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THE RELATIONSHIP BETWEEN THE USE OF ICT IN *DISCOVERING MATHEMATICS CONCEPTS AND LEARNING COMPETENCIES*

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ABSTRACT

The aim of this study is to explore the perceptions of Mathematics teachers using Information and Communications Technology (ICT) as educational tool in their classrooms. This study focuses on the Mathematics teachers' 21st century-oriented pedagogical practices that propagate learning outcomes that are considered essential for all learners to prosper in this ever-changing and demanding information society. The learning competencies considered are termed lifelong competencies as they transcend the classroom and school environment and can thus be used to solve authentic problems in day-to-day life. The development of these learning competencies, especially by using ICT, has become vital in equipping learners with the necessary skills to become confident citizens in this globalised world.

The role the teacher plays is increasingly acknowledged as having a major impact on this process. An essential assumption of this study is that learning activities facilitated by teachers utilising ICT efficiently and effectively as an educational tool have the potential of enhancing the quality of learning competencies. Moreover, as the role of the teacher in these activities is highly important, the teacher's characteristics and background have the potential to determine the overall success of the learners. Using the underlying principles of Activity Theory and the conceptual framework of SITES 2006 this study investigates the relationship between these three components, i.e. ICT integration, learning competencies, and teacher background and characteristics. The intricate relationships that exist among these three components are investigated in this study in the context of Mathematics education.

This is a secondary data analysis study that utilises data from the SITES 2006 South African Mathematics teachers' questionnaire. Only Mathematics teachers who indicated using ICT as an educational tool in the discovery of Mathematics principles and concepts were considered. Using Spearman's correlation coefficient, the data was analysed to determine the strength of the relationships among the variables. Findings of the study suggest that certain teacher characteristics do indeed influence the probability of teachers developing certain learning competencies in learners.

Moreover, the findings indicate that a number of the learning competencies investigated in this study are not as readily attained as others.

Key words: *Computer integrated education, Discovery learning, Learning competencies, Mathematics education, SITES 2006*

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LIST OF ACRONYMS

APA	American Psychological Association
CDL	Concept Discovery Learning
DBE	Department of Basic Education
DOE	Department of Education
EU	European Union
ICCs	International Coordinating Centres
ICT	Information and Communications Technology
ICTs	Information and Communications Technologies
IEA	International Association for the Evaluation of Educational Achievement
IRCs	International Research Centres
NRCs	National Research Centres
ODC	Online Data Collection
PDOE	Provincial Department of Education
PIRLS	Progress in International Reading Literacy Study
SACMEQ	Southern and Eastern Africa Consortium for Monitoring Education Quality
SDL	Scientific Discovery Learning
SET	Science, Engineering and Technology
SIMS	Second International Mathematics Study
SITES	Second Information Technology in Education Study
SITES-M1	Second Information Technology in Education Study Module 1
SITES-M2	Second Information Technology in Education Study Module 2
SPSS	Statistical Package for Social Sciences

TELI	Technology-enhanced Learning Initiative
TIMSS	Trends in International Mathematics and Science Study
UNESCO	The United Nations Educational Scientific and Cultural Organization

CHAPTER 1

INTRODUCTION

1.1 Introduction

The transformation of pedagogical practices through the introduction of Information and Communications Technology (ICT) has been particularly evident in the last decade. Numerous education systems face irrelevance unless the gap is bridged between how learners learn in schools and how they live in the 21st century environment (also referred to as the knowledge or information society) (Anderson, 2008; Holmes & Gardner, 2008). However, "there remains … a profound gap between the knowledge and skills most [learners] learn in school and the knowledge and skills they need in typical 21st century communities and workplaces" (The Partnership for 21st Century Skills, 2004).

This is more so relevant for Mathematics learners who are typically motivated to study the subject so as to have the opportunity to pursue careers in the field of Science, Engineering and Technology (SET). "Yet these same [learners] live in a world permeated by technology – the Internet, satellite communications and mobile phones" (Hoyles & LaGrange, 2010:19). Hoyles and LaGrange (2010) state that for many of these learners simply to secure a middle class income, it would require them to be competent in using these technologies. Johnston-Wilder and Pimm (2005) stress that too many learners are not taking the subject further in their study programmes. This is a shame, because all around there are rapidly changing technologies that require learners to be mathematically inclined (Johnston-Wilder & Pimm, 2005). Technology itself should be inspiration enough to improve learners' understanding of the subject; however, this is not the case. Some of the ways in which ICT has benefited Mathematics education according to Johnston-Wilder and Pimm (2005:32) include the following:

- Learners learn more effectively through instant feedback
- Learners learn by observing patterns and making connections
- Learners work with dynamic images

- Learners have the ability to explore data beyond textbook examples

By introducing ICT into the Mathematics classroom, a dual benefit for the learners and the teachers is met. On the one hand it has been discovered that ICT motivates learners in the subject; on the other hand ICT makes the subject more enjoyable for the teacher to teach (Butler, 2005). Furthermore, the imaging created in a computer-based environment brings the subject into the 21st century, moving away from textbook-based knowledge and it appeals more to learners (Butler, 2005). Lastly, using ICT as an educational tool encourages learners to work on their own or in groups; by so doing learners learn through a learner-centred discovery method which assists in retaining information longer (Butler, 2005).

1.2 Background

South Africa opted for a technology-enhanced learning initiative (TELI) in 1995 (Isaacs, 2007). Almost a decade later, in 2004, the national policy on ICT in education was published in the White Paper on e-Education (Isaacs, 2007). The rationale stated by the Department of Education (2004:17) for the White Paper on e-Education was to ensure that “[e]very South African manager, educator and learner in the general and further education and training bands [should] be ICT capable by 2013”. As this deadline looms, it is essential to determine the progress the country has made in achieving this goal.

The implementation of the national policy on ICT was tasked to individual Provincial Departments of Education (PDOE) (DoE, 2004; Isaacs, 2007). Some initiatives that have been undertaken are more visible in certain provinces than in others. The Western Cape, for example, established the Khanya project in 2001 (Isaacs, 2007; Howie, 2010). The main aim of this project was to equip all schools in the province with ICT. It is reported that to date, over 1 000 schools in the province have been provided with computers and the plan is to supply all schools with computers by 2012 (Isaacs, 2007). The Gauteng Province introduced an online curriculum delivery system, called Gauteng Online, in 2001 to establish computer laboratories and work stations for all schools to use in the province (Isaacs, 2007; Howie, 2010).

A three-year rollout plan was instigated with the anticipation that 1 100 schools in the province would be using the system by 2004 (Isaacs, 2007; Howie, 2010). Isaacs (2007:12) then stated that to date "… Gauteng Online has reached an estimated 1,200 schools with PC labs…". However, currently the Gauteng online system is offline. The Northern Cape has also made significant progress in introducing ICTs into their local schools. The initiatives undertaken in all other provinces are still in their initial stages. Reasons for this state of affairs could be the unequal ICT penetration in each province or as Reddy (2006) suggests, the low human development index (HDI) experienced in these provinces (See section 2.2.2.2). Table 1.1 indicates computer access and use in each province in 2005.

Table 1.1: ICT penetration in the provinces

Province	Total Number of Schools	% Schools with computers	% Schools with computers for teaching and learning
Eastern Cape	6239	23.0	7.8
Free State	1842	77.3	25.9
Gauteng	1897	94.5	78.8
Kwazulu-Natal	5653	43.6	12.0
Mpumalanga	1863	52.9	16.3
Northern Cape	422	91.0	60.4
Limpopo	4187	41.8	8.7
North West	2025	67.6	29.7
Western Cape	1454	97.0	76.6
National	25582	50.9	22.6

[Source: Isaacs, 2007:9]

Table 1.1 clearly illustrates the imbalanced use of computers in the different provinces. The Western Cape and Gauteng are clearly the leading provinces in terms of the use of computers for teaching and learning activities, followed closely by the Northern Cape. The South African statistics are all the more frightening when compared to countries overseas. In 2008 South African Internet users were 78 for every 1 000 people in the population compared to Chile's 267 and Canada's 646 Internet users for every 1 000 people (Howie & Blignaut, 2009; Blignaut, Els & Howie, 2010). The White Paper on e-Education (DoE, 2004:9) clearly states that "… the lack of developed infrastructure for information and communication technologies is widening the gap between Africa and the developed world"; however, this disparity should not cripple the continent but the country should rather strive to realise the benefits of ICTs by developing and producing learners that can fully function in this information age.

This secondary data analysis utilises data collected by the Second Information Technology in Education Study (SITES) 2006. The following section gives a brief background of SITES.

1.2.1 SITES

The Second Information Technology in Education Study (SITES) is an international comparative study conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA) (SITES 2006, 2008). SITES 2006 was administered by the following four consortium partners:

- The University of Twente in Enschede, the Netherlands
- The University of Hong Kong
- The IEA Data Processing and Research Center (DPC) in Hamburg, Germany
- The IEA Secretariat in Amsterdam, the Netherlands

The SITES 2006 research survey is similar to studies previously and currently being conducted on student achievement by the IEA, including the Trends in International Mathematics and Science Study (TIMSS) and the Progress in International Reading Literacy Study (PIRLS) in which South Africa participated (Carstens & Pelgrum, 2009).

SITES 2006 was the third study after SITES Module 1 (SITES-M1) and SITES Module 2 (SITES-M2) undertaken by the IEA related to ICT in education (SITES 2006, 2008). The IEA's research on ICT began in 1989 with research on computers in education study. This study was then followed by SITES, which comprised SITES-

M1 conducted in 1997 and SITES-M2 conducted in 2001 (SITES 2006, 2008). SITES-M1 aimed at determining school readiness to integrate ICT in teaching and learning whereas SITES-M2 aimed at determining innovative pedagogical practices (Pelgrum & Anderson, 2001:44). The main aim of SITES 2006 was to determine the role of ICT as an educational tool in Science and Mathematics classrooms.

