conceptual Mathematics Activity

In order to advance the current knowledge and understanding of the use of ICT in mathematics education, it should be explored by distinguishing between two mathematical activities, namely technical and conceptual activities (Zbiek, Heid, Blume & Dick, 2007). Technical mathematical activities entail procedural activity such as geometric constructions, measurements, transformations, and so forth. Conceptual mathematical activities involve investigation (e.g. finding patterns), verbalisation (e.g. describing patterns found), and explanation (e.g. proving and disproving) (ibid.). Artigue (2002) defined the "technical-conceptual cut" as an epistemological position generally held in the mid-nineties that technical and conceptual mathematical activities are disparate. Technical activity was viewed as being only mechanical and as such, traditional teaching practices were accused of focusing only on procedural development, while conceptual activity is seen as meaningful learning. Incorporating ICT in the teaching and learning of mathematics, leads to the hypothesis that learners would not have to focus their attention on technical work and that they would be able to skip directly to conceptual activity, since ICT would take care of the procedural work and therefore improve the conceptual aspect of mathematical activity (Artigue, 2002; Hoyles, Noss & Kent, 2004; Zbiek et al., 2007). There is however a complex relationship between technical activity and conceptual activity which makes a clear-cut differentiation between technical and conceptual activity difficult (Hoyles et al., 2004; Zbiek et al., 2007). The latter relationship stems from technical activity (mechanical actions through the use of ICT) which may be enlightened by conceptual activity, therefore disputing the disparate nature of technical and conceptual activity (ibid.).

2.3.2 Cognitive Computer Tools for Mathematics Education

While technical and conceptual mathematical activity enlighten the utilisation of ICT for mathematics teaching and learning, it does not clarify the difference between teaching mathematics with or without computers – i.e. the type of mathematical activities learners take on and the mathematical knowledge and comprehension they acquire (Zbiek et al., 2007). Pea (1987, p.91) define cognitive technologies as “any medium that helps transcend the limitations of the mind… in thinking, learning and problem-solving activities” and he furthermore describes computers as “an especially potent type of cognitive technology for learning to think mathematically” (p. 92), since computers are programmable to work with both numbers and symbols, manipulating symbols dynamically. Cognitive computer tools could be used to assist with technical as well as conceptual mathematical activities (Zbiek et al., 2007). Cognitive computer tools assist with technical mathematical activities by enabling learners and teachers to take action on mathematical objects and their representation (ibid.). Cognitive computer tools also assist with conceptual mathematical activities by providing teachers and learners with instantaneous visual feedback of the result of their actions displayed on the computer screen (ibid.). A learner could for example use sliders in GeoGebra and observe in real-time how the graph of a parabola changes by changing different variable values, visualising the effects.

2.3.3 ICT influences how we teach and learn Mathematics

In the previous sections, technical and conceptual mathematical activities, which presented information concerning the utilisation of ICT for mathematics teaching and learning, were discussed. Cognitive computer tools were mentioned as tools, providing assistance with technical as well as conceptual mathematical activities (Zbiek et al., 2007). A discussion of how ICT is used for teaching and learning mathematics follows.

A seemingly obvious statement made by Goldenberg (2000) is that using ICT for teaching and learning is not nearly as important as *how* it is used. The author presents six principles to consider when teachers use ICT for the teaching and learning of mathematics. All these principles explore if and how ICT could be used to realize the goal(s) of a lesson. The aforementioned principles are the: (1) genre principle, (2) purpose principle, (3) answer vs. analysis principle, (4) who does the thinking principle, (5) change content carefully principle and (6) fluent tool use principle. The *genre principle* implies that we should be familiar with the various roles of ICT and use it in such a way as to advance our lesson goals, taking learners' various needs into consideration, instead of just using ICT for the sake of grabbing attention while the ICT diverge (learners and perhaps teachers) from, or is even unfavourable towards our lesson goals. The *purpose principle* entails that ICT should be opted when it will aid in reaching the goal of the lesson. If the lesson goal cannot be reached by adopting ICT, it should not be used. For example, if understanding computation is the goal, but learners use a calculator, learners become distracted from the real lesson goal. The *answer vs. analysis principle* raises the question of whether the aim of ICT is for facilitating learners in solving problems or for aiding learners' pondering upon and analysing a problem. It keeps the purpose principle in mind, stating that the advantage of the step-by-step computational process in reaching an answer aids in clarifying *why* a certain answer is reached, while utilizing ICT will prevent this process of comprehension, even if computation is not the main goal. *The who does the thinking principle* is concerned with ICT interfering with the development of learners' thinking ability because they are becoming dependent on ICT. Goldenberg (2000, p. 6) also refers to the conclusion drawn by the Educational Testing Service that "using technology to teach higher-order thinking skills was positively related to mathematical achievement, while using it to drill lower-order skills was negatively related". The *change content carefully principle* involves making well-reasoned decisions on the obsoleteness of learning material, considering learners' learning outcomes - in particular how their reasoning ability is formed - and not only the capabilities of ICT. The fluent tool use principle holds that if ICT is not mastered, the time wasted is more damaging than the few advantages gained by its use. ICT must be mastered in order to solve complicated problems and to contribute to the teaching and learning of mathematics.

2.4 Using dynamic Mathematics Software for the Teaching and Learning of Mathematics

Some benefits of using ICT for teaching and learning mathematics are that graphing and calculations are instantaneous (Lu, 2008). Mathematical software especially offers visual and dynamic depictions of representations and connections between symbols, variables and graphs (ibid.). Various kinds of software are available for the teaching and learning of mathematics. A few examples are:

- Computer Algebra Systems (CAS) such as Mathematica, Maple, Derive or MuPAD;
- Dynamic Geometry Software (DGS) such as GeoGebra, Cabri, Cinderella or Geometer's Sketchpad and AutoGraph.

A CAS commonly focuses on algebra, analytical geometry and calculus and its purpose is to assist with converting mathematical expressions into symbolic form (Chrysanthou, 2008; Lu, 2008; Preiner, 2008). Dynamic Geometry Software generally covers geometry topics and focuses on links between lines, points, and other objects (Chrysanthou, 2008; Lu, 2008; Preiner, 2008). Dynamic Geometry Software is defined by Kokol-Voljc, (2007) as a collection of software used for doing dynamic geometry and from an educational perspective it is the most suitable tool for facilitating the advancement of geometrical concepts. The key features of Dynamic Geometry Software according to Kokol-Voljc (2007) are: (a) dynamic modelling of the conventional way of teaching (board and chalk) through the drag mode, (b) the choice to reduce a series of commands to create a macro (new command) and (c) the choice of a locus to see the course of the movements of geometrical objects. The correct use of a DGS in the classroom could significantly facilitate geometrical concept development (ibid.). Mathematical topics do sometimes overlap and a need to integrate algebra and geometry exist (Lu, 2008). One such software that aim to integrate algebra and geometry is GeoGebra.

2.4.1 GeoGebra

GeoGebra is free, open source dynamic mathematics software which aims to merge DGS and CAS in order to have a single software package that caters for algebra, calculus as well as geometry and it could be downloaded from the GeoGebra website at http://www.geogebra.org/ (Hohenwarter, Hohenwarter, Kreis & Lavicza, 2008). GeoGebra's is very popular worldwide. By 2013 the number of languages that GeoGebra has been translated into increased to 50 and the official GeoGebra website's visitors increased from 7 000 per month in 2004 to more than one million unique visitors from 190 countries monthly with 500 000 copies of the free GeoGebra software downloaded monthly (Hohenwarter, 2013). Currently GeoGebra are translated into 62 languages with 180 official International GeoGebra Institutes (IGIs) in 80 countries (Botana & Abánades, 2014). These IGIs are used as platforms by teachers and researchers worldwide to collaborate in promoting GeoGebra related research (ibid.).

2.4.2 The Use of GeoGebra for Teaching and Learning Mathematics

GeoGebra can be functional in the teaching of mathematics in the school environment and its application is quite diverse. GeoGebra could be used: (a) for demonstration and visualisation because of its versatility of representations graphically or algebraically, (b) as a tool for making constructions since it consists of all the capabilities required of a proper drawing or designing program, (c) for discovering mathematics since learners are able to arrange data by themselves – making learning more learner-centred as opposed to teacher-centred, (d) by teachers for preparing lesson materials in such a way that GeoGebra could be used as a collaboration, communication, and illustration tool, and (e) to create dynamic worksheets (interactive HTML pages) which could be used independently from GeoGebra on Internet browsers as an e-learning resource (Hohenwarter & Fuchs, 2004). These dynamic worksheets could be accessed by learners at home or at school without the need to work with GeoGebra directly (Hohenwarter et al., 2008). Two learning approaches are possible when using dynamic worksheets to incorporate GeoGebra constructions into the mathematics classroom, namely (a) presentations (which are teacher-centred) and (b) mathematical experimenting (which are learner-centred) (ibid). When teachers prepare GeoGebra files consisting of dynamic figures – in order to develop their learners' mathematical concepts – time could be saved as learners do not have to create figures themselves. This approach is favoured by beginner teacher users of GeoGebra. Another way of using

GeoGebra (which are preferred by more advanced teacher users of GeoGebra) is when teachers create dynamic figures during their lesson as the need arises to react on learners' questions which may arise when concepts are being explained (ibid.). Yet another way to use GeoGebra, is when teachers supply their learners with incomplete interactive GeoGebra constructions with relevant instructions and questions which would lead learners to explore and discover mathematical concepts for themselves (ibid.). If dynamic worksheets are used for this last mentioned learner-centred approach, time is not wasted to teach learners how to use the GeoGebra software itself for they will only use interactive html pages prepared by the teacher (ibid.).

2.5 Previous Studies about Factors that influence the Use of ICT

The literature was reviewed in order to find the main factors that influence the use of ICT in general as well as the main factors that influence the use of ICT in education and more specifically in mathematics education. The main sources for the literature search were ERIC ProQuest, ERIC EBSCOHOST and Google Scholar. Only studies between 2010 and 2014 were examined. Where journal articles were concerned, only peer reviewed articles were considered.
The following search strings were used in each database: (factors OR barriers) AND (Technology OR ICT OR Information and Communication Technology) to find factors that influence the use of ICT in general. Thereafter the search string was adjusted by narrowing the search to ICT usage in education by adding "AND education" to the search string. Finally the search was constricted even further to include only mathematics education. The same search string as the latter was used while adding "AND (mathematics OR math) to it. These articles obtained from the search string were scrutinised and a few of the most relevant articles were selected. Another source of articles was the reference lists of the selected articles, which were inspected to trace additional relevant articles.

The integration of ICT is influenced by factors in a vast number of environments, including:

- the medical or health field (Holden & Karsh, 2010; Moores, 2012; Ortega Egea & Román González, 2011; Söderström & Ytterhus, 2010);
- the field of government transparency (Bertot, Jaeger & Grimes, 2010; Jaeger & Bertot, 2010; Picazo-Vela, Gutiérrez-Martínez & Luna-Reyes, 2012);

- public participation and disaster support (Palen, Vieweg & Anderson, 2010; Semaan, 2011; Starbird & Palen, 2011);
- performance management practices (Kagaari, Munene & Ntayi, 2010; Melville, 2010; Musa, Akodo, Mukooza, Kaliba & Mbarika, 2012);
- and the education field (Escobar-Rodríguez, Carvajal-Trujillo & Monge-Lozano, 2014; Ming, Murugaiah, Wah, Azman, Yean & Sim, 2010; Raman, Don, Khalid, Hussin, Omar & Ghani, 2014; Voigt & Matthee, 2012; Wachira & Keengwe, 2011).

This study however, is more concerned with the utilisation of ICT in education – specifically mathematics education. Findings of previous studies relating to factors that influence the utilisation of ICT in education will be briefly discussed in the next section.

2.5.1 Previous Studies about Factors that influence the Use of ICT in Education

In order to draw conclusions on how the findings of this study fit into and contribute to the current research literature, it is necessary to briefly discuss the findings of current studies on factors that influence ICT utilisation in education. Firstly a few relevant studies on education in general will be discussed and thereafter more relevant studies on mathematics education specifically will be briefly discussed.

Ming et al. (2010) conducted focus group interviews with 20 teachers from 5 Smart Schools in the region of Kuala Lumpur in order to study the challenges they faced with the online *Continuing Professional Development for Teachers* (e-CPDelT) project. The e-CPDelT was designed for teachers' professional development by using online tools. Ming et al. made use of Brinkerhoff's framework on ICT adoption to identify factors that influence the participants' adoption of the project, including the following barriers: (a) resources, (b) institutional and administrative, (c) training and experience, and (d) teachers' anxieties and attitudes. Ming et al. found that resources were a barrier for the study participants' ICT adoption, since tools such as the ViP used in the e-CPDelT project, were not user friendly. The lack of time was another factor that influenced the participants' ICT adoption, because they had such a great workload having to deal with teaching subject matter, doing their administrative work and being involved in extra-mural activities. Inadequate support by their schools was also found to be a barrier for ICT adoption. Finally, teachers' anxieties and attitudes also influenced their adoption of ICT, since some of the participants did not have confidence in their online competence.

Raman et al. (2014) used the Unified Theory of Acceptance and Use of Technology (UTAUT) model to explore the acceptance of smart boards by teachers from 5 schools in Terengganu's Besut District. Their study followed a quantitative design with 68 questionnaires as data collection instrument. Raman et al. hypothesised that teachers' Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions would influence their use of smart boards. The authors found that only Performance Expectancy and Facilitating Conditions had a significant influence on teachers' Behavioural Intention to utilise smart boards with an R^2 of 0,72. This means that 72% of the variance in respondents' intention to use smart boards can be explained by the combination of the two independent variables, namely Performance Expectancy and Facilitating Conditions. In this study, Effort Expectancy and Social Influence were found not to play a significant role in teachers' intention to use smart boards.

In their study of city school teachers' viewpoints on barriers to the integration of ICT in mathematics classrooms, Wachira and Keengwe (2011) followed a mixed method research design. Their sample consisted of 15 female and 5 male teachers enrolled in a graduate course: "Teaching mathematics with technology", which formed part of a masters' degree program. Their study was based on the framework of Snoeyink and Ertmer to classify "the barriers as either internal or external" (p. 19). The study found the following factors to be the main barriers for mathematics teachers' use of ICT: (a) the unavailability and unreliability of ICT, (b) the lack of ICT support and leadership, (c) the fear of ICT and lack of confidence in utilising ICT and (d) a lacking knowledge of ICT. The first two barriers are classified as external barriers and the latter two as internal barriers.

Voigt and Matthee (2012) investigated teachers' and learners' acceptance of using MobiPads (tablets) in mathematics classrooms, forming part of the "connect to learn" (C2L) project. The C2L project focused on initiating "creativity and interactivity into the classrooms of South Africa using various mobile technologies and applications" (p. 172). Voigt and Matthee made use of a case study approach from an interpretivist's point of view, collecting data by conducting semistructured interviews – one with a mathematics teacher and two group interviews with learners. As theoretical framework for the study, the researchers used a combination of the UTAUT model, an extended UTAUT model for learning with tablet computers, TAM, and an extended TAM model for mobile-learning. After they received training, the teacher and a few learners that initially had a low level of confidence in their abilities to utilise MobiPads for learning mathematics gained tablet self-efficacy. “Tablet self-efficacy represents a person’s perception of their capabilities to use the tablet to complete necessary m-learning tasks” (Voigt & Matthee, 2012, p. 174). The authors therefore concluded that a relationship between Facilitating Conditions (training) and tablet self-efficacy existed. Regarding perceived ease of use / Effort Expectancy, “both learners and teacher found the tablet device as well as the applications on the device easy to use” (p. 176). Findings on perceived usefulness / Performance Expectancy, were that both the teacher and perceived MobiPads to be very useful for learning mathematics, identifying opportunities offered by the tablets not previously available to both teacher and learners. Concerning Facilitating Conditions, the teacher as well as 18 learners received formal training for using MobiPads. The integration of a mobile learning project into the curriculum will influence its use (Voigt & Matthee, 2012). The teacher in the study worked closely with developers of the Mobi Project to “design, develop and structure lesson plans to integrate the MobiPads in a suitable way into the mathematics curricula” (p. 178). Voigt and Matthee therefore concluded that a relationship between Facilitating Conditions and perceived usefulness existed. Regarding attitudes, both the teachers and his learners were positive in using MobiPad, especially where the connection of mathematical concepts to real-life situations was concerned. Concerning Social Influence, both the teacher and learners felt their social status among their various peers increased, since they know how to use the MobiPads. Finally Voigt and Matthee concluded that the mobility of the tablets positively influenced user acceptance of mobile learning, even though mobility was restricted to the classroom. The authors suggested that full mobility (if learners could take the MobiPads home), would have resulted in them accepting MobiPads for learning mathematics at an even higher level.

Many of the studies discussed used different Technology Acceptance Models, each with their own constructs. Factors that influence the use of ICT will therefore differ in many studies. Some factors that were found to dictate the integration of ICT are the availability of resources, institutional and administrative barriers, training and experience, teachers' anxieties and attitudes, performance expectancy and facilitating conditions – including resources, support and knowledge (Ming et al., 2010; Raman et al., 2014; Wachira & Keengwe, 2011).

2.6 Teachers' Utilisation of ICT for the Teaching and Learning of Mathematics

Attitudes and beliefs play a pivotal role whether or not ICT will be used adequately or at all for teaching and learning. Hew and Brush (2007) and Teo (2008) regard teachers' attitudes and beliefs towards the use of ICT as some of the greatest obstacles in making use of ICT when teaching. Some of the reasons why incorporating ICT in mathematical lessons is stressful are that (1) teachers who have never been taught themselves on how to make use of ICT as part of their mathematical teaching and learning, lack certain competence which they will have to acquire (Laborde, 2001). This lack of technical skills leads to competence anxiety (Hargreaves, 1994) and (2) using software to assist in mathematics teaching doesn't generally fit in the normal frame of reference of most schools (Laborde, 2001). Hew et al. (2007) analysed 48 empirical studies of which 43 were peer reviewed to identify barriers to the integration of ICT for teaching and learning. The authors applied the "snowball" method and describe the criteria for selecting and excluding certain studies. Hew et al. (2007) found 123 barriers in total for integrating ICT for teaching and learning, which they grouped into six categories, namely (1) resources, (2) knowledge and skills of teachers, (3) institutional, (4) attitudes and beliefs of teachers, (5) assessment and (6) subject culture. The first four barriers to incorporating ICT for teaching and learning are the most pronounced - reported in 40%, 23%, 14% and 13% of the analysed studies respectively - and thought to have a direct influence on the integration of ICT for teaching and learning (ibid.). The relationships between these barriers are represented in Figure 2.2. These six main categories of barriers for integrating ICT for teaching and learning will be discussed briefly.

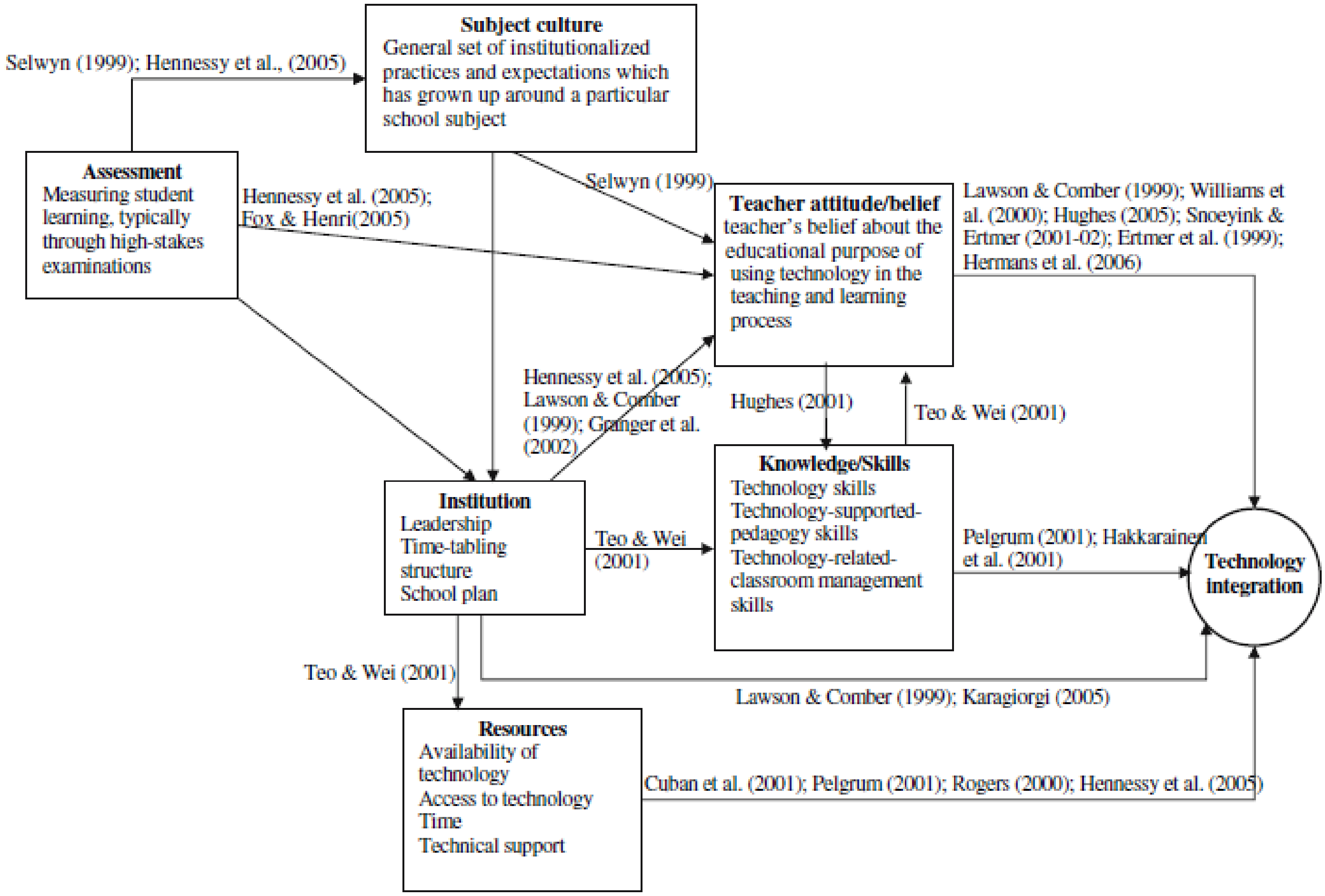

Figure 2.2: The relationships between different barriers to integrating ICT for teaching and learning (Hew et al., 2007, p. 231)

2.6.1 Resources

Resources include the availability of ICT, i.e. computer hardware and software, time and technical support (Hew et al., 2007). If resources are inadequate, teachers are insufficient to incorporate ICT into their classroom practice. Although ICT might be available, teachers might still have to compete with fellow teachers for access to laboratories where the ICT is kept, often resulting in teachers teaching non-technological subjects to have the least priority when competing for access to ICT (Hew et al., 2007). A lot of additional preparation time is needed when teachers prepare their lessons with the aim of incorporating ICT (Hew et al., 2007). Technical support is another key factor for ICT integration (Inan & Lowther, 2010; Hew et al., 2007). On-site technical support needs to be readily available to teachers if they are to integrate ICT in their classrooms more often (Inan et al., 2010).

2.6.2 Knowledge and Skills of Teachers

Knowledge and skills of teachers are found by Sivin-Kachala and Bialo (2000, cited in Inan et al., 2010), who scrutinised more than 300 studies, to be the greatest influential factor for successful computer integration in the classroom. This does not refute the finding of Hew et al. (2007) who reported resources to be the greatest factor, with knowledge and skills of teachers the second greatest factor. If resources are available, skilled teachers are needed to utilise it. In order to be able to incorporate ICT into their teaching and learning, teachers need to have an ICT-supported-pedagogy to tap into (Hew et al., 2007). ICT-supported-pedagogy is categorised into (1) replacement (using ICT to display a poem with a data projector instead of poster on the wall, thereby keeping the lesson goal the same but by an alternative way), (2) amplification (utilising ICT in order to carry out task more proficiently without changing the task, for example learners editing each other's narratives on making use of word processors instead of doing it by hand) and (3) transformation (for example learners using databases and graphing software to do investigative data analysis) (Hew et al., 2007). ICT-related classroom management knowledge is another type of skill that teachers require for successful integration of ICT in their lessons since additional classroom rules, which apply to the ICT in the class, need to be laid down (Hew et al., 2007). On a different level, regarding the discussion of knowledge and skills, competence is seen as one of a few internal factors that influence the integration of ICT for teaching and learning (Osika, Johnson & Butea, 2009). Teachers who are not proficient with or competent in using ICT, will most likely not integrate ICT in their lessons. The lack of proficiency largely stems from a lack of training to incorporate ICT in classrooms (Hennessy, Harrison & Wamakote, 2010; Osika et al., 2009). Investing in computer-based ICT alone will be a waste of money if teachers do not utilise it (Inan et al., 2010).

2.6.3 Institutional Barriers to the Integration of ICT

Apart from resources and teachers' knowledge and skills, institutional barriers may also cause a lack of ICT integration. According to Hew et al. (2007), institutional barriers for integrating ICT consist of (1) leadership (for example, if a school principal is not aware of ICT's importance in a learner-centred curriculum, (2) school timetables (since activities incorporating ICT could be time-consuming, adequate time needs to be allocated for teaching and learning such as a double period and (3) school planning (if administration do not plan ahead regarding how ICT will be utilised, it will not be used appropriately and therefore technological integration in lessons will be at a minimum level or not at all). Osika et al. (2009) categorise institutional support as an external factor influencing the integration of ICT. Institutional support which includes staff development, ease of access of ICT, policies and procedures and ICT support is necessary for teachers to successfully incorporate ICT in their lessons (Osika et al., 2009). School curriculums (forming part of institutional support) in developing countries are inflexible with too much content to be covered most of the time, leaving teachers practically no time to incorporate ICT inventively for teaching and learning, and therefore policy makers should support teachers more effectively to integrate ICT in their classrooms (Hennessy et al., 2010).

2.6.4 Attitudes and Beliefs of Teachers

Teachers' attitudes are about their likes or dislikes of the integration of ICT (Hew et al., 2007). Beliefs, which establish attitudes and include pedagogical beliefs and beliefs regarding ICT, are the assumption that something is true (Hew et al., 2007). Sime and Priestly (2005) summarise beliefs as individual thoughts regarding the positive role that ICT can play in teaching and learning. Similarly Osika et al. (2009) define educational beliefs as referring to the degree to which a teacher believes that a computer attend to vital educational needs deeming it more (or less) valuable and integrating ICT in the same measure as held by its perceived value. Teachers with constructivist pedagogical views – which are more learner-centred – are more prone to integrate computers in demanding ways in their teaching, while those adhering to teacher-centred approaches (traditionalists) are less prone to integrate computers in their teaching and learning (Tondeur, Hermans, van Braak & Valcke, 2008). Inan et al. (2010, p. 938) cite various authors (e.g. Lei & Zhao, 2008; Penuel, 2006; Windschitl & Sahl, 2002; Wozney, Venkatesh, & Abrami, 2006) that regard teacher beliefs as a critical factor for the successful integration of ICT, influencing the frequency of computer usage in their classrooms. Inan et al. (2010, p. 938) also cite other authors (e.g. Wozney et al., 2006) who found "perceived value" of ICT use to be the main factor influencing the integration of ICT for teaching and learning. Some teachers for instance merely see ICT as a means of keeping learners occupied and use it as an incentive for learners to finish their designated assignments (Hew et al., 2007). Two other studies regarding teachers' opinions about the integration of ICT for teaching and learning, conducted in Australia and Cyprus respectively, revealed that teachers did not believe that ICT would improve learners' comprehension of learning material (Hew et al., 2007) which probably led to their failing of successfully integrating ICT in their lessons. Personal beliefs categorised as self-starters, traditionalists, careerists and reluctants could also influence teachers' incorporation of ICT in their lessons (Osika et al., 2009). Beliefs do not always influence implementation of ICT (Ottenbreit-Leftwich, Glazewski, Newby & Ertmer, 2010), since even if teachers believe ICT integration to be advantageous, other factors referred to in this section, such as competence, also play a part in whether they integrate ICT or not (Hennessy et al., 2010).

2.6.5 Assessment

Assessment, which includes formative and summative assessment, is defined as the evaluation of learners' learning (Hew et al., 2007). Generally summative assessment, determining whether a learner passes or fails his grade, could discourage teachers to integrate ICT since they feel pressured to cover the scope of the curriculum and do not want to spend additional time to try and incorporate ICT over and above the jam-packed curriculum (Hew et al., 2007). This notion is supported by a study conducted by Donnelly, McGarr and O'Reilly (2011). One of the teachers with whom Donnelly et al. conducted an interview, claimed that teachers have limited ICT skills, but their current methods of instruction reap rewards as far as exam results are concerned which is all that parents care about. Teachers therefore are not motivated to use ICT unless the way of assessment changed, since they (and the system) are result-driven (Donnelly et al., 2011). The time it takes teachers with limited technological skills to learn how to integrate ICT might have a negative impact on their learners' results which would discourage them from utilising ICT. Reasons integrating ICT for teaching and learning may be quite different than how teaching takes place for enabling learners to pass their formal exams. This claim is made clear by the following statement of Bate (2010, p. 1056):

> *If the creative use of ICT is about empowering students to set their own goals... and find unique ways of solving problems, then the school... is inappropriate for this purpose without fundamental structural reform. Mandated curriculum and high stakes assessment practices, for example, put pressure on teachers to get through the curriculum... and teach for tests.*

Sometimes the integration of ICT seems to stand in stark contrast with external question papers (Hew et al., 2007). To illustrate the latter point, Hennessy, Ruthven and Brindley (2005) described a situation where graphical calculators are not allowed in nationwide question papers; therefore teachers are not inclined to integrate this particular ICT in their lessons for the fear of the disadvantage that might be brought upon their learners if they are used to work with graphical calculators in the class situation, while not being allowed to use it in the nationwide question papers. In South African schools graphical calculators are not allowed either, as stated in the Curriculum and Assessment Policy Statement (CAPS) of the South African education department: "None graphic and none programmable calculators are allowed... Calculators should only be used to perform standard numerical computations and to verify calculations by hand." DoE (2011, p. 54).

2.6.6 Subject Culture

Subject culture is traditionally shaped and underpinned by generations of school practice, subject content, pedagogies and assessment (Hew et al., 2007). Thompson, Higgins and Howell (1991) use the term "subjective culture" and they maintain that it comprises of norms (where members of a culture in given circumstances teach themselves to do what they deem correct and suitable), roles (which also concern behaviours thought to be correct but identified with people holding a specific position in a group, society or social system), and values (categories that are difficult to understand but with strong affective elements). An example of a subject culture is found in a study conducted by Baggott la Velle, Wishart, McFarlane, Brawn and John (2007) where the subject culture in the context of secondary school science is portrayed by a content-packed curriculum and assessment as well as a tradition for needed practical work. Baggott la Velle et al. (2007) state that there is clearly tension between the curriculum's load with its assessment tools, and the traditional demand for learning science through practical experience. The conflict that arises is that the school's subject culture is confronted by the use of ICT since it changes the way teaching and learning takes place (ibid.). Hennessy, Ruthven and Brindley suggest that teachers are unwilling to implement ICT for it appears to be irreconcilable with their subject culture (Hew et al., 2007). Their statement corresponds to John's (2005) statement that subject culture (as well as subject knowledge and subject pedagogy) forms a considerable part of teachers' professional identity that could be extremely opposed to change.

2.7 Theoretical Framework

In this study, the following research question will be addressed: What factors influence mathematics teachers' use of GeoGebra for the teaching and learning of mathematics? In the previous section, factors that influence teachers' utilisation of ICT for the teaching and learning of mathematics were discussed. Hew et al. (2007) grouped 123 barriers to integrating ICT for teaching and learning. They found these barriers by scrutinising 48 empirical studies into six main categories, namely (1) resources, (2) knowledge and skills of teachers, (3) institutional, (4) attitudes and beliefs of teachers, (5) assessment and (6) subject culture (refer to section 2.6 for a discussion of these barriers). Hew et al. (2007) found that 40%, 23%, 14% and 13% of these analysed studies reported the first four barriers to incorporating ICT for teaching and learning are the most pronounced, having a direct influence on the integration of ICT for teaching and learning. Many models in the literature that aim to explain human behaviour exist. Some are refined to explain the acceptance of ICT. A brief overview of some Technology Acceptance Models can be viewed in Table 2.2.

Venkatesh et al. (2003) reviewed eight major models for explaining human behaviour and incorporated components from these models in their unified model – the Unified Theory of Acceptance and Use of Technology (UTAUT). The eight models that Venkatesh et al. (2003) evaluated are:

> *The Theory of Reasoned Action, the Technology Acceptance Model, the Motivational Model, the theory of planned behavior, a model combining the Technology Acceptance Model and the theory of planned behavior, the model of PC utilization, the innovation diffusion theory and the social cognitive theory (p. 425).*

To see an overview of the eight models in terms of their core constructs and definitions, refer to table 1 in Venkatesh et al. (2003, pp. 428-432) as well as a briefer summary made by Birch (2009) displayed in Table 2.2.

Venkatesh et al. (2003) applied the eight models referred to above on data from four organisations over six months and found that these models "explained between 17 percent and 53 percent of the variance in user intentions to use Information Technology" (p. 425). They then applied their UTAUT model on the same data and the results seem to imply that their model surpass all eight models evaluated, with an adjusted R^2 of 69%. Data from two other organisations further confirmed their model to be valid with an adjusted R^2 of 70% (p. 425).

Name of Model	**Acronym / Alternate Name**	**Level of Analysis**	**Main dependent Constructs / Factors**	**Main independent Constructs / Factors**	**Originating Authors**
Theory of Reasoned Action	TRA	Individual	Behavioural intention, behaviour	Attitude toward behaviour, & subjective norm	Fishbein (1967); Ajzen and Fishbein (1973); Fishbein and Ajzen (1975)
Technology Acceptance Model	TAM (adaptation of TRA)	Individual	Behavioural Intention to Use, System Usage	Perceived usefulness, perceived ease of use & subjective norm (only in TAM2)	Davis (1986); Davis (1989)
Motivational Model	MM	Individual	Behavioural intention	Extrinsic motivation & intrinsic motivation	Vallerand (1997)
Behaviour	TPB	Individual	Behavioural intention, behaviour	Attitude toward behaviour, subjective norm, perceived behavioural control	Ajzen (1985); Ajzen (1991)
Combined Theory of Planned Behaviour / Technology Acceptance Model	C-TAM-TPB	Individual	Behavioural usage	Attitude toward behaviour, subjective norm, perceived behavioural control & perceived usefulness	Taylor & Todd (1995)
Model of PC Utilization	MPCU	Individual	Behavioural intention	Job-fit, complexity, long-term consequences, affect toward use, social factors & Facilitating Conditions	Thompson et al. (1991)
Innovation Diffusion Theory	IDT/DOI, Diffusion of Innovations	Group, Firm, Industry, Society	Implementation Success or Technology Adoption	Relative advantage, ease of use, visibility, result demonstration ability, image & compatibility	Lazarsfeld et. al. (1949); Rogers (1962); Rogers and Shoemaker (1971); Rogers (1995)
Social Cognitive Theory	SCT	Individual/ Group	Learning, Change in behaviour	Outcome expectations-performance, outcome expectations-personal, self-efficacy, affect & anxiety	Bandura (1986)

Table 2.2: Brief overview of the Technology Acceptance Models used to create UTAUT (Birch, 2009, pp. 25-26)

The UTAUT model was selected as a theoretical framework for this study since it performed considerably better than other models for explaining human behaviour (see discussion later in this section). The four main constructs of the UTAUT model, namely Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions are viewed by Venkatesh et al. (2003) to directly influence on whether or not people accept and use ICT (see a discussion of these factors later in this section). Although UTAUT is a model that explains the use of ICT in general, it corresponds well with the six categories of barriers for ICT integration for teaching and learning as identified by Hew et al. (2007). Performance Expectancy could be linked to assessment; Social Influence could be linked to subject culture whereas Venkatesh et al.'s (2003) Facilitating Conditions construct could be linked to Hew et al.'s (2007) resources, knowledge/skills and institutional barriers. Venkatesh et al.'s (2003) Effort Expectancy construct is similar to Hew et al.'s (2007) teacher attitudes/beliefs barriers. Venkatesh et al. (2003, p.455) define attitude regarding the use of ICT as "an individual's overall affective reaction to using a system."

Empirical comparisons of eight models were made by Venkatesh et al. (2003, p. 426) by conducting a "within-subjects, longitudinal validation and comparison of the eight models using data from four organi[s]ations." In most of the scrutinised models their definition of attitude corresponded strongly to four constructs of the UTAUT, namely (a) attitude toward behaviour in the TRA, TPB/DTPB and C-TAM-TPB models, (b) intrinsic motivation in the Motivational Model, (c) effect toward use in the model of personal computer utilisation and (d) affect in the social cognitive theory (Venkatesh et al., 2003). Behavioural intention for using ICT was found to be directly influenced by attitude when applying the TRA, TPB/DTPB and MM models, but Behavioural Intention was not directly influenced by attitude applying the C-TAM-TPB, MPCU and SCT models (ibid.). A detailed inspection revealed that attitude as a construct for predicting Behavioural Intention toward the use of ICT is just significant when a model does not contain Performance Expectancy and Effort Expectancy constructs (Venkatesh et al., 2003). The authors hypothesised that "Attitude toward using technology will **not** have a significant influence on behavioural intention" (ibid., p. 456) and they failed to reject the hypothesis, concluding that attitude is not a significant determinant of Behavioural Intention due to the fact that "the effect (is) being captured by (performance) expectancy and Effort Expectancy" (ibid., p. 468).

Computer self-efficacy, computer anxiety and attitude towards the use of ICT were found to be indirect determinants for using ICT (Venkatesh et al., 2003) and are therefore omitted in the adapted UTAUT model (refer to Figure 2.4).

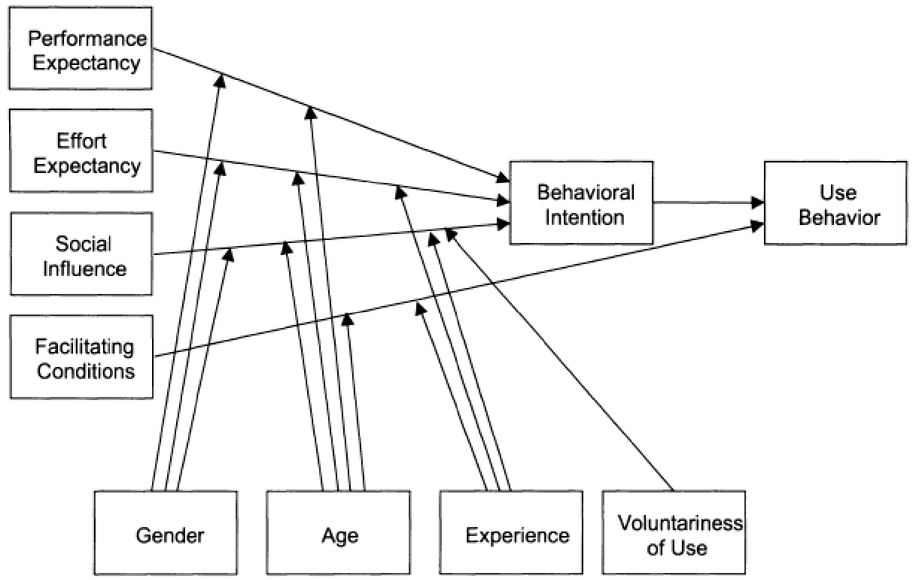

Figure 2.3: Unified Theory of Acceptance and Use of Technology (UTAUT)
(Venkatesh et al., 2003, p. 447)

In their model, Venkatesh et al. (2003) hold the view that four constructs – i.e. Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions – have a direct influence on whether or not people accept and use ICT. They furthermore found that attitudes toward using ICT, computer self-efficacy and computer anxiety do not directly influence people's intention to use ICT. Each component of Venkatesh et al.'s (2003) UTAUT model depicted in Figure 2.3 and adapted as depicted in Figure 2.4 will be discussed in more detail in the following sections. The UTAUT model was adapted by breaking it up into three different main models in order to use the appropriate statistical tests. The statistical tests selected depended on the type of data collected (categorical, or continues for the different constructs). A detailed motivation for the various statistical tests used in this study can be seen in the research design (refer to section 3.2). The group sizes for each of the moderators (i.e. gender, age, experience, and voluntariness of use) differed considerably and it could therefore not be statistically analysed. The effects of the moderators on the UTAUT constructs were consequently omitted in this study.

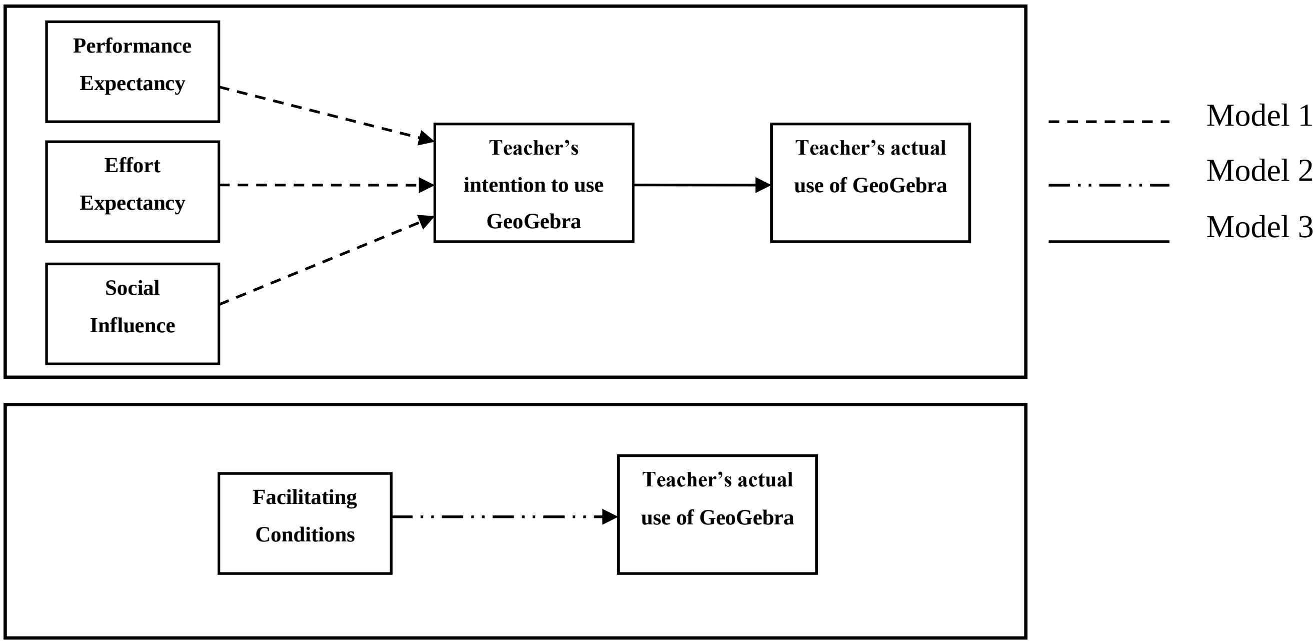

Figure 2.4: Adapted Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003)

2.7.1 Performance Expectancy

Venkatesh et al. (2003) define Performance Expectancy as the extent that a person believes that using ICT will assist them in enhancing their job performance. In terms of this study, Performance Expectancy is the extent to which mathematics teachers believe that using GeoGebra will assist them in improving their teaching and learning of mathematics in the classroom and it might influence their intention to use GeoGebra for teaching and learning. Furthermore, teachers' Performance Expectancy was also measured for specific mathematical topics (refer to the questionnaire in Appendix D) in order to get a better understanding of which mathematical topics (if any) teachers feel GeoGebra would assist them in teaching.

Venkatesh et al. (2003, p. 447) made use of five constructs from various models that are relevant to Performance Expectancy, namely: "perceived usefulness (TAM/TAM2 and C-TAM-TPB), extrinsic motivation (MM), job-fit (MPCU), relative advantage (IDT), and outcome expectations (SCT)". Taylor and Todd (1995) define perceived usefulness as the belief that making use of ICT increases performance. Davis (1989) and Davis, Bagozzi, and Warshaw (1989) define perceived usefulness as the extent of someone's belief that utilising a specific system within an organisational context would improve their job performance with a positive use-performance correlation when using the system. Extrinsic motivation is the driving force behind a certain behaviour (such as using ICT for teaching and learning) since it is thought that it would assist the user to benefit from this behaviour in terms of a salary increase and enhanced job performance, etcetera (Venkatesh & Speier, 1999). Job-fit determines the degree of a person's belief that the utilisation of ICT would boost their job performance by aiding in decision making or assisting with shortening the time needed to complete key tasks (Thompson et al., 1991), which is very similar to perceived usefulness. Relative advantage is described as the extent to which a new idea (or innovation) is thought to be better than its predecessor (Moore & Benbasat, 1991). Outcome expectations relate to the fact that people would rather assume behaviour that is perceived to effect positive results than assume behaviour that they do not believe to be beneficial in enhancing their performance (Compeau & Higgins, 1995; Venkatesh et al., 2003). In their study, Venkatesh et al. (2003) found the performance construct to be the strongest predictor of intention in both intentional and compulsory situations. They furthermore found that gender and age are determining factors on the influence of people's Performance Expectancy on their Behavioural Intention which is especially true for younger men.

2.7.2 Effort Expectancy

Effort Expectancy is a person's perceived ease of use of ICT (Venkatesh et al., 2003). Effort Expectancy in this study is a mathematics teacher's perceived ease of use of GeoGebra for the teaching and learning of mathematics in the classroom which might influence his/her intention to use GeoGebra for teaching and learning. Additionally, teachers' perceived ease of use of specific GeoGebra topics (refer to the questionnaire in Appendix D) were also measured in order to explore for which mathematical topics teachers find the use of GeoGebra more difficult to use. This knowledge could provide insight to organisations that provide GeoGebra training as to which GeoGebra topics mathematics teachers might struggle with.

The three constructs used in Effort Expectancy are: "perceived ease of use (TAM/TAM2), complexity (MPCU), and ease of use (IDT)" (Venkatesh et al., 2003, p. 450). Perceived ease of use is defined as the extent of someone's belief that utilising a specific system would be effortless

(Davis, 1989; Davis et al., 1989) and the author maintain that users will be more prone to accept a system that is perceived to be easier to use than other systems. Venkatesh and Davis (2000) proposed TAM2 as an extension of the Technology Acceptance Model (TAM) and retained perceived ease of use for directly influencing perceived usefulness, since performance is increased by systems that take less effort to use. Contrasting to ease of use, Rogers and Schoemaker define complexity as "the degree to which an innovation is perceived as relatively difficult to understand and use" (Thompson et al., 1991, p. 128). Since Thompson et al.'s (1991) complexity construct is opposite to Davis' (1989) ease of use construct, their hypothesis measures a negative correlation instead of a positive relationship like Davis. Thompson et al. (1991) hypothesise that there is a negative correlation between the perceived difficulty and the use of a computer. This implies that when people perceive ICT as difficult to use, they will not adopt or use it. Similar to *perceived* ease of use and contrasting to complexity, Moore and Benbasat (1991, p. 215) define ease of use as "the degree to which the PWS (personal work station) is easy to learn and use" and all 10 of their initial 14 items that they reserved for scaling the "ease of use" construct were obtained from Davis' scale for "perceived ease of use". Venkatesh et al. (2003) found significant similarities between the Effort Expectancy constructs in both intentional and compulsory situations, but with extensive and continued use of ICT, Effort Expectancy becomes less significant. They also found that Effort Expectancy to be more prominent for older women who are not familiar with the use of certain ICT, with age, gender and experience playing a role in Effort Expectancy's influence on Behavioural Intention.

2.7.3 Social Influence

Social Influence is a person's opinion on what people who are significant to them, think about their use of ICT (Venkatesh et al., 2003). Social Influence in this study is a mathematics teacher's opinion on what people who are significant to them, (namely their principal, HOD or subject head, colleagues and the school governing body), think about their use of GeoGebra for the teaching and learning of mathematics in the classroom and it might influence his/her intention to use GeoGebra for teaching and learning.

The three constructs that make up Social Influence is "subjective norm" (TRA,TAM2, TPB/DTPB, and C-TAM-TPB), social factors (MPCU), and image (IDT)" (Venkatesh, 2003, p.

451). Fishbein and Ajzen defined subjective norm as "the person's perception that most people who are important to him think he should or should not perform the behavior in question" (Venkatesh et al., 2003, p. 428). Likewise Ajzen (1991) define subjective norm as an individual's perception of social pressure whether to carry out certain behaviour or not. Taylor and Todd (1995) refer to subjective norm as Social Influence. Social factors refer to what people think they ought to do (Thompson et al., 1991). Triandis extended the term social norms, and named it social factors which are "the individual's internalization of the reference groups' subjective culture, and specific interpersonal agreements that the individual has made with others, in specific social situations" (Thompson et al., 1991, p. 126). Subjective culture is discussed earlier in the chapter (refer to section 2.6.6). Image, also referred to as social approval, is described as the extent to which the utilisation of new technology is perceived to boost a person's status in his/her social circle (Moore & Benbasat, 1991). In comparing different models, Venkatesh et al. (2003) found Social Influence to be irrelevant in the intentional use of ICT and significant when the use of ICT is compulsory. This, however, is also becoming irrelevant eventually with continued use of ICT. Venkatesh et al. (2003) also found Social Influence to be more prominent for older women who are not familiar with the use of certain types of ICT, with age, gender, experience and compulsory use playing a significant role in social norm's influence on Behavioural Intention.

2.7.4 Facilitating Conditions

Facilitating Conditions are the level of a person's perception that organisational and technical infrastructure exists to support the use of ICT (Venkatesh et al., 2003). Facilitating Conditions in this study are the level of a mathematics teacher's perception that organisational and technical infrastructure (such as resources, knowledge/skills and technical support regarding the use of GeoGebra) exists to support the use of GeoGebra for the teaching and learning of mathematics in the classroom and it might influence his/her actual use of GeoGebra for teaching and learning.