Over 22 education systems took part in SITES 2006 of which South Africa was one (Carstens & Pelgrum, 2009). Fifteen (15) of these had participated previously in SITES-M1 (Carstens & Pelgrum, 2009). The SITES 2006 population considered schools offering education to Grade 8 learners and the Mathematics and Science teachers teaching this target grade (SITES 2006, 2008). A total of 445 schools were sampled in South Africa, using stratified probability sampling (Carstens & Pelgrum, 2009). To ensure equal probability of the number of teachers sampled from each school "… the SITES 2006 research team implemented a sample design that involved … stratifying the school sample frame according to the school size" (Carstens & Pelgrum, 2009:50). Between two and four Mathematics teachers and between two and four Science teachers were sampled in each school, depending on the school size (Carstens & Pelgrum, 2009). Additionally, the level of ICT use of each school was taken into consideration, i.e. high, low and no use of ICT (Carstens & Pelgrum, 2009).

1.3 Problem statement and research question

South Africa as a developing nation faces major challenges in integrating ICT into education. The emphasis has thus far been predominantly on infrastructure development. However, in so doing, the pedagogical practices of the teachers and learners have taken a back seat. The teacher is continually identified as a crucial component playing a vital role in determining the effectiveness of ICT as an educational tool. However, the exact impact the teacher has when using ICT as an educational tool has remained relatively unexplored in South Africa. With all the above mentioned initiatives being undertaken in the various provinces, it is of the utmost importance that the role the teacher plays in effectively integrating ICT in classrooms, specifically Mathematics classrooms, is investigated.

An essential assumption of this study is that activities that utilise ICT efficiently and effectively as an educational tool have the potential of enhancing learning competencies that are essential for learners to succeed in the information or knowledge society. Moreover, the role of the teacher in these activities is highly important, and the teachers' characteristics and background play a vital role in determining the overall success of the learners. This study therefore attempts to explore and identify the possible positive outcomes of using ICT as an educational tool in Mathematics classrooms, specifically looking at it from a teacher's perspective. The main research question is the following:

> *What is the relationship between the use of ICT as an educational tool and the extent to which ICT assists in improving learning competencies?*

1.4 Purpose of the study and sub-research questions

The purpose of the study is to explore the relationship between the use of ICT in a specific Mathematics activity, i.e. discovering Mathematics principles and concepts and the extent to which ICT assists in improving Grade 8 learners' learning competencies. The following learning competencies as identified by SITES 2006 in the teacher questionnaire are investigated (see Addendum B):

- Information handling skills
- Problem-solving skills
- Self-directed learning skills
- Collaborative skills
- Communication skills
- ICT skills
- Ability to learn at the learner's own pace

Since each learning competency is investigated, Table 1.2 outlines the sub-research question corresponding to each learning competency. Additionally, the resultant null and alternative hypotheses are indicated in Table 1.2.

Table 1.2: Sub-research questions, and null and alternative hypotheses

Research question	Hypotheses
1. What is the relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' information handling skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' information handling skills. H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' information handling skills.
2. What is the relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' problem-solving skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' problem-solving skills. H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' problem-solving skills.
3. What is the relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' self-directed skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' self-directed skills. H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' self-directed skills.
4. What is the relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' collaborative skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' collaborative skills. H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' collaborative skills.
5. What is the relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' communication skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' communication skills. H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' communication skills.

Table 1.2: Sub-research questions and null and alternative hypotheses (Continued)

6. What is the relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' ICT skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' ICT skills. H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' ICT skills.
7. What is the relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves the learners' ability to learn at their own pace?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' ability to learn at their own pace. H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts and the extent to which it improves learners' ability to learn at their own pace.

This study also explores the possible influences that teacher characteristics and background may have on the above mentioned learning competencies. Thus, additionally the following teacher characteristics are analysed in this study:

- Gender
- Age group
- Highest level of education
- Degree obtained
- Years of teaching experience
- Access to a computer at home
- The uses of the computer at home

1.5 Rationale for the study

This study will draw attention to the use of ICT as well as the teacher using technology as a contributing factor in improving skills deemed essential for learners to survive in the knowledge society. It is anticipated that the findings of the study will assist in identifying training needs required for Mathematics teachers who use ICT as an educational tool in their classrooms. It is envisaged that insights gained from this study will assist stakeholders in education in making informed ICT policy recommendations and changes.

1.5.1 Significance of the study

For learners to function fully in the knowledge society greater efforts to support their learning needs are called for, especially with regard to ICT use. By investigating the positive outcomes that ICT potentially has on learners' learning competencies, it is envisaged that the findings may compel educational managers to strive after improving the current weaknesses witnessed in the South African education system, especially in regard to ICT implementation. This study is grounded in the belief that since the teacher plays a significant role in propagating learning, supporting teachers in the efficient use of ICT as an educational tool should ultimately assist in improving and developing learners' learning competencies. Bialobrzeska and Cohen (2004:91) point out that for "... successful ICT implementation ..." there is a need for "... the development, and implementation of a thoughtful ICT policy". Adequate supporting ICT policies in place in schools may contribute to a sufficiently equipped learner who has the ability to succeed in the 21st century workplace and environment. This study envisages informing such a policy.

1.6 Limitations

This study is limited to a small sample of South African Mathematics Grade 8 teachers that participated in the SITES 2006 study. The research sample size is therefore too small to reach conclusive findings. The study analysed data collected from teachers and essentially these are the perspectives of their influence on the learners' learning competencies and just what impact they believe using ICT in a Mathematics learning activity may have.

1.7 Outline of the study

Table 1.3 outlines the structure of the chapters in the dissertation.

Table 1.3: Dissertation structure

Chapter	Title	Description
1	Introduction	A brief overview and background of the study.
2	Literature study	Provides a review of literature related to the study as well as the theoretical foundations and conceptual framework governing the study.
3	Research Design	Outlines the research design and methods utilised. The research procedures and processes undertaken are also highlighted.
4	Data Analysis	Detailed data analysis procedures undertaken for the study.
5	Conclusion and Recommendations	A summary of the results of the study with concluding remarks, recommendations and suggestions.

CHAPTER 2

LITERATURE STUDY

2.1 Introduction

In this chapter literature on Mathematics education and ICT integration in the South African context is explored. Furthermore the learning competencies investigated in this study are discussed. Thereafter the chapter outlines the Second Information Technology in Education Study 2006 and also examines secondary data analysis studies that used data from this study. A brief discussion of the conceptual framework that governs the study concludes this chapter.

2.2 Mathematics education

The significance of Mathematics education in today's society is complemented by the ever-increasing dependence on technology (Christiansen, 2007). Mathematics and Science education has become almost synonymous with technological advancements (Vithal, Adler & Keitel, 2005; Reddy, 2006; DoE, 2009). As the demand for technological advances increases so does the need to ensure that the learners in schools are equipped with the right tools to address this demand. The acknowledgement of the importance of Mathematics has highlighted the inequities that exist in the subject. Learners are not required only to have the ability to reason and communicate, solve problems and understand and use concepts in Mathematics; they are also required to develop ICT skills that address societal needs in the process. Thus the development of these skills has become even more vital as they assist learners with the capabilities to contribute to the overall growth of the country.

2.2.1 Mathematics principles and concepts

Troelstra (1998:1) asks: "How does [a learner arrive at Mathematics] concepts and discover the principles holding for those concepts?" Siegler (2003) proposes two solutions; the first, according to Siegler, (2003) involves determining how a child learns Mathematics concepts and principles prior to any formal Mathematics instruction and the second is the investigation into the relationship between conceptual and procedural knowledge. However, before these two options can be explored, the initial question should be: What are Mathematics principles and concepts? *The Curriculum for excellence* (2010) defines Mathematics as a "… universal language of numbers and symbols which allows us to communicate ideas in a concise, unambiguous and rigorous way". This definition suggests that there are fundamental theories, sets of procedures and groups of skills inherent with the advent of learning the subject. Therefore learning Mathematics builds several skills that the *Curriculum for excellence* (2010) lists as "logical reasoning, analysis, problem-solving skills, creativity and the ability to think in abstract ways." In short, Mathematics principles and concepts are the sets of theories and skills that are utilised in the problem-solving contexts of Mathematics. Rittle-Johnson, Siegler and Alibali (2001) add that these sets of theories and skills are generalisable as they are not tied to a specific problem.

So to answer Toelstra's (1998:1) question [See 2.2.1 on p. 11], Siegler's (2003) first point suggests that a child comes with prior informal knowledge of Mathematics concepts before being introduced to formal Mathematics concepts in the school context. Siegler (2003) points out the importance of determining the child's prior knowledge, especially their misconceptions before any further formal instruction is given. This is because the ways in which these sets of procedures and skills are learnt at a young age affect the child's understanding and method of solving problems at an older age. Essentially how and what learners learn at a young age influences how and what they learn later in life. If at a young age the child fails to grasp the core principles and concepts, it is unable to properly build the Mathematics principles and concepts required to solve problems. Siegler (2003) notes that the pattern of errors learnt are simply inherited with each grade level, and this state of affairs exacerbates the learning gap.

Siegler's (2003) second point outlines the importance of looking at the relationship between conceptual and procedural knowledge. Rittle-Johnson et al. (2001:346) define procedural knowledge as "… the ability to execute action sequences to solve problems". Conceptual knowledge is defined by Rittle-Johnson et al. (2001:346) as "… implicit or explicit understanding of the principles that govern a domain and of the interrelationships between the units of knowledge in a domain." There is a lot of debate in literature on which knowledge type – conceptual or procedural knowledge – should be emphasised to ensure maximum learning capacity for Mathematics learning. On the one hand Mathematics is a factual subject – hence the importance of conceptual knowledge; on the other hand procedural knowledge relates to methods of problem-solving techniques that are part and parcel of the subject. Traditionally Mathematics was predominantly taught through memorisation and rote learning of procedures with little concern for the associated concepts that underlie them, according to Bossé and Bahr (2008). However, a balance between conceptual and procedural knowledge is now advocated by various authors (Star, 2000; Rittle-Johnson, Siegler & Alibali, 2001; Siegler, 2003; Kellman & Massey, 2008) because the learning of Mathematics calls for the "... ability to use knowledge flexibly [while] applying what is learned in one setting appropriately in another"(Bossé & Bahr, 2008:4).

Siegler (2003) refers to conceptually-oriented instruction and procedurally-oriented instruction. In a study conducted by Haapasalo and Kadijevich (2000) it is suggested that procedurally-oriented instruction yields better results as opposed to conceptually-oriented instruction. A reason given for this is the more discovery-oriented method in procedurally-oriented instruction. However, most other studies call for a balance between the two forms of knowledge. Star (2000) in his study concludes that the importance of the use of either procedural or conceptual knowledge simply *depends*. He bases this opinion on the various forms of understanding of what procedural and conceptual knowledge is. So essentially the disagreement between knowing versus doing continues as the definition of these concepts evolve (Star, 2000).

Rittle-Johnson et al. (2001) debate on the relationship between conceptual and procedural knowledge and conclude that through the process of learning, both conceptual and procedural knowledge inadvertently influence each other. Rittle-Johnson et al. (2001) propose that conceptual and procedural knowledge be developed iteratively in the process of problem-solving. Rittle-Johnson et al. (2001) developed the iterative model depicted in Figure 2.1. In this model, the development and improvement of one type of knowledge influences the development and improvement of the other type of knowledge.

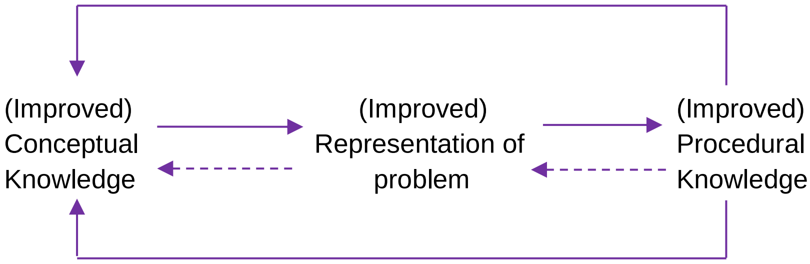

Figure 2.1: Iterative model for the development of conceptual and procedural knowledge
[Source: Rittle-Johnson et al. (2001:347)]

So how does a learner arrive at Mathematics concepts and discover the principles holding for those concepts? Star (2000) plainly states that it depends; it depends on a variety of factors, two of which are discussed in this section. So if a Mathematics teacher is to ensure the successful discovery of Mathematics principles and concepts these factors are only two of the aspects to be considered. There are certainly many more (Siegler, 2003) but the researcher believes these points are as good a departure point as any.

2.2.2 Mathematics achievement in South Africa

In many parts of the world Mathematics is repeatedly identified as the subject with the lowest learner achievement rate (Reddy, 2006; Howie, 2010). Despite major initiatives by various stakeholders in education to promote the subject, very few learners emerge successful. The South African context is no exception. The Department of Education (DoE) in South Africa is tasked with the development of policies nationally but it is up to the individual province to ensure the implementation of these policies. As each province has varying resources, the implementation of policies varies accordingly. The Mathematics achievement for South Africa is discussed in this section, firstly according to each of the nine provinces in the country; secondly, as compared to other African countries and then lastly as compared to international countries. As this study investigates Grade 8 learners' learning competencies, findings from the Trends in International Mathematics and Science Study (TIMSS) 1999 and TIMSS 2003 study are assessed as the TIMSS is the only study to investigate Grade 8 learners' Mathematics achievement in South Africa in the respective years. Therefore a brief description of the TIMSS study is provided.

2.2.2.1 TIMSS

The Trends in International Mathematics and Science Study (TIMSS) like the Second Information Technology in Education Study (SITES) was an international comparative study investigated by the International Association for the Evaluation of Educational Achievement (IEA) to determine learner achievement in Mathematics and Science (Reddy, 2006). The IEA are an international cooperative consisting of government and national research centres and institutions based in the Netherlands (SITES 2006, 2008). The IEA are renowned for conducting international comparative studies with specific foci on education achievement.

Initially the First International Mathematics Study (FIMS) was conducted by the International Association for the Evaluation of Educational Achievement (IEA) in 1964 (Gonzales, Guzman, Partelow, Pahlke, Jocelyn, Kastberg & Williams, 2004). Twelve (12) countries participated in FIMS. From 1980 to 1982 the Second International Mathematics Study (SIMS) was conducted and eight (8) more countries participated in this study (Gonzales et al., 2004). Between 1995 and 1996 the third study in Science was combined with an assessment of Mathematics, and this study was known as the Third Mathematics and Science Study (TIMSS) (Gonzales et al., 2004). It was repeated in 1999 and was aptly called the TIMSS-repeat. South Africa also took part in this study. The purpose of TIMSS was to determine the trends in Grade 8 learner achievement. In 2003 another TIMSS study was conducted in which South Africa once again part took. The last TIMSS study was conducted in 2007; South Africa did not, however, participate in this study (Gonzales et al., 2004).

2.2.2.2 Mathematics achievement in the provinces

The average Mathematics score for Grade 8 learners for each province in South Africa in TIMSS 1999 and TIMSS 2003 respectively is indicated in Table 2.1. As indicated in Table 2.1 only three of the nine provinces showed an increase in their average Mathematics score from TIMSS 1999 to TIMSS 2003; these provinces are the Western Cape, the Northern Cape and Mpumalanga. The majority of the provinces' average Mathematics scores declined for South African Grade 8 Mathematics learners according to TIMSS. The province with the highest average score for Mathematics for both studies was the Western Cape followed in both instances by the Northern Cape and Gauteng respectively. The three lowest performing provinces for both TIMSS were North West, Eastern Cape and Limpopo as depicted in Table 2.1.

Table 2.1: Average Grade 8 Mathematics score for South African provinces for TIMSS 1999 and TIMSS 2003

Province	Average Mathematics Score TIMSS 1999	Average Mathematics Score TIMSS 2003
Western Cape	381	389
Northern Cape	318	333
Gauteng	318	304
Free State	276	265
Mpumalanga	253	261
KwaZulu-Natal	292	255
North West Province	267	251
Eastern Cape	256	223
Limpopo	226	217
National average	*275*	*264*

[Source: Reddy (2006:48)]

However, Reddy (2006) does point out a correlation between the human development index (HDI) of each province and the provincial Mathematics scores attained as illustrated in Figure 2.2.

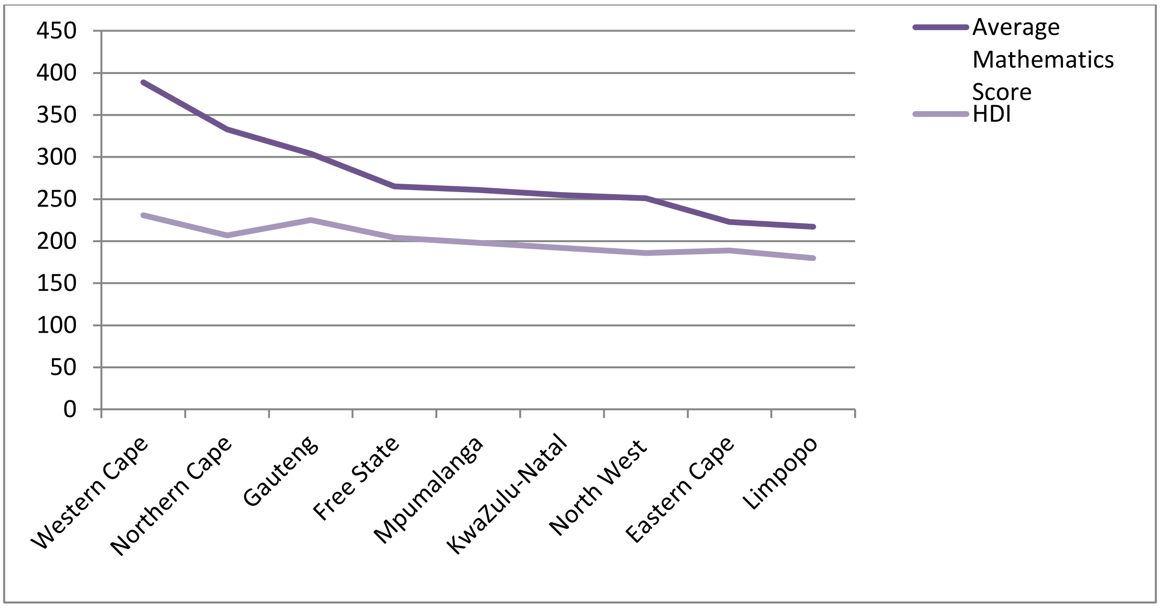

Figure 2.2: Provincial Mathematics scores and HDI by province
[Source: Reddy (2006:48)]

It can be seen from Figure 2.2 that provinces with a high HDI have relatively high Mathematics achievement scores whereas provinces with a low HDI have lower Mathematics achievement scores.