The three constructs that Facilitating Conditions represents are: "perceived behavioral control (TPB/ DTPB, C-TAM-TPB), Facilitating Conditions (MPCU), and compatibility (IDT)", with all of these constructs prepared in a way that will eliminate obstacles when using ICT (p. 453). Perceived behavioural control is defined as an individual's perceived ease or difficulty associated with carrying out a particular behaviour (Ajzen, 1991). A positive correlation between perceived behavioural control and a specific behaviour exists, where behaviour is greatly influenced whether or not a person belief that he/she is capable of executing the behaviour concerned (ibid.). Perceived behavioural control is one of the constructs that directly influence Behavioural Intention, which consecutively influence behaviour (Taylor & Todd, 1995). Facilitating Conditions in the MPCU model refer to unbiased factors in a setting that observers agree on to make an act easy to do (Thompson et al., 1991). In a computer utilisation context, user support is an example of a facilitating condition that affects computer use (ibid.). Compatibility refer to the extent to which new technology is perceived as complying with prospective users' current values, needs and previous experiences (Moore & Benbasat, 1991).Venkatesh et al. (2003) found that Facilitating Conditions will not have a considerable influence on Behavioural Intention in the UTAUT model, since this result is taken into consideration by Effort Expectancy. Facilitating Conditions is significant in forecasting behaviour in the TPB/DTPB though, because Effort Expectancy does not form a part in the latter models (Venkatesh et al., 2003). Facilitating Conditions are also emphasised by age and experience, such that there is a stronger relationship between the use of ICT and Facilitating Conditions for older, experienced people (ibid.).

2.7.5 Behavioural Intention

The first three constructs (i.e. PE, EE and SI) of the UTAUT model are hypothesised to influence Behavioural Intention (Venkatesh et al., 2003). In this study, Behavioural Intention is referred to as the mathematics teachers' intention to use GeoGebra for teaching and learning. In the questionnaire, teachers' intention to use GeoGebra in the next six months since completing the questionnaire was measured. Just as facilitation conditions are predicted to influence '(actual) use behaviour', Behavioural Intention is also anticipated by Venkatesh et al. (2003) to forecast '(actual) use behaviour', consistent with other intention models they have discussed. In this study '(actual) use behaviour' is defined as mathematics teachers' *actual* use of GeoGebra for teaching and learning. As such this study predicts that mathematics teachers' *intention* to use GeoGebra for teaching and learning will determine their *actual* use of GeoGebra for teaching and learning.

2.7.6 Moderator Effects

Venkatesh et al. (2003) hypothesised that gender, age, experience, and voluntariness of use would moderate the effect of the four direct determinants (PE, EE, SI and FC) on Behavioural Intention and actual use (refer to Figure 2.3). Venkatesh et al. (2003) hypothesised that gender and age will moderate the influence of Performance Expectancy on behavioural intension, specifically for younger men. Concerning Effort Expectancy, Venkatesh et al. (2003) hypothesised that gender, age and experience will moderate the influence of Effort Expectancy on Behavioural Intension, specifically for younger women with little experience. Regarding Social Influence, Venkatesh et al. (2003) hypothesised that gender, age, voluntariness and experience will moderate the influence of Social Influence on behavioural intension, specifically for older women in a compulsory environment with little experience. Finally, concerning Facilitating Conditions, Venkatesh et al. (2003) hypothesised that age and experience will moderate the influence of Facilitating Conditions on actual use, especially for older users with greater levels of experience. Since the group sizes for each of the moderators (i.e. gender, age, experience, and voluntariness of use) differed considerably, it could not be statistically analysed. The effects of the moderators on the UTAUT constructs were therefore omitted in this study.

2.8 Chapter Summary

Many barriers for the integration of ICT for teaching and learning exist, but Hew et al. (2007) identified six main categories namely, resources, knowledge and skills of teachers, institutional, attitudes and beliefs of teachers, assessment and subject culture. Limited resources, including lack of technical support, or even limited access to existing resources within a school environment, hampers teachers' use of ICT for teaching and learning. Even if resources are available, teachers need to be skilled and knowledgeable to utilise ICT to its fullest potential for teaching and learning. Investment in resources alone is a waste of money if investment in teachers' training to use these resources is not a priority, since these resources will then become white elephants. Institutional barriers for integrating ICT include leadership, e.g. a school principal who is not in favour of utilising ICT for teaching and learning, the school time-table that does not provide adequate time (such as double periods) to integrate ICT for teaching and learning, school planning by the administration on how ICT should be incorporated in lessons (Hew et al., 2007) and even fixed school curriculums with too much content to be covered, leaving teachers practically no time to incorporate ICT for teaching and learning (Hennessy et al., 2010). Teachers' attitudes and beliefs lead teachers who are more learner-centred to be more prone to integrate ICT for teaching and learning, while those adhering to teacher-centred approaches are less prone to integrate ICT in their teaching and learning (Tondeur et al., 2008). Some authors (Inan et al., 2010) found "perceived value" of ICT use to be the main factor influencing integration of ICT for teaching and learning. Assessment seem to influence the integration of ICT for teaching and learning since external examination for instance might not allow the use of computers and applicable software to solve mathematical problems, therefore discouraging teachers' use of ICT for fear of putting their learners at a disadvantage. Subject culture is a barrier to the utilisation of ICT if it is seen as an intrusion to ways things have always been done, i.e. teaching without the use of ICT. Internal factors such as competence, personal beliefs and anxiety as well as external factors such as demographics – explicitly age and gender, class size, and institutional support also influence the integration of ICT for teaching and learning purposes (Osika et al., 2009). Of the six barriers categorised by Hew et al. (2007) for the integration of ICT for teaching and learning, resources, knowledge and skills of teachers, institutional barriers as well as attitudes and beliefs of teachers are found to be the most prominent barriers to incorporating ICT for teaching and learning and thought to have a direct influence on the integration of ICT for teaching and learning. Venkatesh et al. (2003) developed the UTAUT model that performed significantly better than eight other models for measuring ICT integration. This model found that Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions have a direct influence on the integration of ICT (refer to section 2.7) and it has not been applied in many South African studies. There is a huge gap in the literature for applying the UTAUT model to explain South African mathematics teachers' integration of GeoGebra for teaching and learning.

CHAPTER 3

Research Design and Methods

In Chapter Three, the researcher's own perspective of critical realism as paradigmatic perspective is discussed. Following this discussion, the research design and methods implemented for three main models as well as for the additional hypotheses are described. Subsequently, sampling, data collection strategies, and data analysis for this study are discussed. Finally, validity and reliability concerns, as well as ethical issues are addressed.

3.1 Research Paradigm

Lincoln (2009) emphasises the importance of paradigms as it gives insight into the researcher's perspective. The researcher's inquisition paradigm shapes the research design with researchers conveying their own sets of beliefs to a research project (Draper, 2010). A *knowledge claim* means that a researcher has definite assumptions concerning what knowledge is (ontology) and how they will come to know it through their investigation (epistemology) (Creswell, 2013). Creswell (2013) identified four different paradigms, namely positivism (or post-positivism), constructivism, advocacy and participatory, and pragmatism. Yet another paradigm that gained popularity – and also one which appeals to me – is critical realism. I identify with Bhaskar's critical realist theory (Houston, 2001) that a greater reality, free of our beliefs or ideas exists. Bhaskar distinguishes between three levels of reality, namely: "the empirical level consisting of experienced events; the actual level, comprising all events whether experienced or not; and, lastly, the causal level embracing the 'mechanisms' which generate events" (Houston, 2001, p. 850). Similarly, Easton (2010, p. 128) holds the view that critical reality differentiate between the "real world, the actual events that are created by the real world and the empirical events which we can actually capture and record". Critical realism contains fundamentals of both positivism (objectivism) and constructivism (subjectivism) (Krauss, 2005). This inclusion of elements across the borders of different paradigms is supported by Parker (Madill, Jordan & Shirley, 2000) who disputes the notion that objectivity and subjectivity are inevitably opposed to one another. Critical realism is both aware of the nature of things (positivism), as well as the human agency or factor (constructivism). Critical realism therefore strives to learn about observable and non-observable constructs, free of events produced by them (Krauss, 2005). Both qualitative and quantitative research approaches are suitable in a critical realism paradigm (Krauss, 2005). Methods associated with qualitative approaches, such as case studies and different types of interviews, as well as methods based on statistics which are normally associated with quantitative approaches are considered suitable within a critical realism paradigm (ibid.). According to Krauss (2005, p.762) "[w]ith (critical) realism, the seeming dichotomy between quantitative and qualitative is therefore replaced by an approach that is considered appropriate given the research topic of interest and level of existing knowledge pertaining to it". A critical realism paradigm therefore allows for the researcher to make use of either a quantitative or a qualitative approach or both (mixed method), whichever approach with their appropriate methods will answer the research question. In the following sections I will discuss the research design, research methods, sampling, data collection strategies, data analysis validity and reliability, and ethical issues.

3.2 Research Design

As I favour critical realism as research paradigm where the most appropriate research approach and methods are used that would answer the research question, I deemed that a quantitative approach was suited to answer the study's research question: *What factors influence mathematics teachers' use of GeoGebra for the teaching and learning of mathematics?* The hypotheses were based on three models: model 1 (testing whether or not teachers' Performance Expectancy, Effort Expectancy and Social Influence will have an influence on teachers' intention to use GeoGebra for the teaching and learning of mathematics); model 2 (testing whether or not Facilitating Conditions will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics) and model 3 (testing whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics). Twelve additional hypotheses were tested (refer to section 1.3), whereby specific items of the Performance Expectancy (PE) and Effort Expectancy (EE) constructs were hypothesised to predict the actual use of the corresponding items (i.e. specific GeoGebra topics). Most of these GeoGebra topics are also covered in the Curriculum and Assessment Policy Statement (CAPS) of the South African Education Department, namely graphs, statistics, calculus, geometry and analytical geometry (DoE, 2011). Only transformation geometry was omitted in the CAPS – replacing the previous national curriculum statement (NCS) – although transformation geometry was included in the old NCS (DoE, 2003).

To test the validity of model 1 (testing whether or not teachers' Performance Expectancy, Effort Expectancy and Social Influence will have an influence on teachers' intention to use GeoGebra for the teaching and learning of mathematics) multiple regression and correlation were used. David (2012) claims that regression analysis could be used when exploring the relationship between dependent and one or more independent variables. Similarly Mertler and Vannatta (2002) state that correlation and/or regression is suitable for exploring the relationship between two or more quantitative variables. Correlation offers a measure of degree of association between two variables (including strength, i.e. weak, moderate and strong as well as the direction, i.e. positive or negative) ranging from -1 (perfect negative relationship) to 0 (no relationship) to 1 (perfect positive relationship) (Azman, Frković, Bilić-Zulle & Petrovecki, 2006; Bryman & Cramer, 2011; Crawford, 2006; Huck, 2012). Regression on the other hand is used for prediction of a dependent variable by an independent variable or for the purpose of explanation (Crawford, 2006; Huck, 2012). Multiple regression is used when one dependent and two or more independent variables exist and it identifies the best grouping of independent variables that predict the dependent variable (Bryman et al.,2011; Crawford, 2006; Huck, 2012; Mertler & Vannatta, 2002; Wetcher-Hendricks, 2011). This study therefore made use of multiple regression analysis to investigate the predictive influence of the three UTAUT constructs, namely Performance Expectancy, Effort Expectancy and Social Influence (independent variables) on teachers' intention to use GeoGebra (dependent variable). In order to produce the best grouping of the predictive influence of these three UTAUT constructs on teachers' intention to use GeoGebra for teaching and learning, Mertler and Vannatta (2002) explain that sequential multiple regression is used to examine independent variables one by one for causing the most variance in the dependent variable. Correlation coefficients was used to establish whether correlations between these three UTAUT constructs and teachers' intention to use GeoGebra existed, and if it did, how significant the correlations were – between each item on the survey as well as each UTAUT construct on teachers' intention to use GeoGebra.

The t test was used for both model 2 (testing whether or not Facilitating Conditions will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics) and model 3 (testing whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics). The t test measures group differences and is used when one dependent variable and one independent variable with two categories exist (Mertler & Vannatta, 2002). Comparing two mean values of continuous data necessitate a t test (Wetcher-Hendricks, 2011). In this study model 2 as well as model 3 had one dependent variable, namely AU (actual use) and one independent variable (FC_{mean} for model 2 and BI_{mean} for model 3). Additionally, the variables FC_{mean} and BI_{mean} were continuous and the actual use variable was categorical (yes/no), making the t test the appropriate inferential statistical test.

Regarding the twelve intuitive sub-models of model three, whereby specific items of the Performance Expectancy and Effort Expectancy constructs were hypothesised to predict the actual use of the corresponding items (i.e. specific GeoGebra topics), Fisher's exact test was used. When expected frequencies are not large enough and sample sizes are too small, Fisher's exact test is used instead of the chi-square test (Huck, 2012). The samples sizes of 75 were roughly halved, since only respondents who actually used GeoGebra were included to make statistical inferences on. The logic behind excluding respondents who did not use GeoGebra at all is that the study wanted to test whether a respondent's Performance Expectancy and/or Effort Expectancy for a specific GeoGebra topic such as graphs would predict a respondent's actual use (AU) of GeoGebra for that specific topic (graphs in this example). It did not make sense to include non-users of GeoGebra to test if their respective Performance Expectancy or Effort Expectancy items (specific mathematics topics) would predict their actual use (AU) of GeoGebra for those specific mathematics topics, since they were not using GeoGebra at all. When expected frequencies are not large enough, but the sample data create a 2x2 contingency table, the Fisher's exact test may be used (Huck, 2012). Fisher's exact test may not be used if (a) a one-sample chi-square test with more than two categories or (b) a chi-square test with a contingency table containing in excess of two rows or two columns exist (ibid.). "[T]he problem of small expected frequencies can be solved by redefining the response categories such that two or more of the original categories are collapsed together" (Huck, 2012, p. 424). Similar to the example given by

Huck (2012) merging responses of a five-option Likert-scale question, I dichotomised response categories of seven-option Likert-scale questions into two categories namely "not agree" and "agree" by merging together (1) strongly disagree, (2) disagree, (3) somewhat disagree and (4) neutral as "not agree" and (5) somewhat agree, (6) agree and (7) strongly agree as "agree" for each of the six Performance Expectancy and six Effort Expectancy items concerning GeoGebra mathematics topics respectively. Furthermore, the actual use (AU) variable response categories were also dichotomised into two categories ("yes" or "no" depending on whether or not a respondent actually used GeoGebra for a specific mathematics topic). This created 2 x 2 contingency tables for each of the sub-models as required for using Fisher's exact test (Huck, 2012).

3.3 Research Methods

The sampling and participants in the study, data collection strategies and instruments, as well as data analysis procedures will be discussed in the following sections. I made use of surveys as well as e-surveys to explore teachers' use of GeoGebra for the teaching and learning of mathematics. The questionnaire was piloted among mathematics teachers who were not part of the population under study. Minor changes were made to the questionnaire of which the greatest changes were to add a third option to the demographic question: "Are you teaching in a city, in a rural area or at a township school?" and also adding an additional demographic question: "Are you teaching at a private or government school?" Adding these questions may be used to shed some light on the availability of technological resources in private schools compared to government schools as well as in schools located in townships compared to rural area and city schools. Other than the two questions mentioned, the questionnaire was clear and no other adjustments were needed.

3.3.1 Sample and Participant Profile

The V.A.W. is an association of Afrikaans speaking primary and secondary school mathematics teachers with 492 members. In order to obtain as large a response as possible, a website link to an e-survey, as well as an invitation to participate in the study, were e-mailed by a representative of the V.A.W. to all its members in addition to hard copies of the survey which were distributed and collected at one of their congresses on a date previously agreed upon. Since I did not send out the e-mail myself, feedback was completely anonymous. Respondents of the hard copy questionnaires only entered their names voluntarily if they wanted to take part in a lucky draw in acknowledgment of their time and effort in completing the questionnaire. Their names were not used at all when the data were captured and therefore nobody was identified in the findings and the discussion thereof. In total 75 respondents completed the questionnaires (either online via the e-survey or a hard copy of the same questionnaire). All of the questionnaires were retained in the study. The age range of the study participants was between the ages of 18 and 69 years with one person being older than 69 years (refer to Table 3.1). The largest group of the teachers were the one where teachers were between 40 and 49 years old (34, 67%) and the majority of teachers were younger than 49 years of age (44 of the 75 respondents or 58,67%). Only 18 (24%) of the respondents were male and the rest (57 or 76%) were female (refer to Table 3.2).

Age range	Frequency	Percent
18-29	13	17.33
30-39	5	6.67
40-49	26	34.67
50-59	24	32
60-69	6	8
>69	1	1.33

Table 3.1: Respondents' age range

Gender	Frequency	Percent
Male	18	24
Female	57	76

Table 3.2: Respondents' gender

3.3.2 Data Collection Strategies and Instruments

One instrument was used in this study, administered in two ways, namely a survey and an e-survey questionnaire. The questionnaire had a high degree of structure with mainly close-ended questions asked. High level structuring of the survey and e-survey lead to a high predictability of data collected, given that items on the questionnaire were mostly close-ended questions and therefore data could be pre-coded or classified into categories before data collection (Plowright, 2011). Both the survey and e-survey questionnaires were translated into Afrikaans before data collection commenced - since the population under investigation was Afrikaans.

Hard copies of the questionnaires were handed out at a V.A.W. Congress and I received it back immediately after completion in order to have a better return rate for the questionnaires. As web-based questionnaires are more frequently used in social and educational research (Cohen, Manion, & Morrison, 2011; Plowright, 2011), I additionally invited V.A.W. members electronically via e-mail to participate in the study by including a link to the website where the questionnaire was hosted (Cohen et al., 2011) namely on surveymoz (an online survey creation tool). The rationale behind an electronic survey additional to the hard copy version of the same questionnaire was to obtain a higher response rate for the study, by reaching all of the V.A.W. members on the V.A.W.'s e-mail list – including those who either did not attend the Congress or did not complete the questionnaire at that point in time. All the V.A.W. members therefore had the opportunity to complete the questionnaire, whether completing the hard copy or completing it electronically.

The questionnaire for this study was based on Venkatesh et al.'s (2003, p. 460) items regarding the use of ICT in general, but it was adapted by specifically focusing questions on the use of GeoGebra and also adding additional questions at each UTAUT construct to gain better insight into mathematics teachers' use of various GeoGebra topics. The questionnaire was divided into '*section A*' which was concerned with participants' demographic information, '*section B*' in order to obtain background information of participants regarding the use of GeoGebra, and '*section C*' which measured the UTAUT constructs. The UTAUT constructs for this study were adapted to be in line with the research question of this study (refer to Figure 2.4). '*Section C*' of the questionnaire consisted of questions which were categorised into the four constructs (i.e. Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions) of the UTAUT model that is deemed to have a direct influence on whether or not mathematics teachers accept and use GeoGebra for teaching and learning (Venkatesh's et al., 2003) as discussed in the theoretical framework. Finally, Behavioural Intention to use GeoGebra for the teaching and learning of mathematics was also measured in '*section C*', since it was hypothesised that

Behavioural Intention would have a significant positive influence on mathematics teachers' actual use of GeoGebra for teaching and learning. 'Questions in '*section B*' regarding the actual use (AU) of GeoGebra were asked with the latter in mind.

3.3.3 Data Analysis Procedures

SAS (version 9.3) was used to analyse the data. Respondents' demographic information was illustrated via descriptive statistics. Statistical inferences were used to test the hypotheses related to the three models as depicted in Figure 2.4 as well as on the 12 additional hypotheses (described in section 1.3). As discussed at the research design (refer to section 3.2), multiple regression analysis was used for model 1 to investigate the predictive influence of the three UTAUT constructs, namely Performance Expectancy, Effort Expectancy and Social Influence (independent variables) on teachers' intention to use GeoGebra (dependent variable). Correlation coefficients were used to establish whether correlations between these three UTAUT constructs and teachers' intention to use GeoGebra exist. If correlations existed, one would have to examine the significance of the correlations between each item on the survey as well as each UTAUT construct on teachers' intention to use GeoGebra. The t test was used for both model 2 (testing whether or not Facilitating Conditions will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics) and model 3 (testing whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics). Regarding the twelve additional hypotheses, whereby specific items of the Performance Expectancy and Effort Expectancy constructs were hypothesised to predict the actual use of the corresponding items (i.e. specific GeoGebra topics), Fisher's exact test was used since expected frequencies are not large enough and sample sizes are too small to apply the chi-square test (Huck, 2012).

3.4 Validity and Reliability

Cohen et al. (2011) declare that reliability is synonymous with dependability, consistency and replicability over time, i.e. comparable findings must be the result if research were performed on comparable groups of respondents in a comparable context. Similarly Hunter and Brewer (2003) define reliability as the extent to which measurements could be reproduced, while Denscombe (2010) regard reliability to denote the methods' quality and validity as the data's quality.

Different authors propose that reliability is crucial but inadequate for reaching validity; however, validity is sufficient but not crucial for obtaining reliability (Fraenkel, Wallen, & Hyun, 1993; Huck, 2012). Cronbach's Alpha was used to check the questionnaire's reliability by evaluating the internal consistency of the items for all four UTAUT constructs (see section 4.3.1).

A general definition for validity is that it denotes the degree to which a method measures what it is supposed to measure or what it claims to measure, i.e. if one's measurement of an occurrence is accurate (Dooley, 1984; Fraenkel et al., 1993; Huck, 2012; Plowright, 2011). Four major types of validity identified by Dooley (1984) are: (a) construct validity (whether or not studied constructs are reflected by the study's variables), (b) internal validation (if construct validity exists, are observed effects a result of the study's independent variables only, or could there be other factors involved?), (c) statistical inference validity (whether or not the observed relationship between variables hold for the population or arose by chance) and (d) external validity (if results could be generalised for other people, places and times).

3.4.1 Construct Validity

The questionnaire for this study was based on Venkatesh et al.'s (2003, p. 460) items regarding the use of ICT in general, but it was adapted by specifically focusing questions on the use of GeoGebra and also adding additional questions at each UTAUT construct to gain better insight into mathematics teachers' use of various GeoGebra topics. The adapted questionnaire was scrutinised by an expert in the field.

3.4.2 Internal Validity

Internal validity threats are difficult to prove in correlational research designs and the procedures that are used must be inspected with care in order to verify the possibility of opposing hypothesis (Dooley, 1984). Causation (variable A causes variable B) must be proved in order to claim internal validity (ibid.), but the mere fact that a relationship between two variables exist does not automatically imply causation (Fraenkel et al., 1993). To prove causation between two variables (A and B), Dooley (1984) asserts two conditions must be met: first of all, there need to be a relationship between the two variables and secondly, variable A must occur before variable B (cause before effect). Fraenkel et al.'s (1993) conditions for proving causation correspond to that of Dooley, but additionally they also regard a third condition that must be met, namely that all other causes of variable B must be ruled out (by implementing an experimental design). Similarly Onwuegbuzie (2000) also state that internal validity comes under threat if different explanations cannot be eradicated. The correlational design in this study (model 1) could only indicate whether or not a relationship between the UTAUT constructs (Performance Expectancy, Effort Expectancy and Social Influence) and the Behavioural Intention existed as well as the strength of the relationship. Therefore causation could not be proved beyond any doubt if Dooley and Fraenkel et al.'s conditions for causality were taken into account. Furthermore, other factors (not measured) besides the UTAUT constructs might influence teachers' intention to use GeoGebra.

3.4.3 Statistical Inference Validity

Inferential statistics resolve statistical inferential validity issues, by considering whether or not an observed relationship between variables is because of chance or not (Dooley, 1984). The level of significance refers to "the probability that the difference between the entities being compared has occurred by chance" (Wetcher-Hendricks, 2011, p. 111). Using a significance level of $\alpha = 0,05$ with $p < 0,05$ indicates that "the researcher can be 95% certain that the same difference that exists in the sample also exists in the population" (ibid.). A significance level of $\alpha = 0,05$ was used throughout the analysis of the study's results, indicating that where relationships between variables were found to exist, the claim that a relationship existed could be made with a 95% level of confidence that it did not exist by mere chance. Model 1 (testing whether or not teachers' Performance Expectancy, Effort Expectancy and Social Influence would have an influence on teachers' intention to use GeoGebra for the teaching and learning of mathematics) was found to be a significant model with $p < 0,0001$ which was much smaller than the significance level of 0,05 (refer to section 4.3.4). For model 2, no statistical difference between the FC's means for the "yes" and "no" categories of the actual use was found (refer to section 4.3.5). Model 3 was used to test whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics would influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics and it was found to be a significant model with $p = 0,015$. As for model 1, this value of p was a lot smaller than the significance level of 0,05 indicating that the null hypothesis could be rejected with a 95% certainty level (refer to section 4.3.6).

3.4.4 External Validity

External validity can be assumed if construct, internal and statistical inference validity issues are all addressed (Dooley, 1984). Although construct and statistical inference validity issues were addressed (refer to sections 3.4.1 and 3.4.3), some threats to internal validity (refer to section 3.4.2) still exist. Without internal validity, findings of the study cannot be externally validated – i.e. generalized (Dooley, 1984). Since other factors than the tested UTAUT constructs may influence teachers' intention to utilise GeoGebra, threats to internal validity do exist. Therefore the findings cannot be generalised. However, even if high levels of internal validity for specific findings occurred, one still would not be able to generalise beyond the study context (Onwuegbuzie, 2000).

3.5 Ethical Issues

Seedhouse (1997) constructed an ethical grid for analysing ethics in the field of health care. This grid was adapted by Stutchbury and Fox (2009) to be utilised in educational research (refer to Figure 3.1 below).