2.2.2.3 Mathematics achievement compared to that in African countries

Six (6) African countries participated in TIMSS 2003, namely Botswana, Egypt, Ghana, Morocco, Tunisia and South Africa. Morocco, Tunisia and South Africa were the only three countries that participated in TIMSS 1999. Table 2.2 shows the Average Mathematics score of each country that participated in TIMSS 2003. The gross national index for each country is also indicated in Table 2.2.

Table 2.2: Average grade 8 Mathematics score for TIMSS 2003 and GNI for each African country

Country	Mathematics average	GNI/capita in US$
Tunisia	410	1990
Egypt	406	1470
Morocco	387	1170
Botswana	366	3010
Ghana	276	270
South Africa	264	2500

[Source: Reddy (2006:20)]

Findings from TIMSS 2003 revealed that although South Africa had one of the highest GNI/capita in US$ after Botswana it had the lowest average grade score when compared to all the other five participating African countries (Reddy, 2006).

2.2.2.4 Mathematics achievement of South Africa compared to that in international countries

There were 50 participating countries in TIMSS 2003. The top five performing countries in Mathematics were Singapore, Republic of Korea, Hong Kong (SAR), Chinese Taipei and Japan. The countries at the other end of that spectrum included the Philippines, Botswana, Saudi Arabia, Ghana and South Africa (Reddy, 2006; DoE, 2009). The Mathematics average score for South African Grade 8 learners was the lowest and was significantly lower than the international average score as shown in Table 2.3 for both TIMSS (DoE, 2009:87). Table 2.3 indicates the average Mathematics score for Grade 8 learners in South Africa in comparison to the international average score.

Table 2.3: Average Grade 8 Mathematics score for TIMSS 1999 and TIMSS 2003

	TIMSS 1999
South Africa's average score	275
International average score	487
	TIMSS 2003
South Africa's average score	264
International average score	467

[Source: DoE, (2009:87)]

In both TIMSS studies it is evident that South Africa performed poorly in relation to both other African countries and international countries. The Grade 8 Mathematics average for South Africa is in most cases significantly lower than the international average for both TIMSS.

Similar results have been found in more recent studies that evaluate trends in Mathematics achievement in South Africa. The Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ), for example, conducted studies in 2000 and 2007 respectively to determine trends in the reading and Mathematics achievement of Grade 6 learners (DoE, 2009). SACMEQ is an international non-profit developmental organisation consisting of 15 Ministries of Education from Southern and Eastern Africa which include Botswana, Kenya, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania (Mainland), Tanzania (Zanzibar), Uganda, Zambia and Zimbabwe (SACMEQ, 2012). SACMEQ studies revealed that although there was an improvement in achievement for the Mathematics Grade 6 learners, this improvement was not significant and South Africa still underperformed when compared to the SACMEQ average as shown in Table 2.4.

Table 2.4: Average Mathematics score for each province in SACMEQ 2000 and SACMEQ 2007 studies

Province	2000	2007
Western Cape	591	566
Northern Cape	461	499
Gauteng	552	545
Free State	448	492
Mpumalanga	433	476
KwaZulu-Natal	510	485
North West Province	420	503
Eastern Cape	449	469
Limpopo	446	447
National average	486	495
SACMEQ average	500	510

[Source: Moloi & Chetty, (2010:42-43)]

For both the 2000 and 2007 SACMEQ studies the Western Cape and the Gauteng province were the top performing provinces. This study, however, revealed that there was a significant improvement in the Grade 6 Mathematics average score for the North West province as it outperformed the Northern Cape. As with TIMSS the Eastern Cape and Limpopo province were the lowest performing provinces.

This under performance can also be seen in the Grade 12 Mathematics level. The Grade 12 learners of 2011 had a pass rate of 70.2% but the Mathematics pass rate was a mere 46.3% (Department of Basic Education (DBE), 2011). As shown in Table 2.5, this pass rate includes learners who achieved the minimum promotion mark of 30% (DBE, 2011). Even more worrisome is the decline in the pass rate of South African Mathematics learners as shown in Table 2.5 and Figure 2.3.

Table 2.5: Grade 12 national Mathematics achievement rates 2008-2011

Year	Number who wrote	% Achieved 30% and above	% Achieved 40% and above
2008	300 008	45.4	29.9
2009	290 407	46	29.4
2010	263 034	47.4	30.9
2011	224 635	46.3	30.1

[Source: DBE, 2011:98]

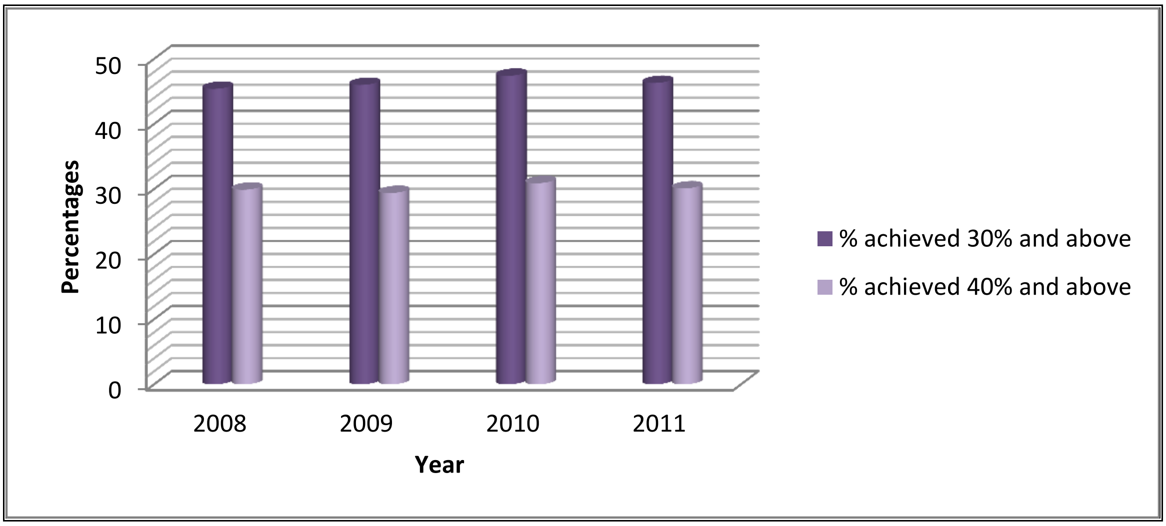

Figure 2.3: National Mathematics achievement 2008-2011
[Source: DBE, 2011:101]

Irrespective of the grade level, it can be seen from the studies above that Mathematics learners do not perform well in general in South Africa.

2.2.3 Teachers as factors related to Mathematics achievement

Literature on factors that influence learner achievement provides much evidence indicating that the teacher is one of the most important factors (Goldhaber & Anthony, 2004; Rivkin, Hanushek & Kain, 2005; Krieg, 2005; Parker & Adler, 2005; Dee, 2006; Gay, 2007; Chudgar & Sankar, 2008; Carstens & Pelgrum, 2009; Rakumako & Laugksch, 2010). The impact of having a high-quality teacher in the classroom is profound according to Goldhaber & Anthony (2004) and has the possibility of transcending the classroom and school environment. Various researchers have found that increasing the quality of teachers leads to greater success in learner achievement and success (Darling-Hammond, 2002; Greenberg, Rhodes, Ye & Stancavage, 2004). A great assumption of SITES 2006 was that although there are several factors that affect overall pedagogical practices (see conceptual framework in section 2.7.2), the teacher's role plays the most pivotal role (Carstens & Pelgrum, 2009). Carstens and Pelgrum (2009) boldly state that in essence teachers are the centre of the SITES study because of the role they play in influencing the learning outcome.

Goldhaber and Anthony (2004:4) point out an essential contradiction; on the one hand evidence in literature shows that teachers have an impact on learning, on the other hand teacher attributes such as credentials, i.e. highest level of education, degree obtained and number of years of teaching experience "…are not strongly related with [learner] learning gains". It has been found that there is no strong correlation between *teacher quality* and *teacher credentials* (Goldhaber & Anthony, 2004). Goldhaber and Anthony (2004) therefore suggest refraining from simply checking teacher credentials but rather concentrating on what is being done in class as it gives a clearer picture of the level of the teacher qualification.

Although there is a tendency in literature to agree on the teacher's role and its impact on learning, Goldhaber and Anthony (2004) point out that the same literature disagrees about which teacher characteristics have the greatest impact. Is it the teacher's credentials, i.e. highest level of education, degree obtained and number of years of teaching experience or is it the teacher's characteristics, i.e. age of the teacher and background (Goldhaber & Anthony, 2004). To address this debate SITES 2006 collected the following data on the demographic background of the teachers (Carstens & Pelgrum, 2009):

- Gender
- Age group
- Highest level and type of education
- Teaching experience
- Access to a computer

This study additionally investigates the possible influences of teacher characteristics and background on the learner's learning competencies. These teacher characteristics are described briefly in the subsequent sections.

2.2.3.1 Gender and Age

Investigations into the effect of teachers' gender on learner achievement offer a variety of conclusions that ask more questions than they answer (Michaelowa, 2001; Dee, 2006; Chudgar & Sankar, 2008). Whereas some studies (Michaelowa, 2001; Dee, 2006) found supporting evidence for same-gender effect, i.e. female learners learn best from female teachers and male learners learn best from male teachers, other studies (Krieg, 2005) have found that most learners (both male and female) learn best when taught by a female teacher.