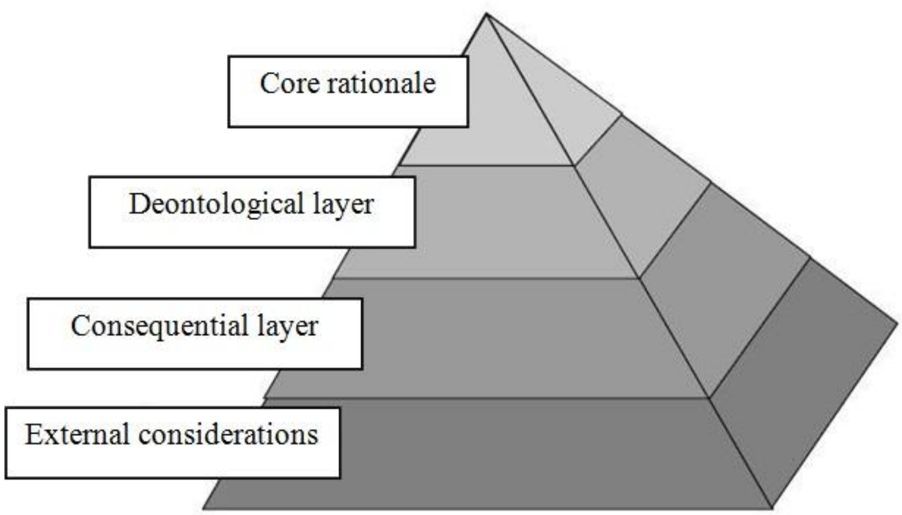

Figure 3.1: Alternative representation of the ethical grid (Stutchbury & Fox, 2009, p. 492)

Stutchbury et al.'s (2009) alternative representation of Seedhouse's ethical grid included the following components that a researcher should take into consideration: (a) *External layer (outer layer)* – consisting of external concerns, including the law, performance policy and utilizing accessible resources, (b) *Consequential layer* – consequences of researcher's actions for individuals, groups or society, (c) *Deontological considerations* – duty (for instance truthfulness and reducing harm to a minimum) taking preference over consequences, and (d) *The inner layer (uppermost layer)* – the core rationale of respecting an individual's independence. All of the above layers of Stutchbury's ethical grid were addressed in this study.

In addressing Terrell's (2012) list of ethical concerns, I asked a V.A.W. representative to send an e-mail to all its members, with a cover letter written by myself as the researcher, explaining to them the purpose and modus operandi of my study, inviting them to follow a link to an online questionnaire (e-survey) if they agree to participate, making participation completely voluntary. Additionally, participants were not allowed to continue with the online questionnaire if they did not click on a tick box indicating that they had read and understood that participation is voluntary and anonymous. Similarly to the online questionnaire, respondents completing the hard copy questionnaires distributed at the Congress, signed an informed consent letter attached to the questionnaire (refer to Appendix C). The informed consent letter covered the standard measures expected of social researchers – as listed by Denscombe (2010) – that must be established in order to minimize the risk of harm caused to respondents, namely: (a) anonymity of respondents, (b) confidentiality, (c) the nature of the research and participants' involvement and (d) participants giving voluntary consent. Respondents were informed that a report on the findings of my study would be made available to them. My study also did not consist of any sensitive data that could be an issue, for instance if I were to study mathematics teachers' ICT usage at a specific school, they could perhaps get into trouble if it became clear that they do not utilise the new technology that the school bought. The latter is however not the case, since my participants are mathematics teachers countrywide who became members of the V.A.W. voluntarily and therefore their use or lack of use of ICT for mathematics teaching and learning would not jeopardize their future (or at the very least put them in a precarious position) at their particular schools. Last but most importantly, ethical clearance was obtained by the researcher from his academic institution, granting him permission to conduct the research.

3.6 Chapter Summary

As a critical realist, the researcher believes that a greater reality, free of our beliefs or ideas exists. Critical realism is both aware of the nature of things (positivism) as well as the human agency or factor (constructivism). Critical realism strives to learn about observable and non-observable constructs, free of events produced by them (Krauss, 2005). A critical realism paradigm therefore allows for the researcher to make use of either a quantitative or a qualitative approach or both (mixed method), whichever approach with their appropriate methods will answer the research question best. In this study a quantitative approach was deemed to best answer the research question. Three main models and twelve sub-models of model three, including the statistical tests applied to each model, were discussed. For model 1 (testing whether or not teachers' Performance Expectancy, Effort Expectancy and Social Influence would have an influence on teachers' intention to use GeoGebra for the teaching and learning of mathematics), multiple regression and correlation were used as inferential statistics. The t test was used for both model 2 (testing whether or not Facilitating Conditions would influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics) and model 3 (testing whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics would influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics). Regarding the twelve additional hypotheses, whereby specific items of the Performance Expectancy and Effort Expectancy constructs were hypothesised to predict the actual use of the corresponding items (i.e. specific GeoGebra topics), Fisher's exact test was used instead of the chi-square test, because expected frequencies were not large enough and sample sizes were too small as suggested by Huck (2012). Research methods included a discussion of the sampling and participants in the study, data collection strategies and instruments, as well as data analysis procedures used. Surveys as well as e-surveys were utilised to explore teachers' use of GeoGebra for the teaching and learning of mathematics. The questionnaire was piloted among mathematics teachers who were not part of the population under study. Validity and reliability concerns were addressed and the limitation that findings could not be generalised beyond the context of this study was mentioned. Finally ethical issues were discussed and addressed.

CHAPTER 4

Results

The results of the study are presented in this chapter. Firstly a summary of respondents' demographic information is given. Secondly a summary of respondents' responses to background questions regarding the use of GeoGebra is provided. Finally the results regarding section C of the questionnaire (see Appendix D) concerning the UTAUT constructs are reported on, including results on the reliability of the questionnaire items measuring UTAUT constructs are discussed.

4.1 Demographic Information

'S*ection A*' of the questionnaire was concerned with respondents' demographic information. As discussed in the sample and participant profile in Chapter Three (refer to Table 3.2), the majority of the respondents were female (57 or 76%) and only 18 (24%) were male. The respondents' ages ranged from 18 to 69 years with one person being older than 69 years. Most of the teachers were between 40 and 49 years old (34,67%).

Most of the respondents taught mathematics at secondary schools during the last five years. Of these respondents that taught at primary schools, the majority taught grade 5 and/or grade 7 mathematics. 15 (20%) respondents taught grade 5 mathematics and 14 (18,67%) taught grade 7 mathematics. No one taught grade 1 or 2 mathematics. The secondary school respondents were fairly evenly spread among grades 8, 9, 11 and 12, with most of them having taught grade 10's (43 or 57, 33%) during the previous 5 years. The grade taught second most of all were grade 11's (35 or 46,67%). For a complete overview of the number of respondents that taught each grade, refer to Table 4.1 below. Furthermore, even if the respondents only taught mathematics to one grade in a specific year, they are likely to have taught mathematics to different grades during the last five years.

Grade previously taught	Number of teachers	Percentage of teachers
1	0	0
2	0	0
3	1	1.33
4	9	12
5	15	20
6	9	12
7	14	18.67
8	32	42.67
9	33	44
10	43	57.33
11	39	52
12	35	46.67

Table 4.1: Grades taught by respondents during the last five years

As expected, since most respondents taught mathematics at secondary schools during the last five years, most of them are secondary school teachers. Most of the primary school teachers are still teaching grade 5 and/or grade 7 mathematics (10 or 13,33% for both grades), but they are slightly less than those that taught these two grades during the last five years.

Grade currently taught (2014)	Number of respondents	Percentage of respondents
1	0	0
2	0	0
3	0	0
4	6	8
5	10	13.33
6	7	9.33
7	10	13.33
8	11	14.67
9	20	26.67
10	23	30.67
11	28	37.33
12	21	28

Table 4.2: Grades currently (2014) being taught by respondents

More of the secondary school teachers teach in the FET band (grades 10-12) than the GET band (grades 8 and 9) and they predominantly teach grade 11's (28 or 37,33%). The number of teachers currently teaching mathematics (for all the different grades) can be viewed in Table 4.2.

As reflected in Table 4.3, respondents predominantly teach at schools located in a city (54 or 72%). Considerably less (15 or 20%) teach in rural areas, with only 2 (2,67%) of respondents teaching at township schools. Four respondents declined to answer the question (refer to Table 4.3).

Location	Frequency	Percent
Not indicated	4	5.33
City	54	72
Rural	15	20
Township	2	2.67

Table 4.3: Schools' location where respondents teach

In general the respondents teach at public schools: 56 (74,67%) of them teach at public schools and just about a quarter (18 or 24%) of them teach at private schools (refer to Table 4.4). One respondent did not answer the question.

Type of school	Frequency	Percent
Not indicated	1	1.33
Private	18	24
Public	56	74.67

Table 4.4: Type of school where respondents teach

4.2 Background regarding the use of GeoGebra

'S*ection B*' of the questionnaire was aimed at obtaining background information of respondents regarding their use of GeoGebra. Almost half of respondents (36 or 48%) have not made use of

GeoGebra. 39 (52%) of the respondents have various levels of experience in using GeoGebra. Sixteen (21,33%) respondents have less than one year's experience using GeoGebra. A small majority (20 or 26,67%) have used GeoGebra for two to three years and only three (4%) of the respondents have used GeoGebra for more than four years (refer to Table 4.5).

# of years that respondents have been using GeoGebra	Frequency	Percent
Not at all	36	48
0-1	16	21.33
2-3	20	26.67
4-5	3	4

Table 4.5: Number of years that respondents have been using GeoGebra

Practically the same number of respondents in Table 4.5 (36 or 48%), compared to the number of respondents in Table 4.6 (38 or 50,67%), indicated that they do not use GeoGebra at all. The small discrepancy might be due to the fact that two of the respondents in Table 4.5 chose the "0-1 years" experience category instead of the "not at all" category. This is one instance that indicates reliability due to consistency of the data. The questionnaire's reliability is also checked by evaluating the internal consistency of the items via Cronbach's Alpha (refer to section 4.3.1). While more or less half of the respondents do not make use of GeoGebra at all, most of those that do use it, do so once a month (21 or 28%). Seven (9,33%) of the respondents almost never use GeoGebra, five (6,67%) utilise GeoGebra weekly and 4 (5,33%) indicated that they make use of GeoGebra on a daily basis (refer to Table 4.6).

Frequency of GeoGebra usage	Frequency	Percent
Not at all	38	50.67
Once a year	7	9.33
Once a month	21	28
Once a week	5	6.67
Daily	4	5.33

Table 4.6: Frequency of GeoGebra usage

4.2.1 Different Uses of GeoGebra by Respondents

GeoGebra has many applications, in addition to using it as an aid for teaching classroom mathematics. As seen in the Table 4.5 and Table 4.6, nearly half of the respondents do not use GeoGebra at all. Respondents may utilise GeoGebra for different tasks, but the greatest uses of GeoGebra are for teaching mathematics (33 or 44%) as well as for setting question papers (31 or 41,33%). Some respondents also make use of GeoGebra for creating worksheets (15 or 20%) and creating dynamic online sketches (9 or 12%). The various uses for GeoGebra by respondents can be seen in Table 4.7. Apart from the listed uses, other uses for GeoGebra were for mentorship and for creating study guides, while "other uses" indicated by two more respondents could be divided into the category for "teaching mathematics", as they specified specific mathematics topics that are explained via GeoGebra.

Respondents' different uses of GeoGebra	Number of respondents	Percentage of respondents
Do not use GeoGebra	32	42.67
Teaching mathematics	33	44
Creating worksheets	15	20
Creating dynamic online sketches	9	12
Setting question papers	31	41.33
Other uses	4	5.33

Table 4.7: Respondents' different uses of GeoGebra

4.2.2 Respondents' Uses of GeoGebra concerning specific mathematical Topics

It is of great value to know what mathematical topics respondents use GeoGebra for to explain mathematics to their learners, since one reason could be that teachers are less familiar with the use of GeoGebra for explaining certain mathematics topics. It could be that certain topics are just not applicable for the grades that respondents teach. If however, the reason for not using GeoGebra for specific mathematics topics is because of a lack of knowledge or experience, it could provide useful insight to organisations that provide GeoGebra training as to which GeoGebra topics mathematics teachers might struggle with. Respondents by far make more use of GeoGebra for explaining graphs (38 or 50,67%) and geometry (33 or 44%) than any other topic. GeoGebra are also used by a lot of respondents for teaching transformation geometry (25 or 33,33%), analytical geometry (17 or 22,67%) and statistics (13 or 17,33%). One respondent stated that he uses GeoGebra for explaining trigonometric graphs (which are a sub section of graphs, but more specific than the graphs category), while another respondent (a primary school teacher) used GeoGebra for teaching fractions. The various results are depicted in Table 4.8.

GeoGebra topical usage	Number of respondents	Percentage of respondents
Do not use GeoGebra	31	41.33
Graphs	38	50.67
Statistics	13	17.33
Calculus	6	8
Analytical geometry	17	22.67
Geometry	33	44
Transformation geometry	25	33.33
Other uses	2	2.67

Table 4.8: Respondents' topical usage of GeoGebra

4.2.3 Respondents' Awareness of GeoGebra

There is only one (1,33%) respondent that never heard of GeoGebra before. Most respondents (55 or 73,33%) were made aware of GeoGebra at a V.A.W. workshop, which means the V.A.W. is mainly responsible for making its members aware of the applications of GeoGebra. Some respondents became aware of GeoGebra through more than one source, although very few were made aware of GeoGebra through other sources than the V.A.W. and colleagues (15 or 20%) – refer to Table 4.9. Other sources for being made aware of GeoGebra were at university and from fellow students (which are similar to hearing from colleagues). Yet another respondent found GeoGebra installed on a school computer where he is teaching and learned the software himself.

GeoGebra awareness	Number of respondents	Percentage of respondents
Never heard of GeoGebra	1	1.33
V.A.W. Workshop	55	73.33
Internet	5	6.67
Colleague	15	20
Other	4	5.33

Table 4.9: Where respondents heard about GeoGebra

4.2.4 Training received by Respondents for using GeoGebra

Just as the V.A.W. is mainly responsible for making their members aware of GeoGebra and its uses, they are also mainly responsible for training their members in the use of GeoGebra with 58 (77,33%) of respondents receiving their GeoGebra training from the V.A.W (refer to Table 4.10).

GeoGebra training received	Number of respondents	Percentage of respondents
No training at all	10	13.33
Provided by the V.A.W.	58	77.33
GeoGebra manual	11	14.67
Trained myself	12	16
University training course	3	4
Other	1	1.33

Table 4.10: GeoGebra training received by respondents

Only 10 (13,33%) respondents did not receive any GeoGebra training at all, while 11 (14,67) made use of the GeoGebra manual as well and 12 (16%) trained themselves. One respondent declared that the V.A.W. tutor gave GeoGebra training at her school at some stage, besides also getting trained at a V.A.W. workshop.

4.2.5 Hardware Resources available which would enable Respondents to use GeoGebra for teaching Mathematics

Hardware resources do not seem to be as readily available as necessary to encourage greater use of GeoGebra, especially for the use of instruction (refer to Table 4.11 and Figure 4.1).

Availability of hardware resources	Number of respondents	Percentage of respondents
Personal computer or laptop	65	86.67
Computer in my classroom	29	38.67
Access to computer and data projector	24	32
Data projector in my classroom	47	62.67

Table 4.11: Availability of hardware resources

A large proportion of the respondents own a personal computer or laptop (65 or 86,67%) and would therefore be able to install and use GeoGebra at home and at least be able to create worksheets or question papers. 47 (62,67%) of the respondents have a data projector in their classrooms but considerably less have a computer in their classes (29 or 38,67%) and they would probably have to connect their own laptops to the data projectors in their classrooms if their respective schools do not have laptops that they could sign out to use. Only 24 (32%) have access to a computer as well as a data projector, which may not necessarily be in their own classroom and they would have to go to a different classroom which might cause time management problems.

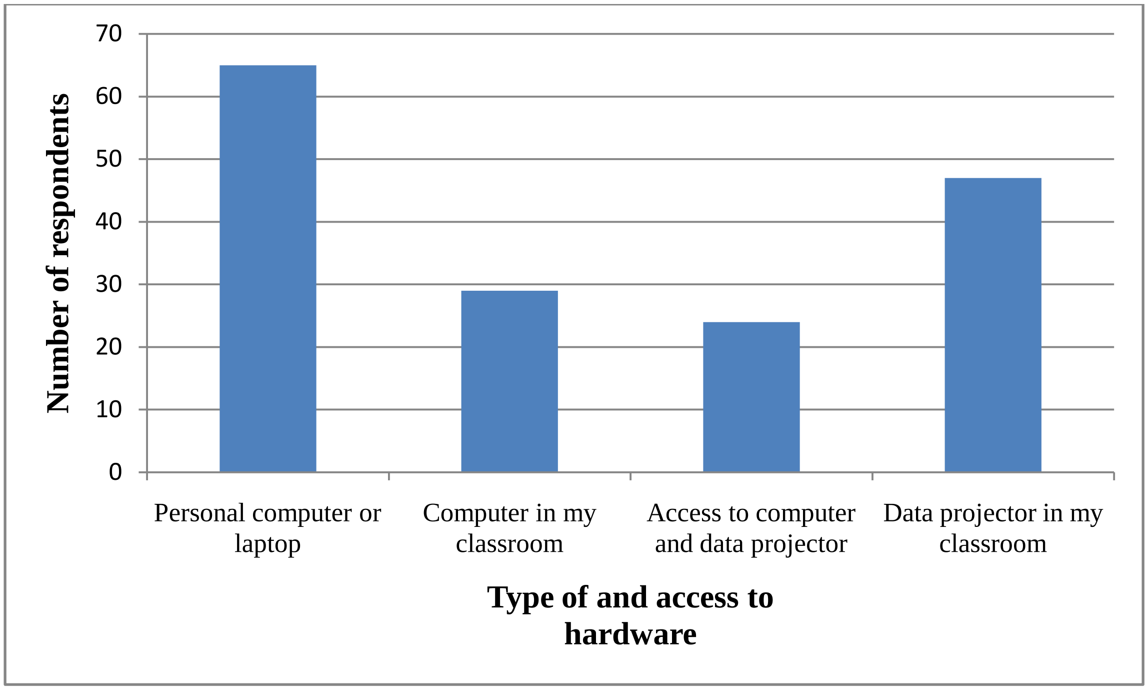

Figure 4.1: Availability of hardware resources

4.2.6 Availability of GeoGebra to Respondents for teaching Mathematics

Table 4.12 summarises the availability of GeoGebra to the respondents of the study. GeoGebra was installed on most respondents' computers (63 or 84%). 25 (33,33%) of the respondents that had computers in their classrooms, had GeoGebra installed (refer to Table 4.12 and Figure 4.2).

Availability of GeoGebra software	Number of respondents	Percentage of respondents
Installed on Personal computer or laptop	63	84
Installed on a computer in my classroom	25	33.33
Installed on computer elsewhere	3	4
Installed on my tablet	6	8

Table 4.12: Availability of GeoGebra software

Seeing that GeoGebra could be downloaded for free, with no licences to be bought, all respondents that could get access to the Internet could download it or they could get it from a colleague or from the V.A.W. After downloading or obtaining GeoGebra it could be very easily installed.

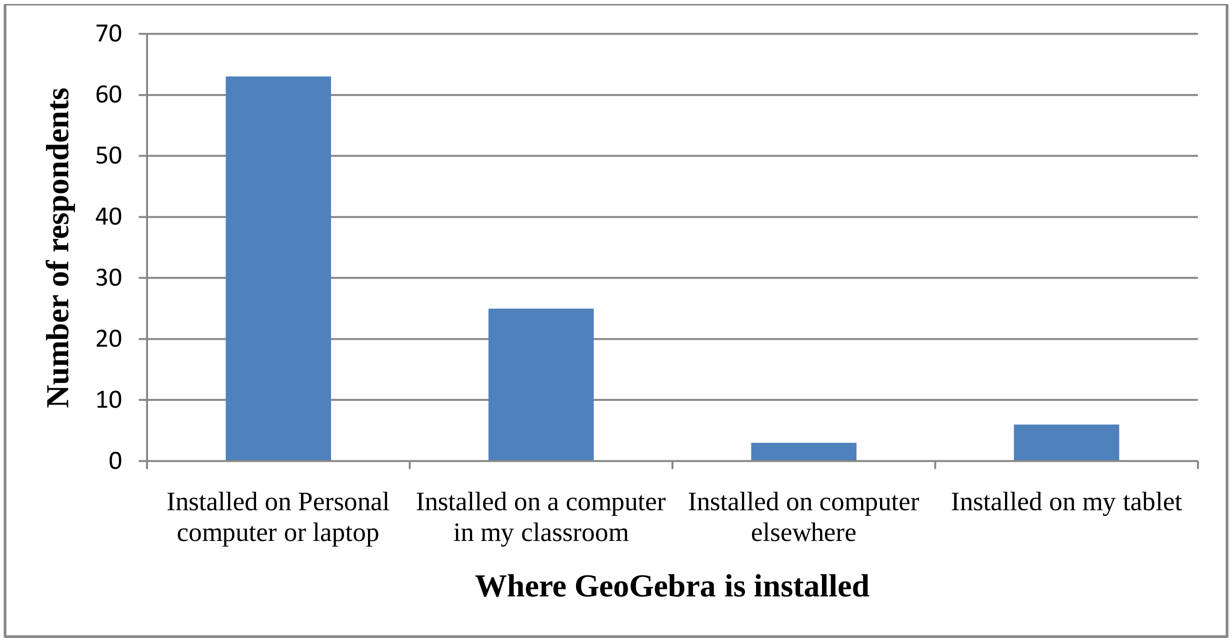

Figure 4.2: Availability of GeoGebra software

4.2.7 Intention to use GeoGebra after Training

A cross-table (two way table) was used to compare how frequently respondents made use of GeoGebra during the past year and how frequently they plan to use GeoGebra after they had received training. By only looking at the totals (see Table 4.13), it is clear that the respondents were a lot more positive concerning the use of GeoGebra after they received training. One can see for example that before training 38 of the 75 respondents (50,67%) indicated that they do not plan to use GeoGebra in the future. However, after the GeoGebra training only three (4%) did not plan to use GeoGebra in the future. On the other side of the coin, where only five (6,67%) respondents used GeoGebra "once a week" before training, 19 (25,33%) intended to use GeoGebra "once or twice a week." Looking more in depth at the individual table cells instead of at the totals only, one can see that of the 38 respondents that did not use GeoGebra at all before training, they plan to change their frequency of GeoGebra usage in the following manner:

- only two do not plan to use it at all;
- 3 only want to use it once;

- 5 intend to use it monthly;
- 6 want to use it every two weeks;
- 8 plan to use it once or twice a week;
- 5 plan to use it three to four times a week;
- 3 intend to use it daily;
- 6 did not answer the question.

	Used in past year					
Use in next 6 months	1 Not at all	2 Once a year	3 Once a month	4 Once a week	5 Daily	**Total**
missing response	6	0	1	1	2	**10**
1 - Not at all	2	1	0	0	0	**3**
2 - Only once	3	0	0	0	0	**3**
3 - Once a month	5	3	4	0	0	**12**
4 - Every 2 weeks	6	1	3	0	0	**10**
5 - 1 or 2 a week	8	1	10	0	0	**19**
6 - 3 or 4 a week	5	1	3	3	0	**12**
7 - Daily	3	0	0	1	2	**6**
Total	**38**	**7**	**21**	**5**	**4**	**75**

Table 4.13: Past use compared to future planned use of GeoGebra

4.3 Findings concerning the measured UTAUT Constructs

In ‘S*ection C*’ of the questionnaire the respondents’ responses to the UTAUT constructs were measured. The items in this section of the questionnaire measured respondents’ Performance Expectancy, Effort Expectancy, Social Influences, Facilitating Conditions and Behavioural Intentions regarding the use of GeoGebra.

In the next sections, the following items will be discussed:

- inter item reliability measuring UTAUT constructs;
- data distributions of the variables;
- frequency distributions of the UTAUT constructs;
- findings on model 1;

- findings on model 2;
- findings on model 3;
- findings on the additional hypotheses.

4.3.1 Item reliability measuring UTAUT Constructs

Cronbach's Alpha coefficient was used to check the questionnaire's reliability by evaluating the internal consistency of the items for all four UTAUT constructs. Gliem and Gliem (2003) compared the reliability of a summated multi-item scale versus a single-item question to show the inappropriateness of making inferences based on single-item questions to measure constructs. They concluded that it is crucial to calculate and report on Cronbach's Alpha coefficient for internal consistency reliability when researchers make use of Likert-scales or other scales. It is generally considered that a Cronbach Alpha of 0,7 to 0,8 are acceptable to indicate reliability (Osborne & Waters, 2002) while Tavakol and Dennick (2011) state that Cronbach's Alphas between 0,7 and 0,95 are reported to be acceptable.

Panayides (2013) advocates caution when interpreting Cronbach's Alpha coefficient since very high values of alpha could be as a result of lengthy scales with redundant items. Huysamen (2006) concurs that the more items are added, the greater Cronbach's Alpha becomes. In this study however the PE construct had the most items, namely 13 (not that much), for measuring it, while only 8, 4, 4 and 3 items were used respectively to measure the EE, IS, FC and BI constructs. High values of Cronbach's Alpha coefficients reported for the constructs in this study could therefore not have been because of lengthy scales with redundant items. Thus it indicates internal consistency reliability. Furthermore Gliem and Gliem (2003) state that the most important output column of the multi-item scale when running the correlation procedure for Cronbach's Alpha is the "Alpha if deleted" column, since it shows how Cronbach's Alpha and subsequent internal item consistency will change if a specific individual item is removed from the scale. As will be seen in the subsequent discussion of Cronbach's Alpha for each measured construct in this study, deleting individual items change the coefficient ever so slightly that it is insignificant in all but one construct (namely BI) – showing that all items are appropriate (and therefore not redundant) for measuring each construct.

The Cronbach Alphas for each construct in this study will be discussed next. PE (13 items) had an alpha of 0,91. Deleting individual items would change the Cronbach Alpha to 0,92 in some cases or 0,93 in other cases. EE (8 items) had a Cronbach Alpha of 0,95 and deleting individual items would change the Cronbach Alpha to 0,94 in all but one case (remaining 0,95). The Cronbach Alpha for SI (4 items) was 0,92 and removing individual items would decrease the coefficient in all cases between 0,89 and 0,91. FC (4 items) had a Cronbach Alpha of 0,79 and as was the case with SI, deleting individual items would decrease the alpha coefficient in all cases, especially in one case where the alpha would change from 0,79 to 0,67, indicating that all items, especially the latter item, should be retained. The Cronbach Alpha for BI (3 items) was 0,88 and deleting individual items would decrease the Cronbach Alpha coefficient in two cases (to either 0,78 or 0,79) but increase the coefficient when removing the final item to 0,92. The Cronbach Alpha coefficients for the UTAUT constructs in this study are summarised in Table 4.14.

When deleting individual items, these changes in the Cronbach Alphas were so insignificant that it implied that all items should be retained for all the constructs except for BI. Where BI was concerned, its third (last) item was removed for the inferential statistics analysis. This specific item (question 20) was however retained for reporting purposes via descriptive statistics. Considering that a Cronbach Alpha between 0,7 and 0,95 are reported to be acceptable, all items measuring the UTAUT constructs had internal consistency reliability.

UTAUT construct	**# items**	**Cronbach Alpha**	**Alpha if deleted (each individual items) ***
PE	13	0,91	0,92 or 0,93
EE	8	0,95	0,94 or 0,95
SI	4	0,92	0,89; 0,90 or 0,91
FC	4	0,79	0,67; 0,75; 0,77 or 0,78
BI	3	0,88	0,78; 0,79 or 0,92

* Values are rounded to two decimal places

Table 4.14: Summary of Cronbach Alpha coefficients for the UTAUT constructs in this study

4.3.2 Data Distributions of the Variables

In the previous section, internal consistency reliability was ascertained which allowed for the mean scores of the items measuring the different UTAUT constructs to be used. These mean scores were represented by the following variables: PE_{mean}, EE_{mean}, SI_{mean}, FC_{mean} and BI_{mean}. Normality of the data was investigated thereafter by considering the skewness of each of these variables. Skewness is the "degree of departure from symmetry" (Dooley, 1984, p. 380). In skewed distributions the majority of the scores are either high or low and the small percentage of scores that are observed in the opposite direction of the majority of the scores forms a tail (Huck, 2012). If the tail points to the left, the distribution is said to be negatively skewed and if the tail points to the right, the distribution is positively skewed (Dooley, 1984). The distribution and probability plots of the mean score variables are depicted in Figure 4.3, Figure 4.4, Figure 4.5, Figure 4.6, and Figure 4.7 below.

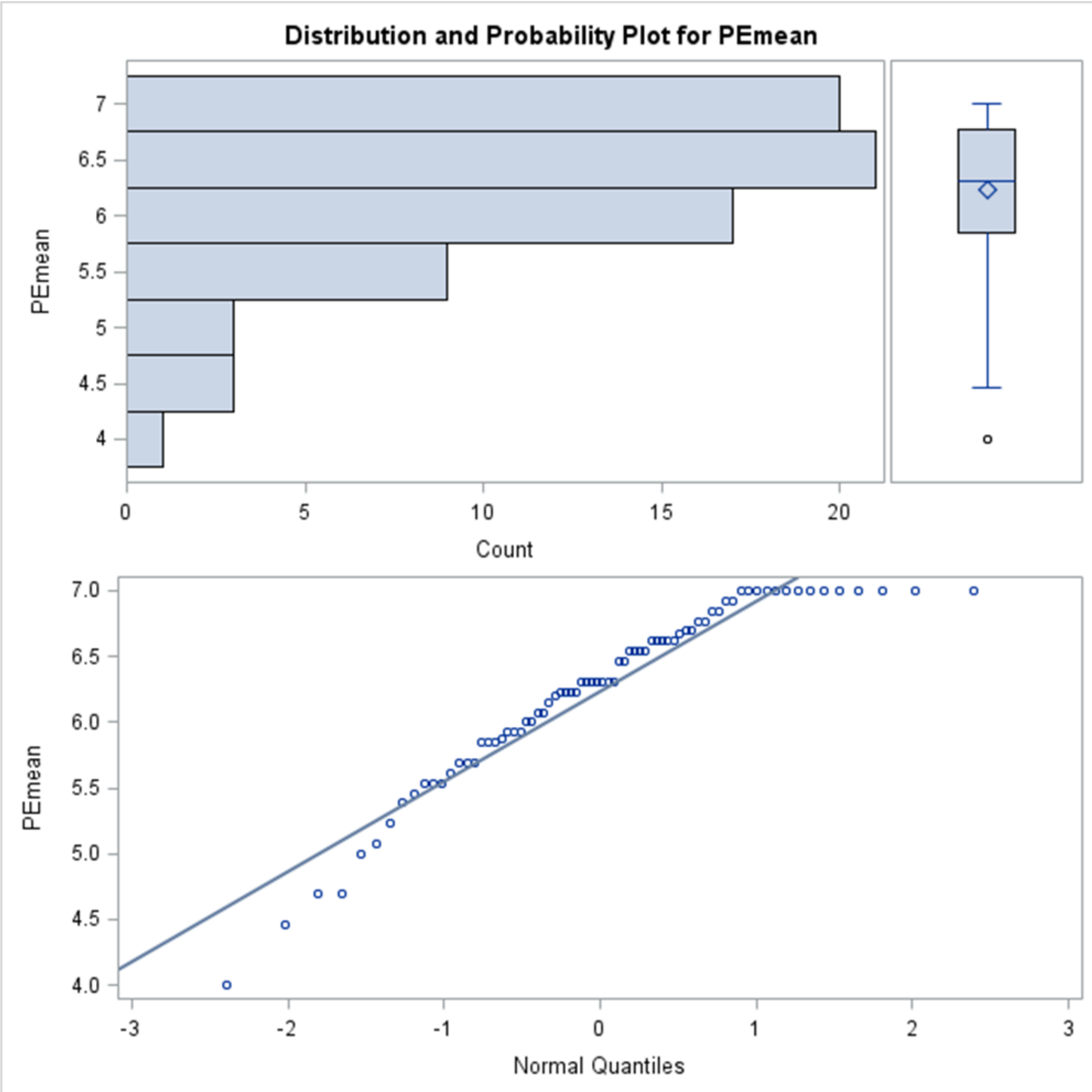

Figure 4.3: Distribution and probability plot for Performance Expectancy (PE_{mean})

Skewness = -1,02

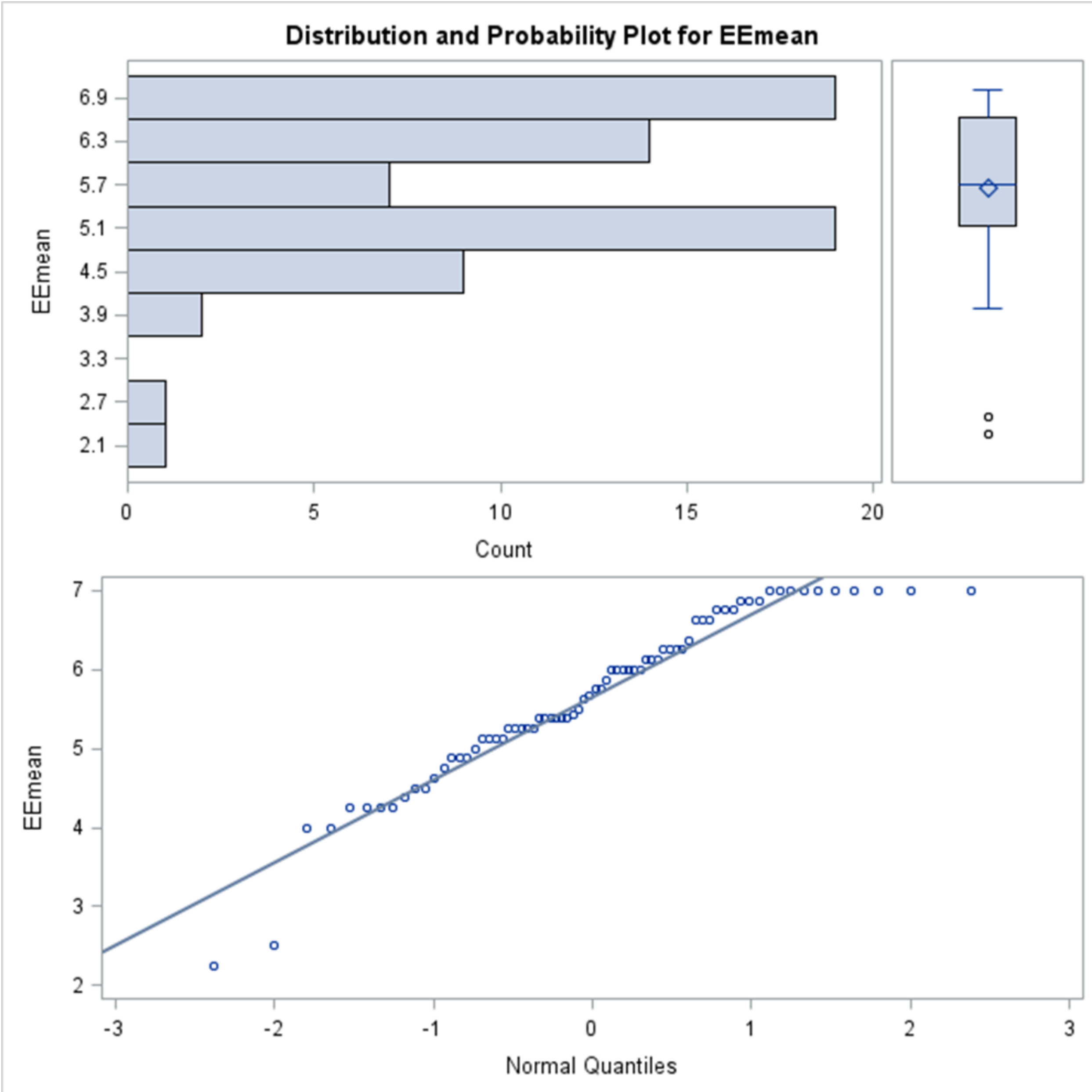

Figure 4.4: Distribution and probability plot for Effort Expectancy (EE_{mean})

Skewness = -0.79

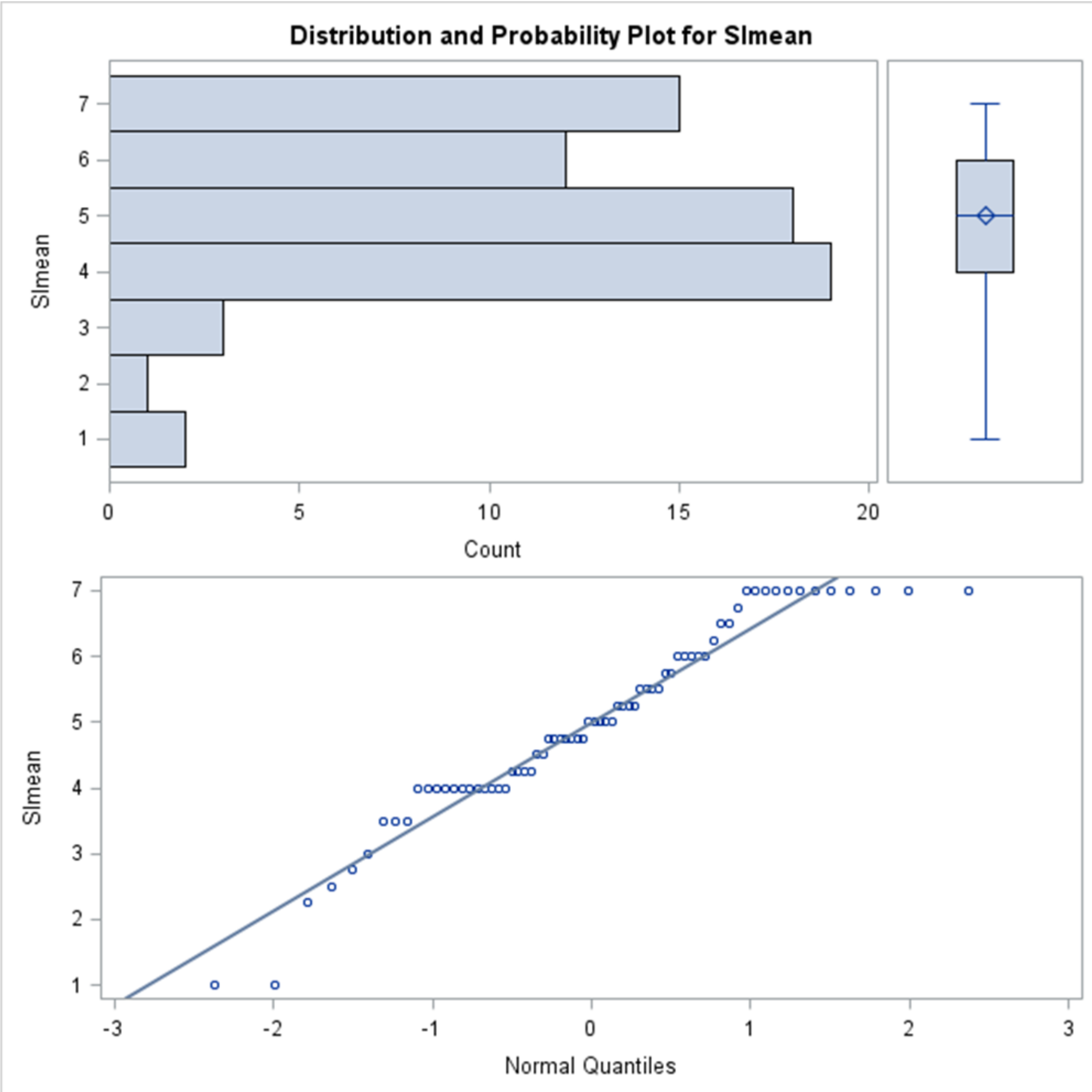

Figure 4.5: Distribution and probability plot for Social Influence (SI_{mean})

Skewness =-0.46

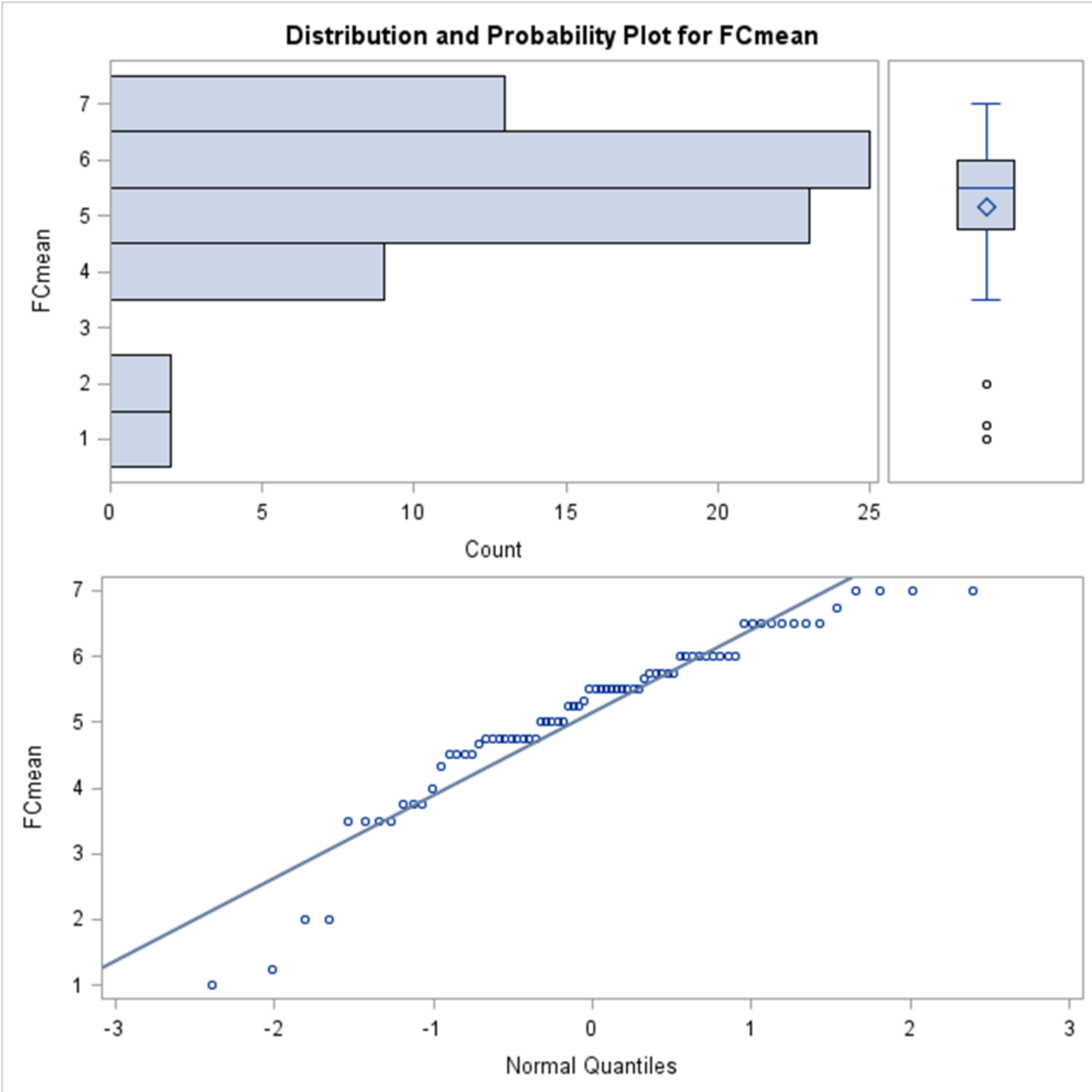

Figure 4.6: Distribution and probability plot for Facilitating Conditions (FC_{mean})

Skewness =-1.20

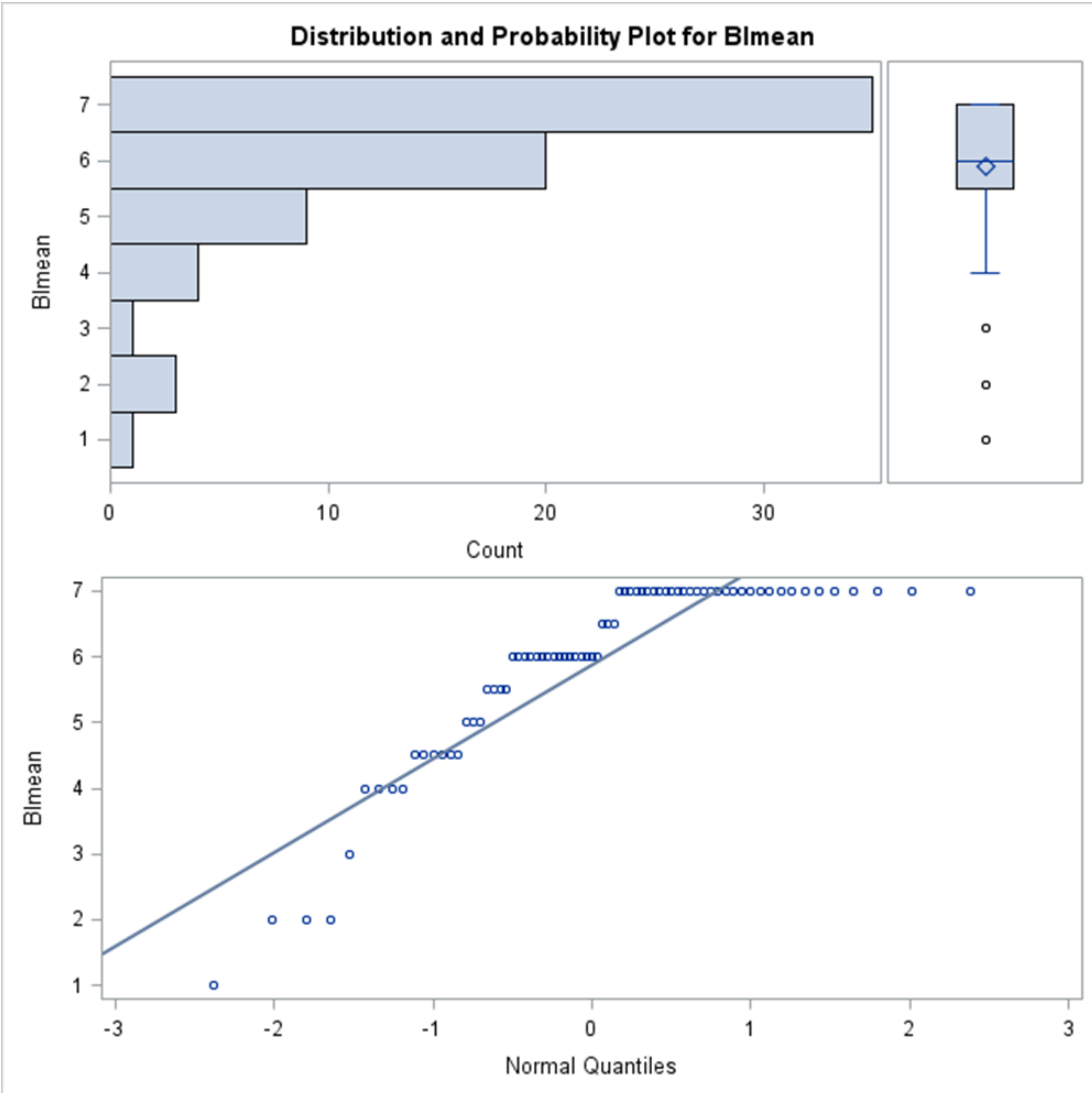

Figure 4.7: Distribution and probability plot for Behavioural Intention (BI_{mean})

Skewness =-1.54

If the range of skewness falls between -1 and 1 the data are regarded as normally shaped by the majority of researchers (Huck, 2012). The skewness of EE_{mean} and SI_{mean} are within range to be considered normally distributed and for PE_{mean}, FC_{mean} and BI_{mean} the data are negatively skewed, although for PE_{mean} the skewness at -1,02 falls just outside the lower acceptable range of -1. A reasonable explanation for the skewness of the data could be the fact that respondents were from a homogenous group. All respondents were mathematics teachers (and V.A.W. members) who voluntarily attended a V.A.W. Congress during the holidays. These respondents are therefore teachers who actively seek to broaden their horizons. This could have contributed to the fact that the respondents were generally positive about their Performance Expectancy for using GeoGebra, as well as being positive about their intention to utilise GeoGebra in future. Since most respondents were teaching at city schools (72%), a great deal less in rural schools (20%) and only 2,67% in township schools, this could explain the skewness of data for FC_{mean} because resources would be more readily available in richer cities compared to poorer townships.

4.3.3 Frequency Distributions of the UTAUT Constructs

The data collected through questionnaires in this study contains both categorical and continuous data. Wetcher-Hendricks (2011, p. 50) claims that "[m]easures of frequency qualify as the only types of descriptive statistic appropriate for summarizing categorical data" and that it could also be used to summarise continuous data. Dooley (1984) confirms that frequency distributions are used to summarise and organise data. Wetcher-Hendricks (2011) furthermore believes that researchers should compute and report frequencies for categorical variables whenever it is possible, especially if a study make use of correlation and regression analysis. The reason for this is that correlation and regression analysis (also applied in this study) may utilise frequencies too (ibid.). Wetcher-Hendricks' belief that researchers should report on frequencies as much as possible is supported by Huck (2012). Huck is of the opinion that it is unfortunate that only a few researchers provide descriptive summaries of their data, since frequency distributions (whether summarised in words, tables or pictures) allow the reader to get a good understanding of the data. Grouped frequency distributions allow the data to be summarised in a more compact manner (Huck, 2012). Clearly frequency distributions form an important part of research and the frequency distributions of each UTAUT construct are therefore discussed and illustrated by tables in the following sections.

4.3.3.1 Frequency Distributions of Performance Expectancy

Performance Expectancy in this study is the extent to which mathematics teachers believe that using GeoGebra will assist them in improving their teaching and learning of mathematics in the classroom and it might influence their intention to use GeoGebra for teaching and learning. Most respondents either “agreed” or “strongly agreed” that GeoGebra is useful for teaching the various mathematics topics, especially where graphs (62,67% “strongly agreed”) and geometry (57,33% “strongly agreed”) are concerned. The majority of the respondents (90,66% either “agreed” or “strongly agreed”) with the statement that using GeoGebra to teach mathematics will make it easier for learners to visualize relationships, while 74,66% believes (either “agreed” or “strongly agreed”) that using GeoGebra to teach mathematics in the classroom saves time. A breakdown of the response frequencies to all items in this construct could be viewed in Table 4.15.