Studies such as the one by Warwick and Haroona's (1994) found that Mathematics male teachers got better learner results compared to Mathematics female teachers. Chudgar and Sankar (2008) in their investigation on the effect of the teachers' gender on learner achievement found very little conclusive evidence on the relationship between these two variables. If this is not confusing enough, Driessen's (2007) study found no relationship between teachers' gender and learner achievement. In summary, literature does not have consensus on the relationship between the teacher's age and learner achievement. Wayne and Youngs (2003:101) so aptly write: "… research either does not exist or has not resulted in clear findings…" in relation to these two variables. However, the relationship between the teacher's gender and the impact it may have on learner achievement is considered. As far as another teacher characteristic is concerned, the teacher's age, seemingly no literature on the relationship between the teacher's age and learner achievement was found.

2.2.3.2 Qualifications

Johnston-Wilder and Pimm (2005) state that the reason the learner performs poorly is because most Mathematics teachers are not properly trained or qualified. Rakumako and Laugksch (2010) found in their study that one of the many factors that have been identified to affect learners' Mathematics achievement is the role of the teacher's pedagogical knowledge and skills in the subject area which links to the teacher's credentials. According to these authors it is essential to have a look at teacher credentials to determine the quality of the teaching. In *The trends in education macro indicators for South Africa report* compiled by the Department of Education (2009) the debate on a connection between teacher credentials and learner achievement is briefly discussed. It is concluded in this report that due to the history of the country with respects to apartheid, a division was created in terms of the qualifications of teachers dependent on racial groups. To readdress this issue national policies have underscored the importance of looking at teacher qualifications as an indicator of quality in education. Thus, for this reason the level of teacher qualifications in South Africa is briefly outlined and investigated in this study.

According to the Department of Education (2009) teachers are considered qualified if they possess a Senior Certificate with a minimum of three years of appropriate training. The DoE (2009) states that noteworthy improvements have been made in assuring qualified teachers. It was reported that in 1990 only 53% of the teachers were appropriately qualified or trained; in 2008 this figure had risen to 94.4% (DoE, 2009). Although a large percentage of the teachers are appropriately qualified or trained, Howie (2009) points out that most Mathematics teachers are not qualified to teach the subject. Howie (2009) states that over 85% of Mathematics teachers are qualified or trained but only half of those teachers have a specialisation in Mathematics.

Research internationally on the relationship between teacher qualifications and learner achievement has revealed mixed findings. In their study Goldhaber and Brewer (2000) found that there was no difference between the results of learners who were taught by a teacher with a Master's degree and those who were not. However, Goldhaber and Brewer (2000) found that "Mathematics students whose teachers had Master's degrees in Mathematics had higher achievement gains than those whose teachers had either no advanced degrees or advanced degrees in non-Mathematics subjects…" (Wayne & Youngs, 2003:102). Furthermore, Goldhaber and Brewer (2000) found that learners were more likely to learn if their teachers had majored in Mathematics. Supporting this study are Welingsky's study (2002:5) and Betts, Zau and Rice's study (2003) that found that learners of teachers who had majored in Mathematics were more likely to perform better than the learners who had a teacher who had not majored in Mathematics.

2.2.3.3 Teaching experience

As with the teacher characteristics previously discussed, teaching experience is no exception in the debate on predicting learner achievement. Similarly, there are two schools of thought looking at teaching experience; one underscores Wayne and Youngs (2003:106) who suggest three reasons why it is difficult to use teacher experience as a predictor of learner achievement. These include the following:

- Teaching experience is dependent on whether teachers are hired during a shortage or a surplus. Hiring teachers during a shortage influences the quality of the teachers hired.
- Teaching experience does not take into account the levels of teacher motivation which is another important factor to consider.
- Teaching experience is influenced by the effectiveness of the teachers who leave the profession and those who stay, which negatively influences the teachers remaining.

Thus Wayne and Youngs (2003) caution using teaching experience to predict learner achievement. A similar viewpoint is shared by Welingsky (2002) who strongly opposes a direct relationship between teaching experience and learner achievement. Welingsky (2002) does however suggest the existence of an indirect relationship between these two variables. Zhang's (2008) hypothesis is that teaching experience acts as a mediating factor implying that "… it may be possible [for teaching experience to] influence one or more other important variables, which then influences student … achievement…" (Zhang, 2008:60). As reiterated in the previous section, *teacher quality* is not strongly related to observed *teacher credentials* and Welingsky (2002) points out that this applies to teaching experience too as the quality of the teacher cannot be quantified simply by looking at the number of years he or she has been teaching.

The other school of thought is shared by Zhang (2008) who implies that teaching experience can indicate the ability of the teacher to manage the classroom efficiently which can then promote learner achievement. Greater or longer teaching experience therefore adds to improving learner achievement. As with the previous teacher characteristics, results examining the relationship between teaching experience and learner achievement are conflicting and contradictory, with some suggesting a positive relationship and others suggesting difficulties of a clear relationship (Welingsky, 2002; Goldhaber & Anthony, 2004).

2.2.3.4 Access to a computer

In today's society the act of *doing work* requires the use of a computer. This implies a computer literate work force. Teachers are by no means excluded. In addition to working with computers, teachers have the added pressure of utilising computers as teaching and learning tools in their classrooms. Teachers' adeptness at using a computer influences their learners as well. There are various incentives in each of the nine provinces in South Africa to equip all schools with computers (see Section 2.3.1). However, if the teachers are unable to use these computers effectively as teaching and learning tools, these initiatives are in vain.

A study conducted by Sime and Priestly (2005) found that teachers that have access to a computer at home are more likely to use them in their classrooms as well. Gay (2007) hypothesises that this is due to two main factors: *time* and *access*. Firstly, for teachers to successfully infuse technology into their classrooms they require enough time to practise and familiarise themselves with the technology. Sime and Priestly (2005) add that because these teachers have a greater opportunity to practise with the technology at home, their attitudes towards technology is more positive and they are more confident in utilising it in class. Gay (2007) concludes that the ability of the teachers to sufficiently practise and plan with computers is a vital factor in ensuring effective integration of computers as an instructional tool.

The second issue according to Gay (2007) that influences computer integration for teachers is adequate access to the technology. This ties in with the first issue; only if teachers have access to the technology can they make or have the time to practise using the technology. Sime and Priestly (2005) point out that the teachers' competency and confidence is a major contributing factor to their willingness to integrate technology in their teaching. Sime and Priestly (2005) conclude that although the benefits of learners using a computer are numerous, if teachers are unable to successfully integrate computers as an educational tool, its benefits will not be realised.

2.3 Previous SDA studies using the SITES 2006

This section examines secondary data analysis studies which used data collected by the International Association for the Evaluation of Educational Achievement (IEA) for the Second Information Technology in Education Study (SITES) 2006. A comparative analysis is done, highlighting the aims and findings of each study. This section is further subdivided by studies undertaken either nationally or internationally. This is to determine the overall findings of each study both locally and internationally.

2.3.1 National studies

The majority of the national studies focus on contextualising South Africa's participation in SITES 2006; therefore most of these studies (Howie & Blignaut, 2009; Blignaut, Els & Howie's, 2010; Howie, 2010), with the exception of one (Draper, 2010), are more qualitative in nature and in the form of reviews. The secondary data was not further reanalysed, but rather the official findings as reported by the IEA were used as a basis to contextualise the South African leg for SITES 2006. As such the South African secondary data as collected by the IEA has not been extensively explored.

Howie and Blignaut's study published in 2009 aimed at analysing the implementation and usage of ICT in secondary schools in a developing country context. One of the major findings of this study was that even though remarkable steps were taken in providing computers to schools and access to the Internet from the year 1998 to 2006, South Africa does not yet provide universal ICT access in education to its learners with more than half (62%) of the schools not having access to computers.

Blignaut, Els and Howie's (2010) study focuses on contextualising the South African leg of SITES 2006. The main purpose of their paper is to compare the results found by SITES 2006 for South Africa with all other countries that participated. Similarly as in the case of the previous study, it was found that although South African schools with Internet access have increased from 52% in 1998 (SITES M-1) to 67% in 2006, South African schools have the second lowest Internet access rate of all education systems that participated in SITES 2006 (Blignaut et al., 2010a).

A comparative study by Howie (2010) identified and contrasted ICT-supported pedagogical practices and policies. Findings from this study revealed that Chile's experience in the development and implementation of ICT in education was essentially much faster and more effective than compared to the South African experience in this regard. Howie (2010) adds that whereas in Chile's case much research was documented on the implementation of ICT in education it was difficult to find literature on its implementation in education in South Africa. The research available in South Africa is predominantly policy documents and the intentions of the Government (Howie, 2010). The challenge for South Africa therefore lies in the successful implementation of these policies.

Draper's (2010) study is the only study conducted nationally that employed a mixed method approach and followed up the secondary data analysis with case studies. This study aimed at understanding the use and integration of ICT by Science teachers in a developing country context. The results of the study concluded that although there is low availability of ICT resources in South African schools, teachers still manage to utilise the limited resources and provide their learners with opportunities to learn (Draper, 2010).

2.3.2 International studies

The international studies are mostly comparative studies focusing on the pedagogical practices of teachers. A major concern in the international papers is to distinguish between pedagogical practices that have been categorised as either in the traditional paradigm or the lifelong learning paradigm. The international studies also favour quantitative data analysis in comparison to the predominantly qualitative studies conducted in South Africa.