Performance Expectancy	% respondents that did not answer the item	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
GeoGebra is ***useful*** for teaching **graphs**.	2.67	0	0	0	4	4	26.67	62.67
GeoGebra is ***useful*** for teaching **statistics**.	6.67	0	0	1.33	17.33	14.67	22.67	37.33
GeoGebra is ***useful*** for teaching **calculus**.	10.67	0	0	2.67	29.33	5.33	20	32
GeoGebra is ***useful*** for teaching **transformation geometry**.	5.33	0	0	0	5.33	2.67	30.67	56
GeoGebra is ***useful*** for teaching **geometry**.	6.67	0	0	0	5.33	4	26.67	57.33
GeoGebra is ***useful*** for teaching **analytical geometry**.	9.33	0	0	0	17.33	8	25.33	40
Using GeoGebra to teach mathematics in the classroom will enhance learners’ understanding.	1.33	0	0	0	4	8	30.67	56
Using GeoGebra makes it easier to draw accurate graphs.	1.33	0	0	0	4	1.33	20	73.33

Using GeoGebra mathematical concepts could be explained in a way that learners grasp the concepts quicker than they would if conventional (board and chalk) methods were used.	1.33	0	0	0	5.33	8	33.33	52
Using GeoGebra to teach mathematics in the classroom will make it easier for learners to visualize relationships.	1.33	0	0	0	1.33	6.67	33.33	57.33
Using GeoGebra to teach mathematics in the classroom will make it easier to explain difficult concepts.	2.67	0	0	0	5.33	12	33.33	46.67
Using GeoGebra to teach mathematics in the classroom saves time.	1.33	0	0	2.67	6.67	14.67	21.33	53.33
If I use GeoGebra to teach mathematics in the classroom, I will increase my employment opportunities, being more in demand as a mathematics teacher.	1.33	0	1.33	1.33	16	18.67	17.33	44

Table 4.15: Frequency distributions of Performance Expectancy (%)

4.3.3.2 Frequency Distributions of Effort Expectancy

Effort Expectancy in this study is a mathematics teacher's perceived ease of use of GeoGebra for the teaching and learning of mathematics in the classroom which might influence his/her intention to use GeoGebra for teaching and learning. Respondents were generally positive about the ease of using GeoGebra for teaching various mathematics topics, with graphs being considered the easiest to apply GeoGebra. 64% either "agreed" or "strongly agreed" that it is easy to use GeoGebra for teaching graphs. GeoGebra in general is believed to be easy to use by 62,67% of the respondents, who either "agreed" or "strongly agreed" with the statement. Frequencies of responses to all eight items used to measure the Effort Expectancy construct are depicted in Table 4.16.

Effort Expectancy	% respondents that did not answer the item	1 - % Strongly Disagree	2 - % Disagree	3 - % Somewhat Disagree	4 - % Neutral	5 - % Somewhat Agree	6 - % Agree	7 - % Strongly Agree
It is ***easy to use*** GeoGebra for teaching **graphs**.	4	0	2.67	0	8	21.33	29.33	34.67
It is ***easy to use*** GeoGebra for teaching **statistics**.	8	0	2.67	1.33	26.67	20	20	21.33
It is ***easy to use*** GeoGebra for teaching **calculus**.	8	0	2.67	2.67	29.33	17.33	22.67	17.33
It is ***easy to use*** GeoGebra for teaching **transformation geometry**.	5.33	0	2.67	1.33	12	14.67	28	36
It is ***easy to use*** GeoGebra for teaching **geometry**.	6.67	0	2.67	0	12	16	28	34.67
It is ***easy to use*** GeoGebra for teaching **analytical geometry**.	8	0	2.67	0	22.67	17.33	21.33	28
In general it is ***easy to use*** GeoGebra for teaching mathematics.	5.33	0	2.67	2.67	6.67	20	30.67	32
Learning to use GeoGebra to teach mathematics in the classroom would be ***easy*** for me.	4	0	0	1.33	8	24	30.67	32

Table 4.16: Frequency distributions of Effort Expectancy

4.3.3.3 Frequency Distributions of Social Influence

Social Influence in this study is a mathematics teacher's opinion on what people who are significant to them (namely their principal, HOD or subject head, colleagues and the school governing body) think about their use of GeoGebra for the teaching and learning of mathematics in the classroom and it might influence his/her intention to use GeoGebra for teaching and learning. More respondents were of the view that their HOD or subject head, and their colleagues would believe that they should utilise GeoGebra (with 40% either "agreeing" or "strongly agreeing" with the statement) rather than their principal (32% "agreed" or "strongly agreed") and the school governing body (26,67%% "agreed" or "strongly agreed"). Table 4.17 presents a complete breakdown of response frequencies for all the items in this construct.

Social Influence	% respondents that did not answer the item	1 - % Strongly Disagree	2 - % Disagree	3 - % Somewhat Disagree	4 - % Neutral	5 - % Somewhat Agree	6 - % Agree	7 - % Strongly Agree
My **HOD or subject** head thinks that I should use GeoGebra to teach mathematics in the classroom.	9.33	2.67	1.33	2.67	22.67	21.33	14.67	25.33
My **principal** thinks that I should use GeoGebra to teach mathematics in the classroom.	10.67	2.67	4	4	29.33	17.33	16	16
The **school governing body** thinks that I should use GeoGebra to teach mathematics in the classroom.	10.67	6.67	4	2.67	37.33	12	12	14.67
My **colleagues** think that I should use GeoGebra to teach mathematics in the classroom.	8	4	2.67	1.33	26.67	17.33	14.67	25.33

Table 4.17: Frequency distributions of Social Influence

4.3.3.4 Frequency Distributions of Facilitating Conditions

Facilitating Conditions in this study are the level of a mathematics teacher's perception that organisational and technical infrastructure (such as resources, knowledge/skills and technical support regarding the use of GeoGebra) exists to support the use of GeoGebra for the teaching and learning of mathematics in the classroom. This might influence his/her actual use of GeoGebra for teaching and learning. Interestingly, almost half of the respondents "strongly agreed" (45,33%) that they had the resources available to them in order to utilise GeoGebra for teaching mathematics in the classroom" while 20% "agreed" with the statement. Respondents were considerably less confident in their knowledge to use GeoGebra for instruction though, with only 12% who "strongly agreed" and 36% who only "somewhat agreed" that they were knowledgeable in this instance.

Facilitating Conditions	% respondents that did not answer the item	1 - % Strongly Disagree	2 - % Disagree	3 - % Somewhat Disagree	4 - % Neutral	5 - % Somewhat Agree	6 - % Agree	7 - % Strongly Agree
I have the **resources** necessary to use GeoGebra to teach mathematics in the classroom.	4	4	2.67	0	10.67	13.33	20	45.33
I have the **knowledge** necessary to use GeoGebra to teach mathematics in the classroom.	1.33	5.33	9.33	6.67	13.33	36	16	12
It is possible for me to use GeoGebra to teach mathematics in the classroom.	2.67	2.67	2.67	5.33	4	18.67	32	32
A specific person (or group) would be available for assistance with difficulties when using GeoGebra to teach mathematics in the classroom.	2.67	8	9.33	4	21.33	18.67	24	12

Table 4.18: Frequency distributions of Facilitating Conditions

Although a greater percentage of respondents were less confident in their GeoGebra skills than the percentage who claimed to have the necessary resources available to them for teaching GeoGebra, still less than a quarter (21,33%) either "strongly disagreed", "disagreed" or "somewhat disagreed" with the statement that they are skilled in using GeoGebra. More conclusions from the data for this construct can be drawn from Table 4.18.

4.3.3.5 Frequency Distributions of Behavioural Intention

In this study Behavioural Intention is referred to as the mathematics teachers' intention to use GeoGebra for teaching and learning. Most teachers were very positive about using GeoGebra during the next 6 months. This could be attributed to the positive effect that GeoGebra training had on the participants. Table 4.19 can be reviewed for a complete breakdown of the frequencies of responses to the questionnaire items relating to Behavioural Intention. Respondents' frequency of indented GeoGebra usage also increased dramatically after they had received training, as discussed previously in section 4.2.7 and depicted in Table 4.13.

Behavioural intention	**% respondents that did not answer the item**	**1 - % Strongly Disagree**	**2 - % Disagree**	**3 - % Somewhat Disagree**	**4 - % Neutral**	**5 - % Somewhat Agree**	**6 - % Agree**	**7 - % Strongly Agree**
I **intend to** use GeoGebra to teach mathematics in the classroom during the next 6 months.	2.67	1.33	4	2.67	4	10.67	29.33	45.33
I am **determined** that I will use GeoGebra to teach mathematics in the classroom during the next 6 months.	5.33	1.33	5.33	0	12	8	22.67	45.33

Table 4.19: Frequency distributions of Behavioural Intention

4.3.4 Findings on Model 1

Findings on Model 1 (refer to Figure 2.4) will be presented in this section. Model 1 was used to test whether or not teachers' Performance Expectancy, Effort Expectancy and Social Influence will have an influence on teachers' intention to use GeoGebra for the teaching and learning of mathematics. It was hypothesised that no relationship between teachers' intention to use GeoGebra and their Performance Expectancy, Effort Expectancy and Social Influence exist, with the alternative hypothesis that such a relationship does exist. Table 4.20 shows the correlations of independent variables (PE_{mean}, EE_{mean} and SI_{mean}) with the dependent variable (BI_{mean}) as well as the mean and standard deviation of each variable.

	Mean	**Std Dev**	PE_{mean}	EE_{mean}	SI_{mean}	BI_{mean}
PE_{mean}	6.23	0.68	-	0.77**	0.34**	0.35**
EE_{mean}	5.66	1.05	-	-	0.28*	0.28*
SI_{mean}	5.00	1.43	-	-	-	0.55**
BI_{mean}	5.88	1.43	-	-	-	-

Table 4.20: Correlations between independent (PE_{mean}, EE_{mean} and SI_{mean}) and dependent (BI_{mean}) variables

Notes:

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

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

PE - Performance Expectancy, EE - Effort Expectancy, SI - Social Influence, BI - Behavioural Intention

Multiple regression was used to determine whether the UTAUT constructs (PE, EE and SI) are significant predictors of the respondents' intention (BI) to use GeoGebra for the teaching and learning of mathematics. SAS' regression procedure was used for the analysis. The results can be seen in Table 4.21.

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	31.0276	10.3425	9.05	<.0001
Error	63	71.9724	1.14242		
Corrected Total	66	103			
Root MSE	1.06884	**R-Square**	0.3012		
Dependent Mean	6	**Adj R-Sq**	0.268		
Coeff Var	17.814				

Parameter Estimates						
Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Partial R-square by variable**
Intercept	**1**	1.00872	1.25533	0.8	0.4247	
PE_{mean}	**1**	0.43061	0.30526	1.41	0.1633	0.0816
EE_{mean}	**1**	0.1158	0.19428	0.6	0.5533	0.0039
SI_{mean}	**1**	0.32967	0.10737	3.07	0.0032	0.2157

Table 4.21: Multiple regression (Model 1)

The level of significance was chosen at $\alpha = 0{,}05$. The p-value of the F-test ($p < 0{,}0001$) compared to the significance level of 0,05 indicates that H_0 is rejected in favour of H_1 for model 1. Model 1 is therefore a significant model. An R^2 of 0,3 was obtained which indicates that 30% of the variance in respondents' intention to use GeoGebra can be explained by the combination of the three independent variables (i.e. PE, EE and SI). The p-values of the significance per factor indicated that only SI ($p = 0{,}0032$) was significant on its own to predict a user's intention to use GeoGebra. On the other hand, PE ($p = 0{,}16$) and EE ($p = 0{,}55$) were not significant by themselves for predicting a user's intention to use GeoGebra. The simplest regression equation for predicting BI is: BI = 1,00872 + 0,33 (SI). Looking at the Partial R^2 values by variable,

Table 4.21 shows that SI only has an R^2 of 0,22 which is smaller than the R^2 of 0,3 when all three independent variables are included. A users' intention to use GeoGebra could therefore be better predicted by the following regression equation: BI = 1,00872 + 0,43 (PE) + 0,12 (EE) + 0,33 (SI).

4.3.5 Findings on Model 2

Findings on Model 2 (refer to Figure 2.4) will be presented in this section. Model 2 was used to test whether or not Facilitating Conditions will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics). It was hypothesised that Facilitating Conditions' means (FC's means for both categories) are the same, with the alternative hypothesis that they are different. The results of the t test can be seen in Table 4.22.

Variable	**T-tests; Grouping: AU (Group 1: Yes & Group 2: No)**						
	Mean Yes	Mean No	t-value	df	p	Valid N Yes	Valid N No
FC_{mean}	5.315315	4.995495	1.096553	72	0.276491	37	37

Table 4.22: Grouping Actual use (AU) with variable FC_{mean}

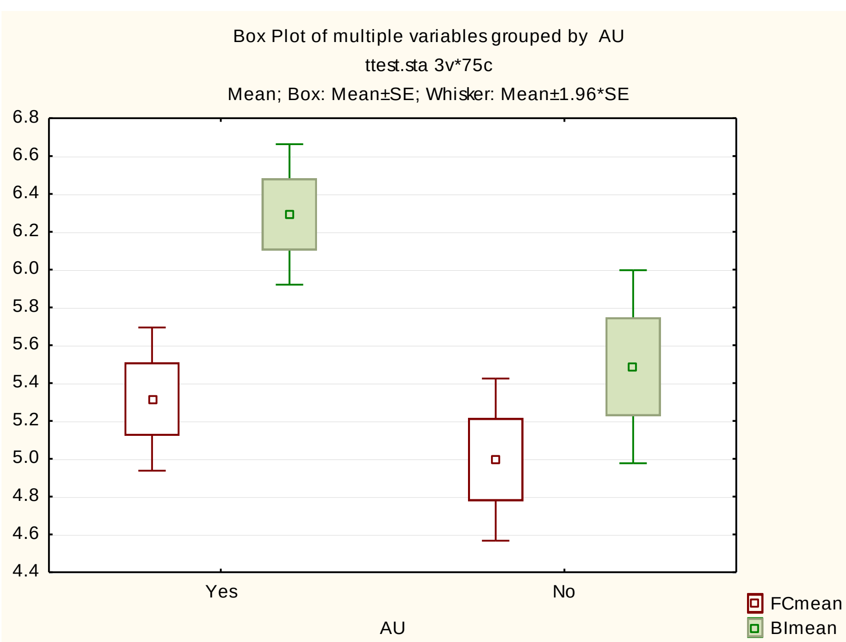

Figure 4.8: Box plots of FC_{mean} (Model 2) and BI_{mean} (Model 3) grouped by actual use

The dependent variable (AU – actual use) is categorical with n=37 for both the “yes” and “no” categories. The mean for the “yes” category is 5,32 and for the “no” category it is 5,0 (see Table 4.22 and compare it with Figure 4.8). A significance level of α = 0,05 was used. The p-value of the t test is 0,28. H_0 can therefore not be rejected. This means that there is no statistical difference between the FC means for the “yes” and “no” categories of the actual use. Consequently, Model 2 is not a significant model. Hence, Facilitating Conditions does not necessarily predict the actual use of GeoGebra for teaching and learning.

4.3.6 Findings on Model 3

Findings on Model 3 (refer to Figure 2.4) will be presented in this section. Model 3 was employed to test whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics. It was hypothesised that the means for teachers' *intention* to use GeoGebra (BI means for both categories) are the same, with the alternative hypothesis that they are different.

Variable	**T-tests; Grouping: AU (Group 1: Yes & Group 2: No)**						
	Mean Yes	Mean No	t-value	df	p	Valid N Yes	Valid N No
BI_{mean}	6.291667	5.486486	2.490315	71	0.015105	36	37

Table 4.23: Grouping Actual use (AU) with variable BI_{mean}

The dependent variable (AU – actual use) is categorical with n=36 for the “yes” category and n=37 for the “no” category. The “yes” category has a mean 6,29 and for the “no” category it is 5,49 (see Table 4.23 and compare it with Figure 4.8 in the previous section). A significance level of α = 0,05 was used. The p-value of the t (p=0,015) compared to the significance level of 0,05 indicates that H_0 is rejected in favour of H_1 for Model 3. This implies that there is indeed a statistical difference between the BI means for the “yes” and “no” categories of the actual use. Consequently, Model 3 is a significant model. Hence, one can state with a 98,5% level of confidence (p=0,015) that teachers' *intention* to use GeoGebra does predict the *actual* use of GeoGebra for teaching and learning.

4.3.7 Findings on the additional Hypotheses

Findings on the hypotheses, additional to the ones on which Models 1-3 were based, will be presented in this section. The samples' sizes of 75 were roughly halved, since only respondents who actually used GeoGebra were included to make statistical inferences on. The logic behind excluding respondents who did not use GeoGebra at all is that one wanted to test whether a respondent's Performance Expectancy (PE) and/or Effort Expectancy (EE) for a specific GeoGebra topic such as graphs would predict a respondent's actual use (AU) of GeoGebra for that specific topic (graphs in this example). It did not make sense to include non-users of GeoGebra to test if their respective PE or EE items (specific mathematics topics) would predict their actual use (AU) of GeoGebra for those specific mathematics topics, since they were not using GeoGebra at all. The hypotheses, their alternatives, p-values and whether or not the null hypotheses are rejected are summarised in Table 4.24. A significance level of $\alpha = 0{,}05$ was used.

The first hypothesis regarding *Performance Expectancy* and actual use (teachers' Performance Expectancy of GeoGebra's usefulness of graphs is independent of their *actual use* of GeoGebra for the teaching and learning of graphs) could not be tested since the PE item "*useful* for teaching graphs" has a frequency of 0 in the "not agree" category and therefore no comparisons could be drawn.

The first hypothesis regarding *Effort Expectancy* and actual use (teachers' Effort Expectancy of GeoGebra's ease of use of graphs is independent of their *actual use* of GeoGebra for the teaching and learning of graphs) could not be reported on since the "not agree" frequency of the EE item "It is *easy to use* GeoGebra for teaching graphs" is too small (only 4 out of 36) to report on its p-value.

The null hypothesis regarding teachers' Performance Expectancy of GeoGebra's usefulness of statistics for teaching and learning and their actual use of GeoGebra for the teaching and learning of statistics is rejected in favour of the alternative hypothesis. Therefore teachers' Performance Expectancy regarding statistics seemed to be associated with their actual use of statistics. Teachers' actual use of calculus, transformation geometry, geometry and analytical geometry did not seem to be associated with teacher's Performance Expectancy for these mathematical topics, as the researcher failed to reject each of the null hypotheses concerning Performance Expectancy and these abovementioned mathematics topics. The p-values for Fishers' exact test regarding Performance Expectancy of GeoGebra for using geometry and analytical geometry however, are border cases (see Table 4.24), which indicate a tendency for significance. The null hypotheses regarding teachers' Effort Expectancy of GeoGebra's ease of use of statistics, transformation geometry, geometry and analytical geometry for teaching and learning and their actual use of GeoGebra for the teaching and learning of these topics are all rejected, indicating an association between teachers' Effort Expectancy and actual use for each of these topics. Only concerning calculus were the teachers' Effort Expectancy and their actual use not associated by means of failing to reject that specific null hypothesis (refer to Table 4.24).

General null hypothesis (H_0)	**General alternative hypothesis (H_1)**	**Topic**	**P-value**	**Null hypothesis rejected or not rejected**
Teachers' **PE** of GeoGebra's usefulness of **refer to the "topic" column** is independent of their *actual use* of GeoGebra for the teaching and learning of **refer to the "topic" column (in this table)**	Teachers' **PE** of GeoGebra's usefulness of **refer to the "topic" column** is associated with their *actual use* of GeoGebra for teaching and learning **refer to the "topic" column**.	graphs	* Cannot perform the test	n.a.
		statistics	0.037	rejected
		calculus	0.2713	not rejected
		transformation geometry	0.2017	not rejected
		geometry	0.0605	***not rejected
		analytical geometry	0.0625	***not rejected
Teachers' **EE** of GeoGebra's ease of use of **refer to the "topic" column** is independent of their *actual use* of GeoGebra for the teaching and learning of **refer to the "topic" column**	Teachers' **EE** of GeoGebra's ease of use of **refer to the "topic" column** is associated with their *actual use* of GeoGebra for teaching and learning **refer to the "topic" column**.	graphs	* Cannot report this p-value	n.a.
		statistics	0.0169	rejected
		calculus	0.2728	not rejected
		transformation geometry	0.0191	rejected
		geometry	0.0183	rejected
		analytical geometry	0.0152	rejected

Table 4.24: Additional hypotheses concerning the actual use of GeoGebra for various mathematics topics

Note: PE = Performance Expectancy, EE = Effort Expectancy

* The PE item "useful for teaching graphs" has a frequency of 0 in the "not agree" category and therefore no comparisons could be made;

** The "not agree" frequency is too small (only 4 out of 36) to report on its p-value;

*** H_0 is not rejected, although there is a tendency for significance.

4.4 Chapter Summary

In Chapter Four a summary of respondents' demographic information as well as their responses to background questions regarding the use of GeoGebra were presented. Three Models were used to test various hypotheses. Multiple regression was used for Model 1 to determine whether the UTAUT constructs (Performance Expectancy, Effort Expectancy and Social Influence) are significant predictors of the respondents' intention to use GeoGebra for the teaching and learning of mathematics. It was found that 30% of the variance in respondents' intention to use GeoGebra could be explained by the three independent variables. The t test was applied for both Models two and three. Model 2 was not found to be a significant Model. Hence, Facilitating Conditions was not found to predict the actual use of GeoGebra for teaching and learning. Model 3 on the other hand was found to be a significant Model. It could be stated with a 98,5% level of confidence (p=0,015) that teachers' *intention* to use GeoGebra did predict their *actual* use of GeoGebra for teaching and learning. Last of all, twelve hypotheses were tested to see whether or not teachers' Performance Expectancy and Effort Expectancy of GeoGebra for specific mathematics topics would predict their actual use of GeoGebra for those specific mathematics topics.

CHAPTER 5

Discussion of the Results

The purpose of my research was to explore the factors that influence mathematics teachers' use of dynamic mathematics software (specifically GeoGebra) for teaching and learning. Many models in the literature, that aim to explain human behaviour, exist. Some were refined to explain the acceptance of ICT. A brief overview of some Technology Acceptance Models can be viewed in Table 2.2. The UTAUT model was selected to base the theoretical framework on, since it performed considerably better than other models for explaining human behaviour. Many of the studies discussed in the literature review (see section 2.5) used different Technology Acceptance Models, each with their own constructs. Factors that influence the use of ICT will therefore differ in many studies. Some factors that were found to dictate the integration of ICT are the availability of resources, institutional and administrative barriers, training and experience, teachers' anxieties and attitudes, Performance Expectancy and Facilitating Conditions (including resources, support and knowledge), (Ming et al., 2010; Raman et al., 2014; Wachira & Keengwe, 2011). In this study a quantitative approach was followed with 75 survey questionnaires that were completed by participants in the study. In Chapter Five the findings of this study are summarised, conclusions are drawn and implications of the study are suggested. The chapter also states contributions of this study where silence in literature exists and makes recommendations for future research to be conducted.

5.1 Discussion of the Research Question

The purpose of my research was to explore the factors that influence mathematics teachers' use of dynamic mathematics software (specifically GeoGebra) for teaching and learning. This lead to the following research question:

1. What factors influence mathematics teachers' use of GeoGebra for the teaching and learning of mathematics?

In order to address this question, three null hypotheses as well as their alternatives where formulated as follows:

- Model 1 (testing whether or not teachers' Performance Expectancy, Effort Expectancy and Social Influence will have an influence on teachers' intention to use GeoGebra for the teaching and learning of mathematics):

  H_0: No relationship between teachers' intention to use GeoGebra and their Performance Expectancy, Effort Expectancy and Social Influence exist.

  H_1: There is a relationship between teachers' intention to use GeoGebra and their Performance Expectancy, Effort Expectancy and Social Influence.

- Model 2 (testing whether or not Facilitating Conditions will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics):

  H_0: Facilitating Conditions' means (FC's means) are the same.

  H_1: Facilitating Conditions' means (FC's means) are different.

- Model 3 (testing whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics):

  H_0: Behavioural intention's means (BI's means) for teachers' *intention* to use GeoGebra are the same.

  H_1: Behavioural intention's means (BI's means) for teachers' *intention* to use GeoGebra are different.

These hypotheses are related to the theoretical framework and based on Venkatesh et al. (2003) for mathematics teachers' intention towards utilising GeoGebra for teaching and learning as well as their actual use of GeoGebra.

GeoGebra could be used for various topics covered in the South African secondary school curriculum (namely CAPS), since GeoGebra could be used for graphs, statistics, calculus, transformation geometry, geometry and analytical geometry. Teachers' use and beliefs about the use of GeoGebra for teaching and learning and their actual of GeoGebra could differ too. Twelve additional hypotheses were therefore tested concerning teachers' actual use of GeoGebra for these specific mathematics topics (refer to section 1.3).