Bryderup, Larson and Trentel in 2009 reported using an integrated qualitative-quantitative comparative study between data collected for SITES-M1 and SITES 2006. Their study aimed at comparing teachers and principals' pedagogical paradigms in schools in Denmark (Bryderup et al., 2009). The findings of this study indicate that there was a decrease in principal's perception of the importance of the lifelong learning paradigm. The findings further indicate that in actuality there was dominance in teachers' usage of the practices that were in the traditional paradigm (Bryderup et al., 2009).

An integrated qualitative-quantitative study was reported by Law (2009) who examined the relationship between ICT use and pedagogical practices in Mathematics and Science with the associated policy implications. The results indicate that although teachers still predominantly followed traditional teaching and learning practices in their classrooms there was a gradual showing of evidence of lifelong learning practices in several schools (Law, 2009).

Another integrated qualitative-quantitative study by Pelgrum and Voogt in 2009 aimed at exploring the differences between pedagogical practices of Mathematics teachers who use ICT as an educational tool on a regular basis and Mathematics teachers who do not use ICT on a regular basis. The findings indicate that teachers who used ICT as an educational tool on a regular basis applied more learner-centred approaches and consequently enhanced lifelong learning competencies more than teachers who did not use ICT on a regular basis (Pelgrum & Voogt, 2009).

In their study Blignaut, Hinostroza, Els and Brun (2010) compare the ICT in education policy and development between South Africa and Chile. This study is similar in purpose and findings to the study by Howie (2010) in section (2.4.1.1). This comparative study adopted the data collection methods used by SITES 2006. The study concluded that both countries were inclined to concentrate computers in laboratories instead of placing them in classrooms for easier access to learners. The findings further indicate that in comparison to Chile, South Africa provided minimal technical support to their teachers. Furthermore it was found that in South Africa a higher percentage of Mathematics teachers use ICT as an educational tool compared to Chile where a higher percentage of Science teachers do (Blignaut et al., 2010b).

A comparative study between Hebrew and Arab-speaking schools on several aspects of ICT-related issues was conducted by Nachmias, Mioduser and Forkosh-Baruch (2010). The research results indicate that principals in Arab-speaking schools recognise a greater importance of using ICT as an educational tool than their counterparts in Hebrew-speaking schools. It was also found that Arab-speaking

Mathematics teachers use ICT in their classrooms twice as much as Hebrew-speaking Mathematics teachers (Nachmias et al., 2010).

A study by Ottestad in 2010 examined the pedagogical practices of using ICT in three Nordic countries, namely Finland, Norway and Denmark. The study found that in general fewer Finnish teachers reported the use of ICT compared to Danish and Norwegian teachers (Ottestad, 2010). The results also showed that the Norwegian teachers were more likely to utilise practices that fell into the lifelong learning category when compared to Danish and Finnish teachers (Ottestad, 2010).

Voogt (2010) explored the different innovative and traditional pedagogical practices among Science teachers who use ICT extensively and those who do not. The findings showed that although both the Science teachers who used ICT extensively and those who did not, equally considered traditional and lifelong learning practices in their classrooms, it was found that the Science teachers who used ICT extensively had a stronger orientation towards lifelong learning (Voogt, 2010). Needless to say the teachers who used ICT extensively applied more ICT-supported pedagogical practices in their classrooms (Voogt, 2010).

2.4 Discovery learning

Discovery learning is defined by van Joolingen (1999:385) as "… the type of learning where learners construct their own knowledge by experimenting with a domain and inferring rules from the results of these experiments". Discovery learning was initially referred to as *concept discovery learning* [CDL]; however, it has now evolved to be known as *scientific discovery learning* [SDL] since learners are given the opportunity to design their own experiments in these discovery learning environments (Van Joolingen, 1999; Reid, Zhang & Chen, 2003; Zhang, Chen, Sun & Reid, 2004). Currently SDL environments are predominantly characterised by the provision of exploratory learning environments to learners with the use of computer simulations, according to Reid et al. (2003). Veermans, De Jong and Van Joolingen (2000:229) consider computer simulations to be the perfect environments to develop discovery learning because they provide the learner with the capability to "… generate data, extract and construct knowledge from these data". This has the advantage of allowing the learners to set and achieve their own learning goals (Veermans et al., 2000).

Since they allow learners to set and achieve their own goals "these activities will result in deeper rooting of the knowledge, enhanced transfer, regulatory skill acquisition and increased motivation" (De Jong, Van Joolingen, Swaak, Veermans, Limbach, King & Gureghian, 1998; Veermans et al., 2000:230). As these environments foster constructive learning, Van Joolingen (1999) determines that learners will develop higher order thinking skills as this type of learning is not superficial learning but requires deep learning.

Veermans et al. (2000) describe two different processes that occur in discovery learning. Firstly, during the *transformative process* the learner is engaged in analysing, generating hypotheses, testing and evaluating. The second process is called the *regulative process* where the learner is engaged in planning, verifying and monitoring (Veermans et al., 2000). However, as pointed out by Veermans et al. (2000) and Reid et al. (2003), research evaluating the differences of the outcomes between simulation-based discovery learning to more traditional methods has revealed minor differences in terms of learning efficiency. De Jong and Van Joolingen (1998) explain that this is due to the many difficulties experienced by learners when engaged in simulation-based discovery learning. The learning difficulties are most often experienced in one or both the aforementioned processes. De Jong and Van Jooligen (1998) list the learning difficulties experienced by learners in simulation-based environments as follows:

- Generating and adapting hypotheses
- Designing experiments
- Interpreting data
- Regulating discovery learning

So although SDL has the ability to enhance learning environments, as evident from the abovementioned learner difficulties, effective learning cannot be assured when using SDL environments (De Jong & Van Joolingen, 1998; Reid et al., 2003). Reid et al. (2003) and Zhang et al. (2004), however, add that effective discovery learning can be adequately promoted if the appropriate support mechanisms are in place.

Zhang et al. (2004) recognise three types of learning support that can be provided to ensure successful SDL. These include the following:

- Interpretative support (IS)
- Experimental support (ES)
- Reflective support (RS)

Interpretative support is intended to assist learners in making the appropriate links between problems and prior knowledge. In this manner meaning is added to the discovery learning process, thereby allowing the learners to generate the hypotheses and construct coherent understandings (De Jong & Van Joolingen, 1998; Reid et al., 2003; Zhang et al., 2004). Experimental support refers to assisting learners in using appropriate scientific methods and procedures when solving a problem. Learners require the know-how in designing experiments in a systematic and logical way while still being able to draw reasonable conclusions (Zhang et al., 2004). Reflective support necessitates "… self-monitoring of the discovery processes and the reflective abstraction and integration of the discovered rules and principles" (Reid et al., 2003:10). This entails support that enables learner self-awareness while engaged in analysing and synthesising information in all aspects of the SDL process.

Van Joolingen (1999:386) concludes that for SDL to flourish learners need firstly to possess the adequate discovery skills. These skills include *hypothesis generation*, *experiment design*, *prediction*, *data analysis, planning* and *monitoring* according to Van jooligen (1999). Van Joolingen (1999) adds that these skills should not be seen as a bi-product of the discovery learning process but as learning outcomes in themselves as these skills are essential in all aspects of learning. A lack of these skills results in ineffective discovery learning methods which in turn lead to the learner being unable to generate new knowledge that contributes to the knowledge or information society (Van Joolingen, 1999).

2.5 Learning competencies

Learners in the 21st century require a variety of skills and a great deal of expertise to succeed in an increasingly demanding and continuously changing school and work environment. These vital skills required for all learners are known by a variety of names that include 21st century skills, 21st century competencies and as Anderson (2008) coined them, lifelong learning competencies. These skills are considered lifelong learning competencies as they transcend the classroom and school environment and can be used in authentic contexts in normal day to day life.

For the purpose of this study these skills will simply be referred to as learning competencies. Several authors (Anderson & Plomp, 2002; Law, Lee & Chow, 2002; the Partnership for 21st Century Skills, 2004; Pelgrum & Voogt, 2009) suggest examples of these learning competencies. Law, Lee and Chow's (2002:416) examples of learning competencies include the ability of the learner to do the following:

- Access and evaluate information
- Communicate effectively
- Collaborate with others
- Solve complex open-ended problems
- Use appropriate technology

In addition to these, Pelgrum and Voogt (2009:294) list the following examples "… digital literacy (such as (Internet) communication skills and information handling skills), and higher order skills such as teamwork, problem-solving and project management". The Partnership for 21st Century Skills (2004) lists the following learning competencies: creativity, critical thinking, collaboration, media and technology and adapting to new environments.

Lastly, Anderson and Plomp (2002) in their list include the following learning competencies: the retrieval and organisation of knowledge, the ability to solve complex problems, and collaboration and communication skills. However varied these learning competencies may be for each author, they are all essential in equipping learners in today's information or knowledge society. This study investigates seven learning competencies as listed and defined in Table 2.6. These learning competencies have been selected as they form part of the learning areas as identified for the SITES 2006 teachers' questionnaire question 20 (See Figure 3.3 in Chapter 3).

Table 2.6: Learning competencies

Learning competency	Definition
Information handling skills	The ability to search, explore, select and analyse data from a variety of sources (Holmes & Gardner, 2006).
Problem-solving skills	The ability to analytically and critically process decisions until a solution is reached (Jonassen, 2006).
Self-directed learning skills	The ability of individual responsibility and initiative to learn at any time and in any place without external motivation (Knowles, 1975).
Collaborative skills	The ability to work in teams or group situations with the aim of accomplishing a common goal (Holmes & Gardner, 2006).
Communication skills	The ability to successfully share meaningful information with others by means of an interchange of experiences (Mac, 2011).
ICT skills	The ability to demonstrate a variety of efficient and effective skills related to information, media and technology (The Partnership for 21st Century Skills, 2004).
Ability to learn at the learner's own pace	The ability of a learner to be self-reliant, work independently and acquire knowledge by his or her own efforts (Hesmondhalgh, 2011).