Hew et al. (2007) grouped 123 barriers to integrating ICT for teaching and learning. They found these barriers by scrutinising 48 empirical studies into six main categories, namely (1) resources, (2) knowledge and skills of teachers, (3) institutional, (4) attitudes and beliefs of teachers, (5) assessment and (6) subject culture (refer to section 2.6 for a discussion of these barriers). Hew et al. (2007) found that 40%, 23%, 14% and 13% of these analysed studies reported the first four barriers to incorporating ICT for teaching and learning are the most pronounced, having a direct influence on the integration of ICT for teaching and learning.

The UTAUT model, used as theoretical framework for this study, corresponds well with the six categories of barriers for ICT integration for teaching and learning as identified by Hew et al. (2007). Performance Expectancy could be linked to assessment; Social Influence could be linked to subject culture whereas Venkatesh et al.'s (2003) Facilitating Conditions construct could be linked to Hew et al.'s (2007) resources, knowledge/skills and institutional barriers. Venkatesh et al.'s (2003) Effort Expectancy construct is similar to Hew et al.'s (2007) teacher attitudes/beliefs barriers. Venkatesh et al. (2003, p.455) define attitude regarding the use of ICT as "an individual's overall affective reaction to using a system."

5.1.1 Discussion of Findings on Model 1

Model 1 tested whether or not teachers' Performance Expectancy, Effort Expectancy and Social Influence will have an influence on teachers' intention to use GeoGebra for the teaching and learning of mathematics.

Pearson's product moment correlation was used to determine the relationship between respondents' (a) Performance Expectancy and their *intention* to use GeoGebra, (b) Effort Expectancy and their *intention* to use GeoGebra and (c) Social Influence and their *intention* to use GeoGebra respectively. Performance Expectancy had a correlation of 0,35 (at the 0,05 significance level) with respondents' Behavioural Intention to use GeoGebra. The correlation between Effort Expectancy and Behavioural Intention had a value of 0,28 (at the 0,01 significance level). Social Influence had a correlation of 0,55 (at the 0,05 significance level) with respondents' Behavioural Intention. One suggested indication of how weak or strong a relationship exists between two variables is that a correlation of 0,1 suggests a small; 0,3 a medium and 0,5 a strong effect size (Cohen, Cohen, West & Aiken, 2013). Based on these effect sizes, the relationship between respondents' Performance Expectancy and their *intention* to use GeoGebra was of medium strength. The strength of the relationship between respondents' Effort Expectancy and their *intention* to use GeoGebra bordered on medium strength. Social Influence was the only construct that had a strong relationship with respondents' *intention* to use GeoGebra.

Multiple regression was used to determine whether the UTAUT constructs (Performance Expectancy, Effort Expectancy and Social Influence) were significant predictors of the respondents' *intention* to use GeoGebra for the teaching and learning of mathematics. Venkatesh et al. (2003) found that Performance Expectancy, Effort Expectancy, and Social Influence directly influenced whether or not people intended to use ICT. In this study, the combination of Performance Expectancy, Effort Expectancy and Social Influence were found to explain 30% of the variance in respondents' *intention* to use GeoGebra (R^2 = 0,3). Different from Venkatesh et al., this study found that only Social Influence was significant on its own to predict a respondent's *intention* to use GeoGebra, with Performance Expectancy and Effort Expectancy not being significant predictors of respondents' *intention* to use GeoGebra by themselves.

Raman et al. (2014) only found Performance Expectancy and Facilitating Conditions to play a significant role in teachers' intention to use smart boards, but not Effort Expectancy and Social Influence. A relationship of medium strength between the respondents' *intention* to use GeoGebra and their Performance Expectancy and Effort Expectancy respectively existed though. Respondents were generally very positive about the use of GeoGebra for improving teaching and learning (Performance Expectancy) as well as the ease of use of GeoGebra (Effort Expectancy). It is therefore interesting that high levels of Performance Expectancy and Effort Expectancy did not predict respondents' *intentional* use of GeoGebra. A possible explanation for Performance Expectancy and Effort Expectancy not being significant predictors of respondents' *intention* to use GeoGebra by themselves is that it does not carry such a high motivational value as Social

Influence does. Being concerned about what their peers and superiors (head of departments and principals) think seems to carry a lot more weight for respondents' *intentional* utilisation of GeoGebra. This could be verified by the findings of Voigt and Matthee (2012) who found that concerning Social Influence, both the teacher and learners felt their social status among their various peers increased, since they know how to use the MobiPads.

5.1.2 Discussion of Findings on Model 2

Model 2 tested whether or not Facilitating Conditions will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics.

The t test was used to verify whether or not Facilitating Conditions would influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics. Venkatesh et al. (2003) found that Facilitating Conditions directly influenced whether or not people actually used ICT. Conversely this study did not find a difference between the mean values for the "yes" category (5,32) and the "no" category (5,0) of respondents' *actual* use of GeoGebra. The p-value of the t test was 0,28 which meant that the null hypothesis could not be rejected and therefore Facilitating Conditions was found not to predict the actual use of GeoGebra for teaching and learning in this study.

Ming et al. (2010) found that resources (i.e. Facilitating Conditions) were a barrier for the study participants' ICT adoption, since tools such as the ViP used in the e-CPDelT project, were not user friendly. In their study, Wachira and Keengwe (2011) found the following factors to be the main barriers for mathematics teachers' use of ICT: (a) the unavailability and unreliability of ICT, (b) the lack of ICT support and leadership, (c) the fear of ICT and lack of confidence in utilising ICT and (d) a lacking knowledge of ICT. The first two and latter of the above factors relate to facilitating conditions. Different from the two studies above, in the case of my study teachers' generally had GeoGebra available to them (available resources) and they generally did not lack support or knowledge. This would imply that even if resources and technical support are available and teachers have the knowledge to use GeoGebra it does not mean that they will actually use it. Other factors might influence their *actual* use of GeoGebra. For instance, schools might have spent a considerable sum of money on the latest technology, but if teachers lack the motivation to use it, it would become a white elephant.

5.1.3 Discussion of Findings on Model 3

Model 3 tested whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics.

As was the case with Model 2, the t test was also used to verify Model 3, namely whether or not teachers' *intention* to use GeoGebra for the teaching and learning of mathematics will influence teachers' *actual* use of GeoGebra for the teaching and learning of mathematics. Venkatesh et al. (2003) found that people's Behavioural Intention directly influenced their actual use of ICT. This result was confirmed by the study. The mean values for the "yes" category (6,29) and the "no" category (5,49) of respondents' *actual* use of GeoGebra differed significantly at a level of 0,05 with a p-value of 0,015. The null hypothesis was therefore rejected in favour of the alternative hypothesis, implying that there was indeed a statistical difference between the means of the respondents' *intention* to use GeoGebra for the "yes" and "no" categories of the *actual* use. It could be stated with 98,5% level of confidence (p=0,015) that teachers' *intention* to use GeoGebra does in fact predict the *actual* use of GeoGebra for teaching and learning confirming this specific finding of Venkatesh et al.'s (2003).

5.1.4 Discussion of Findings on additional Hypotheses

Fishers' exact test was applied to test twelve hypotheses (additional to the three main hypotheses on which the three models were based – refer to section 1.3). Two of the twelve hypotheses could not be tested or reported on. The hypothesis that teachers' Performance Expectancy of GeoGebra's usefulness of graphs is independent of their *actual use* of GeoGebra for the teaching and learning of graphs could not be tested since the PE item "*useful* for teaching graphs" had a frequency of 0 in the "not agree" category and therefore no comparisons could be drawn. Another hypothesis that could not be reported on was the hypothesis that teachers' Effort Expectancy of GeoGebra's ease of use of graphs is independent of their *actual use* of GeoGebra for the teaching and learning of graphs since the "not agree" frequency of the EE item "It is *easy to use* GeoGebra for teaching graphs" is too small (only 4 out of 36) to report on its p-value.

Teachers' Performance Expectancy regarding statistics was found to be associated with their actual use of statistics. Teachers' Effort Expectancy of GeoGebra's ease of use of statistics, transformation geometry, geometry, and analytical geometry for teaching and learning seemed to be associated with their actual use of GeoGebra for the teaching and learning of these topics, since the null hypotheses in each of these cases were rejected.

Teachers' actual use of calculus, transformation geometry, geometry, and analytical geometry were found to be unrelated with teacher's Performance Expectancy for these mathematical topics, as the researcher failed to reject each of the null hypotheses concerning Performance Expectancy and these abovementioned mathematics topics. Only concerning calculus were the teachers' Effort Expectancy and their actual use not associated by means of failing to reject that specific null hypothesis. The p-values for Fishers' exact test regarding Performance Expectancy of GeoGebra for using geometry ($p = 0{,}0605$) and analytical geometry ($p = 0{,}0625$) however, were border cases, which indicated a tendency for significance.

5.2 Concluding remarks

The combination of Performance Expectancy, Effort Expectancy and Social Influence were found to explain 30% of the variance in respondents' *intention* to use GeoGebra in this study. On its own however, only Social Influence was found to be a direct determinant of a respondent's *intention* to use GeoGebra, with Performance Expectancy and Effort Expectancy not being significant predictors of respondents' *intention* to use GeoGebra by themselves. Venkatesh et al.'s (2003) hypotheses that Performance Expectancy, Effort Expectancy would be predict respondents' *intention* to use ICT were not confirmed in this study, but their hypothesis that Social Influence would predict *intentional* use of ICT was confirmed. Venkatesh et al. (2003) found that Facilitating Conditions directly influenced whether or not people actually used ICT. The latter finding could not be confirmed by the study. Venkatesh et al.'s (2003) hypothesis that users' *intentional* use of ICT predict their *actual* use of ICT was confirmed in this study, since it could be stated with 98,5% level of confidence ($p = 0{,}015$) that teachers' *intention* to use

GeoGebra does in fact predict the *actual* use of GeoGebra for teaching and learning. Since Social Influence was found to be the only direct determinant of intentional use of GeoGebra, future research should be conducted to determine what interventions are needed to increase the Social Influence that heads of departments, colleagues, principals and governing bodies have on teachers for increased use of GeoGebra for the teaching and learning of mathematics.

5.3 Limitations of the Study

This study is limited to South African mathematics teachers with V.A.W. membership and may not be representative of all mathematics teachers in general. Another limitation is that teacher perceptions and attitudes towards GeoGebra integration may be altered in the future by various factors that might be addressed, such as gaining more experience in utilising ICT for teaching and learning, positive social feedback, etcetera. Therefore a longitudinal study would have better informed the research question, but a longitudinal study is too time-consuming for the scope of this study. A related limitation to the study not being longitudinal is that the actual use of GeoGebra that is measured, is teachers' actual use before the V.A.W. workshop on GeoGebra. The actual behaviour of some of the teachers who were not familiar with GeoGebra before this course might therefore be altered in the future (and the measurement of this future actual use is beyond the scope of the study).

5.4 Implications of the Study

The findings from this study have important implications for the utilisation of dynamic geometry software for the teaching and learning of mathematics. Teachers' *intention* to use GeoGebra for teaching and learning was found to predict their *actual* use of GeoGebra. Since intentional use is a direct determinant of actual use, it is worthwhile to investigate the direct determinants of intentional use. As a whole, three UTAUT constructs (Performance Expectancy, Effort Expectancy and Social Influence) were found to be significant predictors of the respondents' *intention* to use GeoGebra for the teaching and learning of mathematics. Individually however, only the Social Influence construct was significant to predict a respondent's *intention* to use GeoGebra, which in turn directly determines *actual* use. Social construct items in the questionnaire related to what respondents thought their department heads' or subject heads', principals', school governing bodies' and colleagues' opinions were about the utilisation of

GeoGebra for the instruction of mathematics. As such, organisations such as the V.A.W. or any other institution promoting the integration of GeoGebra for the teaching and learning of mathematics, should focus on these formerly mentioned groups of people that influence teachers to utilise GeoGebra, by conducting information sessions. Subject heads, principals and school governing bodies should be made aware of the capabilities of GeoGebra as well as its impact on improving mathematics education, and department heads should be trained in the use of GeoGebra so that they could influence the mathematics teachers to use GeoGebra.

Facilitating Conditions in this study was found not to predict the actual use of GeoGebra for teaching and learning. This implies that even if resources and technical support are available and teachers have the knowledge to use GeoGebra it does not mean that they will actually use it. It would therefore not be worthwhile for schools to spend a lot of money on the latest technology (such as computers and data projectors) needed for utilising GeoGebra if teachers lack the motivation to use it. Ways must be found to motivate mathematics teachers to use technology with GeoGebra for the teaching and learning of mathematics, perhaps by first getting their superiors motivated.

5.5 Contributions of the Study and Recommendations

The UTAUT model has not been applied in many South African studies where the integration of dynamic mathematics software (especially GeoGebra) is concerned. A huge gap in literature therefore exist for applying the UTAUT model to explain South African mathematics teachers' integration of specifically GeoGebra for teaching and learning. Another component of this study which adds to its significance is that it also explores teachers' use of GeoGebra for different mathematical topics. This could be informative to GeoGebra developers for making sure that certain GeoGebra topics are more user-friendly if it were found not to be used optimally. There seems to be a gap in the research regarding the utilisation of GeoGebra for specific mathematics school curriculum topics, since no study was found to specifically explore teachers' use of GeoGebra for the various mathematical topics, but only their use of GeoGebra in general.

This study provided insights on the factors that influence mathematics teachers' use of dynamic geometry software for teaching and learning. The three constructs – Performance Expectancy, Effort Expectancy and Social Influence – as a whole were found to be significant predictors of the respondents' *intention* to use GeoGebra for the teaching and learning of mathematics. Individually however, only the Social Influence construct was a significant predictor of a respondent's *intention* to use GeoGebra, which in turn directly determines actual use. Facilitating Conditions in this study was found not to predict the actual use of GeoGebra for teaching and learning. In light of the findings, contributions, implications and limitations of this study the following recommendations are made:

- Research should be conducted on ways to better inform principals, school governing bodies and department heads of the advantages of using GeoGebra for the teaching and learning of mathematics;
- Research could be conducted to explore teachers' use of GeoGebra for specific mathematics school curriculum topics;
- Training in the utilisation of GeoGebra should firstly be focused on department heads so that they would be motivated to make use of GeoGebra and in turn motivate the mathematics teachers in their departments to utilise GeoGebra;
- Schools should not spend money on technology unless they have structures in place that would encourage teachers to utilise it;
- As this study was limited to V.A.W. members, which formed a homogenous group of mathematics teachers, research should be conducted on a broader spectrum of mathematics teachers, including those from township areas which might yield different findings;
- Longitudinal studies should be conducted to better inform the research question.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes*, *50*(2), 179-211.

Anekwe, J. U., & Williams, C. H. E. T. A. (2014). Educational Technology in Nigeria Universities: Statues Quo and Visions for the Future. *AFRREV STECH: An International Journal of Science and Technology*, *3*(1), 128-149.

Artigue, M. (2002). Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between technical and conceptual work. *International Journal of Computers for Mathematical Learning*, *7*(3), 245-274.

Azman, J., Frkovic, V., Bilic-Zulle, L., & Petrovecki, M. (2006). Correlation and regression. [Korelacija i regresija] *Acta Medica Croatica : Casopis Hravatske Akademije Medicinskih Znanosti*, *60 Suppl 1*, 81-91.

Baggott la Velle, L., Wishart, J., McFarlane, A., Brawn, R., & John, P. (2007). Teaching and learning with ICT within the subject culture of secondary school science. *Research in Science & Technological Education*, *25*(3), 339-349.

Baldwin, L., & Sabry, K. (2003). Learning styles for Interactive Learning Systems. *Innovations in Education and Teaching International*, *40*(4), 325-340.

Bate, F. (2010). A bridge too far? Explaining beginning teachers' use of ICT in Australian schools. *Australasian Journal of Educational Technology*, *26*(7), 1042-1061.

Bertot, J. C., Jaeger, P. T., & Grimes, J. M. (2010). Using ICTs to create a culture of transparency: E-government and social media as openness and anti-corruption tools for societies. *Government Information Quarterly*, *27*(3), 264-271.

Birch, A. (2009). *Preservice Teachers' Acceptance of Information and Communication Technology Integration in the Classroom: Applying the Unified Theory of Acceptance and use of Technology Model.* (Master's thesis). University of Victoria, Canada. Retrieved from http://8080-dspace.library.uvic.ca.innopac.up.ac.za/handle/1828/2805

Botana, F., & Abánades, M. A. (2014). Automatic deduction in (dynamic) geometry: Loci computation. *Computational Geometry*, *47*(1), 75-89.

Bryman, A., & Cramer, D. (2011). *Quantitative data analysis with IBM SPSS 17, 18 & 19: A guide for social scientists*. Routledge.

Chen, Y. L., Hong, Y. R., Sung, Y. T., & Chang, K. E. (2011). Efficacy of Simulation-Based Learning of Electronics Using Visualization and Manipulation. *Educational Technology & Society*, *14*(2), 269-277.

Chrysanthou, I. (2008). *The use of ICT in primary mathematics in Cyprus: The case of GeoGebra* (Master's Thesis). University of Cambridge, UK. Retrieved from http://www.geogebra.org/publications/2008-Chrysanthou-ICT-Primary-GeoGebra.pdf

Cohen, L., Manion, L., & Morrison, K. (2011). Research methods in education. Milton Park. *Abingdon, Oxon,[England]: Routledge*.

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2013). *Applied multiple regression/correlation analysis for the behavioral sciences*. Routledge.

Compeau, D. R., & Higgins, C. A. (1995). Application of social cognitive theory to training for computer skills. *Information systems research*, *6*(2), 118-143.

Crawford, S. L. (2006). Correlation and regression. *Circulation*, *114*(19), 2083-2088.

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

Cunska, A., & Savicka, I. (2012). Use of ICT teaching-learning methods make school math blossom. *Procedia-Social and Behavioral Sciences*, *69*, 1481-1488.

David, O. N. (2012). Using mixed method approach to understand acceptance and usage of ICT in Nigerian Public University. *International Journal of Computers & Technology*, *2*(3), 47-63.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of Information Technology. *MIS quarterly*, 319-340.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. *Management science*, *35*(8), 982-1003.

Denscombe, M. (2010). *The good research guide for small-scale social research projects*. Maidenhead, England: McGraw-Hill/Open University Press

DoE (Department of Education). (2011). *Curriculum and Assessment Policy Statement (CAPS) FET Band Mathematics Grades 10-12.* Retrieved April 3, 2013, from http://www.education.gov.za/LinkClick.aspx?fileticket=QPqC7QbX75w%3d&tabid=420&mid=1216

DoE. (2003). *National Curriculum Statement Grades 10 – 12 (General) Mathematics*. Retrieved from http://www.education.gov.za/LinkClick.aspx?fileticket=WBtQtdS0Azk=

DoE. (2004). *White Paper on e-Education*. Retrieved September 25, 2013, from http://www.education.gov.za/DocumentsLibrary/Legislation/WhitePapers/tabid/191/ItemId/977/Default.aspx

Donnelly, D., McGarr, O., & O'Reilly, J. (2011). A framework for teachers' integration of ICT into their classroom practice. *Computers & Education*, *57*(2), 1469-1483.

Dooley, D. (1984). *Social research methods*. Englewood Cliffs, N.J: Prentice-Hall.

Draper, K. (2010). *Understanding science teachers 'use and integration of ICT in a developing country context* (Doctoral dissertation). University of Pretoria, South Africa.

Easton, G. (2010). Critical realism in case study research. *Industrial Marketing Management*, *39*(1), 118-128.

Escobar-Rodríguez, T., Carvajal-Trujillo, E., & Monge-Lozano, P. (2014). Factors that influence the perceived advantages and relevance of Facebook as a learning tool: An extension of the UTAUT. *Australasian Journal of Educational Technology*, *30*(2).

Fitzallen, N. (2005). Integrating ICT into professional practice: A case study of four mathematics teachers. *Proceedings of the 28th Mathematics Education Research Group of Australasia*, 353-360.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (1993). *How to design and evaluate research in education* (Vol. 7). New York: McGraw-Hill.

Gliem, J. A., & Gliem, R. R. (2003). Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education. Retrieved from https://0-scholarworks.iupui.edu.innopac.up.ac.za/handle/1805/344

Goldenberg, E. P. (2000). *Thinking (and talking) about technology in math classrooms: K-12 mathematics curriculum center issues paper series*. Newton, MA: Education Development Center, Inc.

Hargreaves, A. (1994). *Changing teachers, changing times: Teachers' work and culture in the postmodern age*. Continuum International Publishing Group.

Heinecke, W. F., Milman, N. B., Washington, L. A., & Blasi, L. (2001). New directions in the evaluation of the effectiveness of educational technology. *Computers in the Schools*, *18*(2-3), 97-110.

Hennessy, S., Harrison, D., & Wamakote, L. (2010). Teacher factors influencing classroom use of ICT in sub-saharan africa. *Itupale Online Journal of African Studies*, *2*(1), 39-54.

Hennessy, S., Ruthven, K., & Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: commitment, constraints, caution, and change. *Journal of curriculum studies*, *37*(2), 155-192.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, *55*(3), 223-252.

Hohenwarter, M. (2013). GeoGebra 4.4–From desktops to tablets. *Indagatio Didactica*, *5*(1).

Hohenwarter, M., & Fuchs, K. (2004, July). Combination of dynamic geometry, algebra and calculus in the software system GeoGebra. In *Computer Algebra Systems and Dynamic Geometry Systems in Mathematics Teaching Conference. Pecs, Hungary.*

Hohenwarter, M., Hohenwarter, J., Kreis, Y., & Lavicza, Z. (2008). Teaching and learning calculus with free dynamic mathematics software GeoGebra. In *11th International Congress on Mathematical Education. Monterrey, Nuevo Leon, Mexico.*

Holden, R. J., & Karsh, B. T. (2010). The Technology Acceptance Model: its past and its future in health care. *Journal of biomedical informatics*, *43*(1), 159-172.

Houston, S. (2001). Beyond social constructionism: Critical realism and social work. *British Journal of Social Work*, *31*(6), 845-861.

Howie, S. J. (2010). ICT-supported pedagogical policies and practices in South Africa and Chile: emerging economies and realities. *Journal of Computer Assisted Learning*, *26*(6), 507-522.

Howie, S. J., & Blignaut, A. S. (2009). South Africa's readiness to integrate ICT into mathematics and science pedagogy in secondary schools. *Education and Information Technologies*, *14*(4), 345-363.

Hoyles, C., Noss, R., & Kent, P. (2004). On the integration of digital technologies into mathematics classrooms. *International Journal of Computers for Mathematical Learning*, *9*(3), 309-326.

Huck, S. (2012). *Reading statistics and research*. Boston: Pearson.

Hunter, A., & Brewer, J. (2003). Multimethod research in sociology. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 577–594). London: Sage.

Huysamen, G. K. (2006). Coefficient alpha: Unnecessarily ambiguous; unduly ubiquitous. *SA Journal of Industrial Psychology*, *32*(4), p-34.

Inan, F. A., & Lowther, D. L. (2010). Laptops in the K-12 classrooms: Exploring factors impacting instructional use. *Computers & Education*, *55*(3), 937-944. doi: 10.1016/j.compedu.2010.04.004

Internet Live Stats. (2014a). *Internet Users*. Retrieved August 19, 2014, from http://www.internetlivestats.com/internet-users/

Internet Live Stats. (2014b). *Internet Users by Country*. Retrieved August 19, 2014, from http://www.internetlivestats.com/internet-users-by-country/

Internet World Stats. (n.d.a). *Usage and population statistics*. South Africa Internet Usage and Marketing Report. Retrieved August 19, 2014, from http://www.internetworldstats.com/af/za.htm

Internet World Stats. (n.d.b). *Usage and population statistics*. AFRICA. Retrieved August 19, 2014, from http://www.internetworldstats.com/africa.htm#za

ITU. (2014). *The world in 2014: ICT facts and figures*. Retrieved August 18, 2014, from http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2014-e.pdf

Jaeger, P. T., & Bertot, J. C. (2010). Transparency and technological change: Ensuring equal and sustained public access to government information. *Government Information Quarterly*, *27*(4), 371-376.

John, P. (2005). The sacred and the profane: subject sub-culture, pedagogical practice and teachers' perceptions of the classroom uses of ICT. *Educational Review*, *57*(4), 471-490.

Johnson, L., Adams Becker, S., Cummins, M., Estrada V., Freeman, A., & Ludgate, H. (2013). *NMC Horizon Report: 2013 K-12 Edition*. Austin, Texas: The New Media Consortium.

Kadiyala, M., & Crynes, B. L. (2000). A review of literature on effectiveness of use of Information Technology in education. *Journal of engineering education*, *89*(2), 177-189.

Kagaari, J. R. K., Munene, J. C., & Ntayi, J. M. (2010). Performance management practices, information and communication technology (ICT) adoption and managed performance. *Quality Assurance in Education*, *18*(2), 106-125.

Keitel, C. (1997). Numeracy and scientific and technological literacy. In A. J. Bishop (Ed.), *Mathematics Education: Major Themes in Education* (vol. 1, pp. 191-205). London: Routledge.

Keong, C., Horani, S., & Daniel, J. (2005). A study on the use of ICT in mathematics teaching. *Malaysian Online Journal of Instructional Technology, 2*(3), 43-51.

Kilpatrick, J. (2007). Developing common sense in teaching mathematics. *Mathematisation and dematematisation: Social, philosophical and educational ramifications*, 161-170.

Kokol-Voljc, V. (2007) Use of mathematical software in pre-service teacher training: the case of GeoGebra, *Proceedings of the British Society for Research into Learning Mathematics*, 27(3), 55-60.