It is important to note that these skills should not be considered independently but rather simultaneously as the adequate combination and use of these skills has the ability to efficiently direct and control learning experiences (Patterson, Crooks & Lunyk-Child, 2002). Law (2009) points out that for these skills to be effectively fostered, a lifelong learning paradigm should be adopted as opposed to the more traditional paradigm distinguished in the various teacher and learner practices in Table 2.7. This is because learners are more proactive than reactive in these environments, according to Patterson et al. (2002). Patterson et al. (2002) add that learners in this environment will tend to be more motivated which may lead to greater retention of information and better use for longer periods of time. Law (2009) concludes that the learning process therefore has learning outcomes that are vital in solving authentic problems.

Table 2.7: The two pedagogical paradigms

Traditional paradigm	Lifelong learning paradigm
Teacher's practice ○ Presenting information/demonstrations and/or giving class instructions ○ Assessing learners' learning through tests/quizzes ○ Using classroom management to ensure an orderly, attentive classroom	*Teacher's practice* ○ Providing remedial or enrichment instruction to individual learners and/or small groups of learners ○ Providing feedback to individuals and/or small groups of learners ○ Providing counselling to individual learners ○ Helping/advising learners regarding exploratory and inquiry activities ○ Organising, observing or monitoring student-led whole-class discussions, demonstrations, presentations ○ Organising, monitoring and support team-building and collaboration among learners
Learner's practice ○ Listening and completing worksheets, exercises	*Learner's practice* ○ Learning and/or working during lessons at their own pace ○ Giving presentations ○ Determining own content goals for learning ○ Explaining and discussing own ideas with teacher and peers ○ Self- and/or peer evaluation ○ Reflecting on own learning experience review (e.g. writing a learning log) and adjusting own learning strategy

[Source: Bryderup et al. (2009:367)]

The acquisition of these competencies by learners is a top priority for many departments of education, of which the national department in South Africa is no exception. The importance of developing ICT skills that prepare learners with the essential skills to become self-assured members society in the globalised world is becoming more and more prevalent in many education departments (Plomp, Anderson, Law & Quale, 2009; Law, Lee & Chan, 2010). These competencies are deemed essential as they equip learners with the know-how to survive in this ever-changing information or knowledge society. The development of learners' learning competencies, especially while using ICT, has become more vital as it contributes to the innovation and development of the South African society according to the Department of Education (2004). The national policy in the White Paper on e-Education moreover encourages the use of ICT to develop the following areas (DoE, 2004:19):

- "Learner-centred learning;
- active, exploratory, inquiry-based learning;
- collaborative work among learners and teachers; and
- creativity, analytical skills, critical thinking and informed decision-making."

Law et al. (2010) outline the importance of ICT in this regard. Whereas traditionally curricula were focused on *technological literacy,* that is ICT as a subject, recently ICT has been used for either *knowledge deepening* or *knowledge creation*. *Knowledge deepening* implies using ICT to improve the effectiveness of learning whereas *knowledge creation* is the use of "... ICT as an agent of curriculum and pedagogical change to foster learners' development of 21st century skills." (Law et al., 2010). This is a view clearly shared in the White Paper on e-Education (DoE, 2004:19) where it is outlined that the use of ICT in schools is evolving from *learning about ICTs* to *learning with ICTs* and then ultimately from *learning through the use of ICTs*.

2.6 Conceptual framework

An essential assumption of this study is that activities that utilise ICT effectively as an educational tool have the potential to enhance the quality of learning competencies that are essential for learners to succeed in the information or knowledge society. Using the underlying principles of Activity Theory and the conceptual framework of SITES 2006 (see Section 2.7.1 and 2.7.2) this study focuses on the interaction between the teacher, the learner and ICT in a specific Mathematics activity, i.e. the discovery of Mathematics principles and concepts. The conceptual framework of this study focuses on the influences of teacher characteristics on learners' learning competencies when using ICT as an educational tool in the discovery of Mathematics principles and concepts. During the transformation process the postulation is that learners' learning competencies are improved. The conceptual framework is illustrated in Figure 2.4.

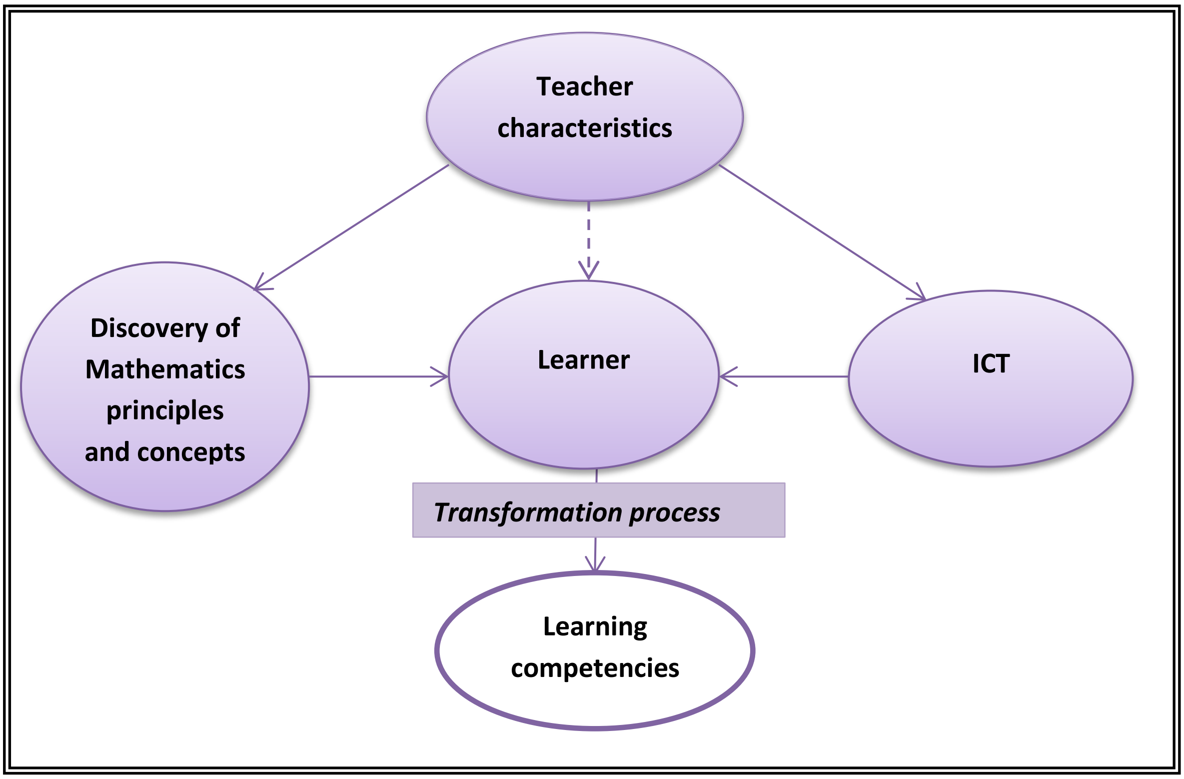

Figure 2.4: Conceptual framework of the study

2.6.1 Theoretical Framework: Activity Theory

As this study uses the underlying principles of Activity Theory, the main features of Activity Theory are briefly outlined in the subsequent sections.

2.6.1.1 Background to Activity Theory

Activity Theory was founded through the work of the Russian psychologist Vygotsky (Kuutti, 1997; Nardi, 1997). Vygotsky uncovered what is now referred to as the triangular model of an activity (see Figure 2.5) after introducing the concept of *mediation* (Bakhurst, 2009). Bakhurst (2009:199) writes that Vygotsky noticed defects in the stimulus-response of *behaviourism* and concluded "... that human behaviour [is] not simply called forth by stimuli, but is [rather] mediated by artifacts that are created to prompt or modulate action".

Activity Theory was then further developed by Vygotsky's student, Leontiev (Uden, 2007; Bakhurst, 2009). Leontiev's work went one step further by establishing hierarchical levels of an activity (Jonassen & Rohrer-Murphy, 1999; Bakhurst, 2009). Leontiev made a clear distinction between what he termed an *action* and an *activity*

(Bakhurst, 2009). Bakhurst (2009:200) points out that Leontiev defined an action as "... conducted by an individual or group to fulfil [a specific] goal [whereas] an activity, in contrast, is undertaken by a community". An activity, according to Uden (2002), "… is undertaken by subjects in a community using tools to achieve an object or an objective as set by that community". The goal of the activity is to transform the object into an outcome (Kuutti, 1997; Jonassen & Rohrer-Murphy, 1999; Uden, 2007).

Engeström elaborated on Leontiev's work by referring to this model as an *activity system* (Jonassen & Rohrer-Murphy, 1999; Bakhurst, 2009). Engeström suggests "... that the dynamics of the system – the forces of its development – result from *contradictions* between its elements" (Bakhurst, 2009:200). Bakhurst (2009:199) makes known that there are three "... generations of activity theory or *cultural-historical activity theory* (CHAT) as it is ..." sometimes referred to (Engeström, 1987:12). The first generation started in the 1920s with Vygotsky; the second was followed with Leontiev's work and in 2009 Activity Theory was in its third generation (Bakhurst, 2009). This study utilises principles of the first generation of Activity Theory as defined by Vygotsky.