Krauss, S. E. (2005). Research paradigms and meaning making: A primer. *The Qualitative Report, 10*(4), 758-770.

Laborde, C. (2001). The use of new technologies as a vehicle for restructuring teachers' mathematics. In A. J. Bishop (Ed.), *Mathematics Education: Major Themes in Education* (vol. 2, pp. 155-174). London: Routledge.

Lincoln, Y. S. (2009). "What a Long, Strange Trip It's been...": Twenty-Five Years of Qualitative and New Paradigm Research. *Qualitative Inquiry*.

Lu, Y.-W. A. (2008). *Linking geometry and algebra: A multiple-case study of upper-secondary mathematics teachers' conceptions and practices of GeoGebra in England and Taiwan.* (Masters' thesis, University of Cambridge). Retrieved from http://www.geogebra.org/publications/2008-Lu-GeoGebra-England-Taiwan.pdf

Madill, A., Jordan, A., & Shirley, C. (2000). Objectivity and reliability in qualitative analysis: Realist, contextualist and radical constructionist epistemologies. *British Journal of Psychology, 91*(1), 1-20. doi: 10.1348/000712600161646

Mann, D. (1999). Documenting the Effects of Instructional Technology: A Fly-Over of Policy Questions.

Melville, N. P. (2010). Information systems innovation for environmental sustainability. *Mis Quarterly, 34*(1), 1-21.

Mertler, C. A., & Vannatta, R. A. (2002). Advanced and multivariate statistical methods. *Los Angeles, CA: Pyrczak.*

Ming, T. S., Murugaiah, P., Wah, L. K., Azman, H., Yean, T. L., & Sim, L. Y. (2010). Grappling with technology: A case of supporting Malaysian Smart School teachers' professional development. *Australasian Journal of Educational Technology*, *26*(3), 400-416.

Mofokeng, P. L., & Mji, A. (2010). Teaching mathematics and science using computers: How prepared are South African teachers to do this?. *Procedia-Social and Behavioral Sciences*, *2*(2), 1610-1614.

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an Information Technology innovation. *Information systems research*, *2*(3), 192-222.

Moores, T. T. (2012). Towards an integrated model of IT acceptance in healthcare. *Decision Support Systems*, *53*(3), 507-516.

Musa, M., Akodo, R., Mukooza, M., Kaliba, A. R., & Mbarika, V. W. (2012). Impact of investment in information and communication technology on performance and growth of microfinance institutions in uganda. *Applied Econometrics and International Development*, *12*(2), 151-164.

NCTM (National Council of Teachers of Mathematics). (2000). *Executive Summary: Principles and Standards for School Mathematics*. Reston, VA. Retrieved July 30, 2014 from National Council of Teachers of Mathematics Web site: http://www.nctm.org/uploadedFiles/Math_Standards/12752_exec_pssm.pdf

NCTM. (2013). *NCTM Strategic Plan.* Williamsburg, VA. Retrieved January 3, 2015 from National Council of Teachers of Mathematics Web site: http://www.nctm.org/uploadedFiles/About_NCTM/Mission/NCTM%20Board%20Strategic%20Plan%202014.pdf

NCTM. (2008). *The Role of Technology in the Teaching and Learning of Mathematics: A position of the National Council of Teachers of Mathematics.* Reston, VA. Retrieved July 30, 2014 from National Council of Teachers of Mathematics Web site: http://www.nctm.org/about/content.aspx?id=14233

Onwuegbuzie, A. J. (2000). Expanding the Framework of Internal and External Validity in Quantitative Research. In *the annual meeting of the Association for the Advancement of Educational Research (AAER). Ponte Vedra, Florida, November, 21, 2000.*

Ortega Egea, J. M., & Román González, M. V. (2011). Explaining physicians' acceptance of EHCR systems: an extension of TAM with trust and risk factors. *Computers in Human Behavior*, *27*(1), 319-332.

Osborne, J., & Waters, E. (2002). Four assumptions of multiple regression that researchers should always test. *Practical assessment, research & evaluation*, *8*(2), 1-9.

Osika, E., Johnson, R., & Butea, R. (2009). Factors influencing faculty use of technology in online instruction: A case study. *Online Journal of Distance Learning Administration, 12*(1). Retrieved from http://0-www.westga.edu.innopac.up.ac.za/~distance/ojdla/spring121/osika121.html

Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P. A. (2010). Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers & Education*, *55*(3), 1321-1335. doi: 10.1016/j.compedu.2010.06.002

Palen, L., Vieweg, S., & Anderson, K. M. (2010). Supporting "everyday analysts" in safety-and time-critical situations. *The Information Society*, *27*(1), 52-62.

Panayides, P. (2013). Coefficient Alpha: Interpret With Caution. *Europe's Journal of Psychology*, *9*(4), 687-696.

Pea, R. D. (1987). Cognitive Technologies for Mathematics Education. In A. H. Schoenfeld (Ed.), *Cognitive science and mathematics education* (pp. 89-122). Hillsdale, NJ: Erlbaum.

Picazo-Vela, S., Gutiérrez-Martínez, I., & Luna-Reyes, L. F. (2012). Understanding risks, benefits, and strategic alternatives of social media applications in the public sector. *Government information quarterly*, *29*(4), 504-511.

Plowright, D. (2011). *Using mixed methods: Frameworks for an integrated methodology*. SAGE Publications.

Preiner, J. (2008). *Introducing Dynamic Mathematics Software to Mathematics Teachers: the Case of GeoGebra.* (Dissertation in Mathematics Education Faculty of Natural Sciences, University of Salzburg). Retrieved from http://www.geogebra.org/publications/jpreiner-dissertation.pdf

Raman, A., Don, Y., Khalid, R., Hussin, F., Omar, M. S., & Ghani, M. (2014). Technology Acceptance on Smart Board among Teachers in Terengganu Using UTAUT Model. *Asian Social Science*, *10*(11), p84-91

Richey, R. C., Silber, K. H., & Ely, D. P. (2008). Reflections on the 2008 AECT Definitions of the Field. *TechTrends*, *52*(1), 24-25.

Ringstaff, C., & Kelley, L. (2002). *The learning return on our technology investment: A review of findings from research.* San Francisco: WestEd RTEC.

Sabry, K., & Barker, J. (2009). Dynamic Interactive Learning Systems. *Innovations in Education and Teaching International*, *46*(2), 185-197.

Seedhouse, D. (1997). What's the difference between health care ethics, medical ethics and nursing ethics?. *Health Care Analysis*, *5*(4), 267-274.

Semaan, B. C. (2011). *Recovery, Resilience and Beyond: ICT Use During Ongoing Disruption* (Doctoral dissertation). University of California, Irvine.

Sime, D., & Priestley, M. (2005). Student teachers' first reflections on information and communications technology and classroom learning: implications for initial teacher education. *Journal of computer assisted learning*, *21*(2), 130-142.

Söderström, S., & Ytterhus, B. (2010). The use and non-use of assistive technologies from the world of information and communication technology by visually impaired young people: a walk on the tightrope of peer inclusion. *Disability & Society*, *25*(3), 303-315.

Spector, J. M. (2010). An overview of progress and problems in educational technology. *Digital Education Review*, (3), 27-37.

Starbird, K., & Palen, L. (2011, May). Voluntweeters: Self-organizing by digital volunteers in times of crisis. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1071-1080). ACM.

Stephens, M., & SLIS, S. (2014, July) Serving the User When and Where They Are: Hyperlinked Libraries. Retrieved August 19, 2014 from http://tametheweb.com/2014/07/16/serving-the-user-when-and-where-they-are-hyperlinked-libraries/

Stutchbury, K., & Fox, A. (2009). Ethics in educational research: introducing a methodological tool for effective ethical analysis. *Cambridge Journal of Education*, *39*(4), 489-504.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International journal of medical education*, *2*, 53-55.

Taylor, S., & Todd, P. (1995). Assessing IT usage: The role of prior experience. *MIS quarterly*, 561-570.

Teo, T. (2008). Pre-service teachers' attitudes towards computer use: A Singapore survey. *Australasian Journal of Educational Technology*, *24*(4), 413-424. Retrieved from http://www.ascilite.org.au/ajet/ajet24/teo.html

Terrell, S. R. (2012). Mixed-methods research methodologies. *The Qualitative Report, 17*(1), 254-280.

Thompson, R. L., Higgins, C. A., & Howell, J. M. (1991). Personal computing: toward a conceptual model of utilization. *MIS quarterly*, 125-143.

Tondeur, J., Hermans, R., van Braak, J., & Valcke, M. (2008). Exploring the link between teachers' educational belief profiles and different types of computer use in the classroom. *Computers in Human Behavior, 24*(6), 2541-2553. doi: 10.1016/j.chb.2008.02.020

Varughese, J. (2011). *The ICT pedagogic challenges and enablers of grade eight Natural Science and Mathematics teachers in South African classrooms* (Doctoral dissertation). North-West University, South Africa.

Venkatesh, V., Morris, M. G., Gordon B. Davis, & Davis, F. D. (2003). User acceptance of Information Technology: Toward a unified view. *MIS Quarterly, 27*(3), 425-478.

Venkatesh, V., & Speier, C. (1999). Computer technology training in the workplace: A longitudinal investigation of the effect of mood. *Organizational behavior and human decision processes*, *79*(1), 1-28.

Voigt, T., & Matthee, M. (2012). Tablets with Restricted Mobility: Investigating User Acceptance in a South African Mathematics Mobile Learning Project. In *mLearn* (pp. 172-179).

Wachira, P., & Keengwe, J. (2011). Technology integration barriers: Urban school mathematics teachers perspectives. *Journal of Science Education and Technology*, *20*(1), 17-25.

Wetcher-Hendricks, D. (2011). *Analyzing quantitative data: An introduction for social researchers* John Wiley & Sons.

Williams, D., Coles, L., Wilson, K., Richardson, A., & Tuson, J. (2000). Teachers and ICT: Current use and future needs. *British journal of educational technology*, *31*(4), 307-320.

Zbiek, R. M., Heid, M. K., Blume, G. W., & Dick, T. P. (2007). Research on technology in mathematics education: A perspective of constructs. *Second handbook of research on mathematics teaching and learning*, *2*, 1169-1207.

Appendix A: Permission Letter to V.A.W.

FACULTY OF EDUCATION
Mr. SJ Venter
Groenkloof Campus
University of Pretoria

17 June 2014

Letter of Informed Consent of the V.A.W.

Dear Dr./Mr./Ms

I hereby request permission to conduct research on V.A.W. members' use of dynamic geometry software (specifically GeoGebra) for the instruction of mathematics. I would like to invite mathematics teachers in the intermediate and/or senior and/or FET phase to participate in this research aimed at investigating how mathematics teachers use GeoGebra in their classrooms. This research will be reported upon in my Master's dissertation at the University of Pretoria.

I would appreciate it if I could hand out hard copies of the questionnaire at one of the congresss. The questionnaire should not take more than 10 minutes to complete (see the attached questionnaire). After the congress I would also like e-mails to be sent out to V.A.W.'s mailing list with the attached questionnaire as well as a link to a website hosting the questionnaire in order to increase the response rate and get the highest response rate possible.

All participation is voluntary and once committed to the research the V.A.W. and its members may still withdraw at any time. Confidentiality and anonymity will be guaranteed at all times since V.A.W. members will complete the questionnaire anonymously. V.A.W. members will therefore not be identifiable in the findings of my research. The data collected will only be used for academic purposes. After the successful completion of my Master's Degree I will give feedback to the V.A.W. in the form of a written report.

For any questions before or during the research, please feel free to contact me. If you are willing to allow members of your organisation to participate in this study, please sign this letter as a declaration of your consent.

Yours sincerely

_____________________ _____________________

Researcher: Mr. SJ Venter Date

_____________________ _____________________

Supervisor: Prof. G Stols Date

I, the undersigned, hereby grant consent to Mr. SJ Venter to conduct his research with V.A.W. members for his Master's research.

V.A.W. representative's name: _______________________

V.A.W. representative's signature: ____________________ Date: ________________

E-mail address: __________________________________

Contact number: _________________________________

Appendix B: Data Collection Protocol

Data Collection Protocol

adapted from Birch (2009):

ADMINISTRATION PROCEDURE:
The Survey will be administered at the V.A.W. conference venue after invited speaker X's (to be determined) speech. After completion of the questionnaire, it will collected by the researcher. The survey will also be made available online for those V.A.W. members who either could not attend the conference or opted not to complete the questionnaire on the day of the conference.

INTRODUCTION STATEMENT:
My name is Stephan Venter and my supervisor is Prof. Gerrit Stols (one of the invited speakers). I am a Master's Degree student at the University of Pretoria conducting research on mathematics teachers' use of dynamic geometry software (specifically GeoGebra) for the instruction of mathematics. As part of the data collection phase of my study, I will be distributing a questionnaire regarding mathematics teachers' intention to use GeoGebra as well as their actual use of GEOGEBRA for the instruction of mathematics. Attached to the survey is a letter of consent to be signed if you are willing to participate voluntarily as well as space provided for your contact details if you are willing to be included in the second phase of the study by voluntarily participating in a telephone interview that could be arranged at a time that suits you.

Please review the consent form to determine whether you wish to participate in this study. Your participation must be voluntary and please note that you can withdraw at any point in the study. If you choose to participate, you will be compensated as a token of appreciation for your time. Each questionnaire will be numbered and a corresponding number will be attached for your safekeeping. The questionnaire should not take more than 10 minutes to complete. Once I collected all the questionnaires directly after completion, a lucky draw will be held and one lucky participant will win a shopping voucher to the value of R200.

To participate in the study:

1. Complete the questionnaire, including your demographic information.

Appendix C: Consent Form

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Letter of Informed Consent of the Mathematics Teacher

Dear Sir/Madam

You are invited to participate in a study aimed at investigating mathematics teachers' use of dynamic geometry software (specifically GeoGebra) for the instruction of mathematics. This research will be reported upon in my Master's dissertation at the University of Pretoria.

It is proposed that you form part of this study's data collection phase by completing a questionnaire which should not take more than 10 minutes to complete.

Your participation in this research is voluntary and confidential and you may still withdraw at any point in time from the study. Confidentiality and anonymity will be guaranteed at all times since V.A.W. members will complete the questionnaire anonymously. V.A.W. members will therefore not be identifiable in the findings of my research. The data collected will only be used for academic purposes. After the successful completion of my Master's Degree I will give feedback to V.A.W. in the form of a written report which could be distributed to its members.

A lucky draw will be held after completion and collection of the hard copies of the questionnaire as set out in the data collection protocol where one lucky participant could win a R200 shopping voucher. Please note that your agreement to participate must be voluntary. The above-mentioned compensation is only a small token of appreciation for your time spent to complete the questionnaire. If you agree to participate in this study, this form of compensation to you must not be influential. It is unethical to provide excessive compensation or inducements to research participants. If you would not participate if the compensation was not offered, then you should decline.

If you are willing to participate in this study, please sign this letter as a declaration of your consent, i.e. that you participate willingly and that you understand that you may withdraw at any time.

Yours sincerely

______________________ ______________________

Researcher: Mr. SJ Venter Date

______________________ ______________________

Supervisor: Prof. G Stols Date

I, the undersigned, hereby consent to (please select the correct option by indicating it with an X in the appropriate block):

Completing a questionnaire	Yes	No

Participant's name and surname: ____

Participant's signature: ________________________ Date: ________________

E-mail address: ______________________________

Contact number: _____________________________

Appendix D: Survey questionnaire: Factors that influence Mathematics teachers' use of dynamic software for instruction

Please select the correct option(s) by indicating it with an X in the appropriate block:

Section A: Demographic information

Office use

1 What is your gender?

1 M	**2** F

Office use: a1__

2 Which grade(s) did you teach <u>mathematics</u> during the last 5 years? (Please select **<u>all</u>** the appropriate grades).

1	2	3	4	5	6	7	8	9	10	11	12
0 or 1	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**

Office use: **For <u>each</u> option use 1-yes 0-no**
a2.1__ a2.2__
a2.3__ a2.4__
a2.5__a2.6__
a2.7__ a2.8__
a2.9__ a2.10__
a2.11__ a2.12__

3 Which grade(s) are you currently teaching <u>mathematics</u>? (Please select **<u>all</u>** the appropriate grades).

1	2	3	4	5	6	7	8	9	10	11	12
0 or 1	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**	**0 or 1**

Office use: **For <u>each</u> option use 1-yes 0-no**
a3.1__ a3.2__
a3.3__ a3.4__
a3.5__ a3.6__
a3.7__ a3.8__
a3.9__ a3.10__
a3.11__ a3.12__

4 Are you teaching in a city, in a rural area or at a township school?

1 City school	**2** Rural school	**3** Township school

Office use: a4__

5 Are you teaching at a private or government school?

1 Private school	**2** Government school

Office use: a5__

6 Please indicate your age range (in order to explore if age has an influence on the use of GeoGebra).

1 18-29	**2** 30-39	**3** 40-49	**4** 50-59	**5** 60-69	**6** > 69

Office use: a6__

1

Section B: GeoGebra usage - Background questions

7 How long have you been using GeoGebra to teach mathematics in the classroom?

1 Not at all	**2** 0-1 years	**3** 2-3 years	**4** 4-5 years	**5** > 5 years

8 How frequently have you made use of GeoGebra for instruction <u>during the past year</u>?

1 Not at all	**2** Once a year	**3** Once a month	**4** Once a week	**5** Daily

9 What are you using GeoGebra for? (Please select **all** the appropriate options).

0 or 1 I do not use GeoGebra	**0 or 1** For teaching mathematics	**0 or 1** For creating worksheets	**0 or 1** For creating dynamic online sketches
0 or 1 For setting question papers			

0 or 1 Other (Please specify):

____

10 For which mathematical topics are you using GeoGebra? (Please select **all** the appropriate options).

0 or 1 I do not use GeoGebra	**0 or 1** Graphs	**0 or 1** Statistics	**0 or 1** Calculus	**0 or 1** Analytical Geometry
0 or 1 Geometry	**0 or 1** Transformation Geometry			

0 or 1 Other (Please specify):

____

11 Where did you hear about GeoGebra? (Please select **all** the appropriate options).

0 or 1 Never heard of it	**0 or 1** At a workshop presented by V.A.W.	**0 or 1** On the internet	**0 or 1** From a colleague

0 or 1 Other (Please specify):

____

Office use
b7__
b8__
For <u>each</u> option use 1-yes 0-no b9.1__ b9.2__ b9.3__ b9.4__ b9.5__ b9.6__
For <u>each</u> option use 1-yes 0-no b10.1__ b10.2__ b10.3__ b10.4__ b10.5__ b10.6__ b10.7__ b10.8__
For <u>each</u> option use 1-yes 0-no b11.1__ b11.2__ b11.3__ b11.4__ b11.5__

Background questions continued…

12 Did you receive any training for using GeoGebra? (Please select **all** the appropriate options).

0 or 1 Not at all	**0 or 1** V.A.W. provided GeoGebra training	**0 or 1** I used a GeoGebra training manual
0 or 1 I trained myself	**0 or 1** I received GeoGebra training at a university as part of my teaching course	

0 or 1 Other (Please specify):

____

Office use

For each option use 1-yes 0-no
b12.1__ b12.2__
b12.3__ b12.4__
b12.5__ b12.6__

13 Are you in possession of the following hardware resources which would enable you to use GeoGebra for teaching mathematics? (Please select **all** the appropriate options).

0 or 1 I own a personal computer or laptop	**0 or 1** I have a computer in my own classroom	**0 or 1** I have access to a computer and data projector	**0 or 1** I have a data projector in my own classroom

For each option use 1-yes 0-nos
b13.1__ b13.2__
b13.3__ b13.4__

14 Do you have GeoGebra available for teaching mathematics? (Please select **all** the appropriate options).

0 or 1 I have GeoGebra installed on my own personal computer or laptop	**0 or 1** I have GeoGebra installed on a computer in my own classroom	**0 or 1** I have access to GeoGebra installed on a computer in another classroom or computer lab	**0 or 1** I use GeoGebra on my tablet

For each option use 1-yes 0-no
b14.1__ b14.2__
b14.3__ b14.4__

Section C: GeoGebra usage – measuring UTAUT constructs

Please encircle the number that best describes your agreement or disagreement with each statement (on a scale from 1 to 7).

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

Performance expectancy

Item No.	Statement	1	2	3	4	5	6	7	Office use
15.1	GeoGebra is ***useful*** for teaching **graphs**.	1	2	3	4	5	6	7	PE1__
15.2	GeoGebra is ***useful*** for teaching **statistics**.	1	2	3	4	5	6	7	PE2__
15.3	GeoGebra is ***useful*** for teaching **calculus**.	1	2	3	4	5	6	7	PE3__
15.4	GeoGebra is ***useful*** for teaching **transformation geometry**.	1	2	3	4	5	6	7	PE4__
15.5	GeoGebra is ***useful*** for teaching **geometry**.	1	2	3	4	5	6	7	PE5__
15.6	GeoGebra is ***useful*** for teaching **analytical geometry**.	1	2	3	4	5	6	7	PE6__
15.7	Using GeoGebra to teach mathematics in the classroom will enhance learners' understanding.	1	2	3	4	5	6	7	PE7__
15.8	Using GeoGebra make it easier to draw accurate graphs.	1	2	3	4	5	6	7	PE8__
15.9	Using GeoGebra mathematical concepts could be explained in a way that learners grasp the concepts quicker than they would if conventional (board and chalk) methods were used.	1	2	3	4	5	6	7	PE9__
15.10	Using GeoGebra to teach mathematics in the classroom will make it easier for learners to visualize relationships.	1	2	3	4	5	6	7	PE10__
15.11	Using GeoGebra to teach mathematics in the classroom will make it easier to explain difficult concepts.	1	2	3	4	5	6	7	PE11__
15.12	Using GeoGebra to teach mathematics in the classroom save time.	1	2	3	4	5	6	7	PE12__
15.13	If I use GeoGebra to teach mathematics in the classroom, I will increase my employment opportunities, being more in demand as a mathematics teacher.	1	2	3	4	5	6	7	PE13__

Effort expectancy

Item No.	Statement	1	2	3	4	5	6	7	Office use
16.1	It is ***easy to use*** GeoGebra for teaching **graphs**.	1	2	3	4	5	6	7	EE1__
16.2	It is ***easy to use*** GeoGebra for teaching **statistics**.	1	2	3	4	5	6	7	EE2__
16.3	It is ***easy to use*** GeoGebra for teaching **calculus**.	1	2	3	4	5	6	7	EE3__
16.4	It is ***easy to use*** GeoGebra for teaching **transformation geometry**.	1	2	3	4	5	6	7	EE4__
16.5	It is ***easy to use*** GeoGebra for teaching **geometry**.	1	2	3	4	5	6	7	EE5__
16.6	It is ***easy to use*** GeoGebra for teaching **analytical geometry**.	1	2	3	4	5	6	7	EE6__
16.7	In general it is ***easy to use*** GeoGebra for teaching mathematics.	1	2	3	4	5	6	7	EE7__
16.8	Learning to use GeoGebra to teach mathematics in the classroom would be ***easy*** for me.	1	2	3	4	5	6	7	EE8__

Social influence

Item No.	Statement	1	2	3	4	5	6	7	Office use
17.1	My **HOD or subject** head think that I should use GeoGebra to teach mathematics in the classroom.	1	2	3	4	5	6	7	SI1__
17.2	My **principal** thinks that I should use GeoGebra to teach mathematics in the classroom.	1	2	3	4	5	6	7	SI2__
17.3	The **school governing body** thinks that I should use GeoGebra to teach mathematics in the classroom.	1	2	3	4	5	6	7	SI3__
17.4	My **colleagues** think that I should use GeoGebra to teach mathematics in the classroom.	1	2	3	4	5	6	7	SI4__

Facilitating conditions

Please answer the following in terms of the answers that you have provided to background questions 12-14 in section B.

Item No.	Statement	1	2	3	4	5	6	7	Office use
18.1	I have the **resources** necessary to use GeoGebra to teach mathematics in the classroom.	1	2	3	4	5	6	7	FC1__
18.2	I have the **knowledge** necessary to use GeoGebra to teach mathematics in the classroom.	1	2	3	4	5	6	7	FC2__
18.3	It is possible for me to use GeoGebra to teach mathematics in the classroom.	1	2	3	4	5	6	7	FC3__
18.4	A specific person (or group) would be available for assistance with difficulties when using GeoGebra to teach mathematics in the classroom.	1	2	3	4	5	6	7	FC4__

Behavioural intention to use GeoGebra
Please note that these questions measure **intention** to use GeoGebra and **not** the actual use as measured in the background questions.

Item No.	Statement	1	2	3	4	5	6	7	Office use
19.1	I **intend to** use GeoGebra to teach mathematics in the classroom in the next 6 months.	1	2	3	4	5	6	7	BI1__
19.2	I am **determined** that I will use GeoGebra to teach mathematics in the classroom in the next 6 months.	1	2	3	4	5	6	7	BI2__

20 Please indicate how frequently you plan to use GeoGebra during the next 6 months, by encircling the most appropriate answer.

- **1** I do not plan to use GeoGebra at all;
- **2** only once;
- **3** once a month;
- **4** once every two weeks;
- **5** once or twice a week;
- **6** three to four times a week;
- **7** daily.

Office use
BI3__

Thank you for your participation and time.

Please send the completed surveys as well as the signed consent letters to the end of each row where it will be collected by the researcher.

6