2.6.1.2 Components of an activity

The unit of analysis in Activity Theory is the activity (Kuutti, 1997). An activity consists of three main components: the subject, the object and the tool. Table 2.8 lists the components of an activity and their function.

Table 2.8: Components of an activity

Component	Function
Subject	The subject is the person or persons involved in the activity (Jonassen & Rohrer-Murphy, 1999).
Object	The object can be a material or immaterial item that is manipulated and transformed during the activity to obtain a specific outcome (Kuutti, 1997:28).
Tool	Tools are "... anything used in the transformation process, physical, such as hammers or computers or mental, such as models or heuristics" (Jonassen & Rohrer-Murphy, 1999:62).

A learner is an example of a subject in a given activity. The subject, in this case the learner, acts on the object; this action transforms the object, and the object is then converted to the outcome of the activity (Jonassen & Rohrer-Murphy, 1999). Kuutti (1997) adds that the subjects do not only transform the object but also share in the manipulation of it. The manipulation of the object refers to the ability of the subject to alter the object in some way (Kuutti, 1997). Examples of objects, according to Jonassen and Rohrer-Murphy, (1999:63) include "... physical objects (e.g. a house that is built), soft objects (e.g. a computer program) or conceptual objects (e.g. a theory or model)".

Tools, also referred to as artifacts, "... can be anything used in the transformation process" (Jonassen & Rohrer-Murphy, 1999). Artifacts are utilised during an activity and enhance the mental process through interaction with the subject and the object (Bakhurst, 2009). The transformation process is the conversion of the object into an outcome (Uden, 2007). Examples of tools include signs, instruments, computers and design models (Jonassen & Rohrer-Murphy, 1999). An essential supposition of Activity Theory is that the tools are mediators of human activity (Jonassen & Rohrer-Murphy, 1999). The relationship between the subject and the object of an activity is always mediated by tools. Figure 2.5 illustrates the relationship between the three components of an activity.

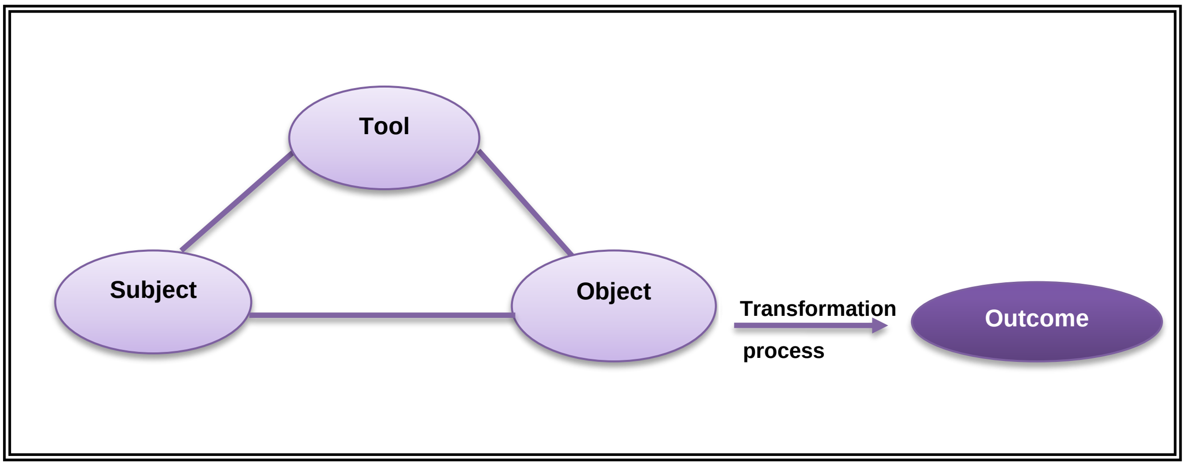

Figure 2.5: Relationships between the three components of an activity
[Source: Kuutti (1997:28)]

2.6.2 Conceptual Framework of SITES 2006

The conceptual framework of this study as illustrated in Figure 2.4 additionally uses principles from the conceptual framework of SITES 2006. Therefore the SITES 2006 conceptual study is briefly highlighted in this section.

The main aim of SITES 2006 was to determine the role of ICT as an educational tool in Science and Mathematics classrooms in the participating education systems (SITES 2006, 2008). As with the subsequent studies SITES Module 1 (SITES-M1) and SITES Module 2 (SITES-M2), the conceptual framework adopted for "…SITES 2006 takes the view that ICT-using pedagogical practices are part of the overall pedagogical practices of the teacher" (Carstens & Pelgrum, 2009:11). However, as the SITES 2006 conceptual framework clearly illustrates in Figure 2.6, there are several factors that affect overall pedagogical practices. In the bigger scheme of the school environment pedagogical practices are affected by school and system factors.

However, additional to this, teacher characteristics such as academic qualifications, teaching experience, gender, etc. play a vital role in pedagogical practices. Another aspect to consider is the learner or student characteristics. The learner's age, prior knowledge and level affect which pedagogical practices the teacher adopts. An additional factor to consider is the learning outcomes as the teachers' pedagogical practices are altered to accommodate the learner and the learning outcomes (Carstens & Pelgrum, 2009).

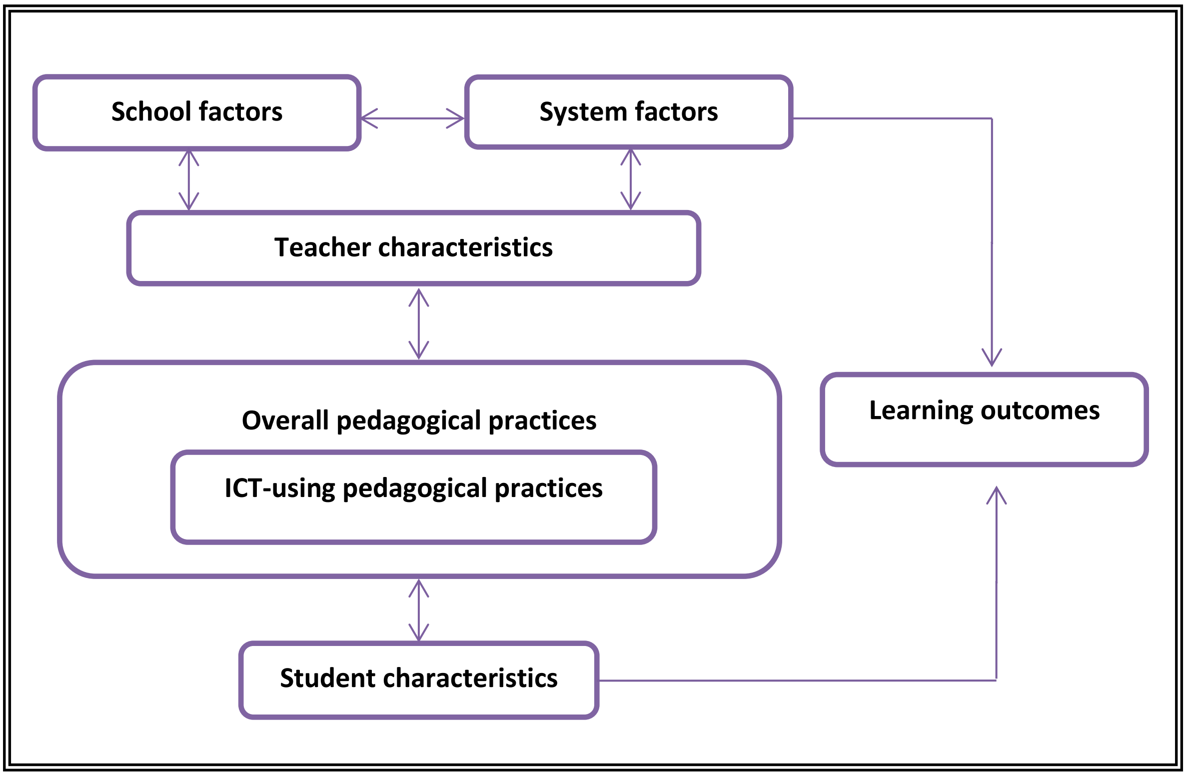

Figure 2.6: Overall Conceptual Framework for SITES 2006
[Source: Carstens & Pelgum, (2009:13)]

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the various research methods selected to address the research questions. It begins by outlining the philosophical foundations of the study to embed the study in well-established research methodology theories. These theories are described with a view to identifying the researcher's interpretation and subsequent implementation of these theories. The research design selected for the study is then defined with the subsequent sub-sections explaining the reasoning for selecting the design. The major aspects detailed as part of the design include secondary data analysis, data types, instruments used for the study, an outline of the original study's data collection procedure, sampling and sub-sampling, data access, statistical tests, validity, reliability and ethical considerations.

3.2 Philosophical foundations

A researcher's world view encompasses three categories of assumption:

- Ontological assumptions
- Epistemological assumptions
- Methodological assumptions

These philosophical assumptions are briefly discussed in the subsequent sections, thereby exposing the lens which the researcher utilised to analyse the data.

3.2.1 Ontology

Pearsall and Trumble (2006:1016) define ontology as the study of the "… nature of *being, existence* or *reality*". Bryman and Teevan (2005:12) add that social ontology is "… concerned with whether social entities can and should be considered objective entities with a reality external to specific social actors or whether they can and should be considered temporary social contractions built up from perceptions and actions of these actors". Taylor (2010) believes that both the natural world and the social world consist of *external realities* that have the ability to affect people's actions in various ways.

There are two opposing schools of ontology. The first school of ontological thought expresses the possibility of acquiring knowledge in an objective manner (Poetschke, 2003). This ontological viewpoint affirms the importance of imitating natural sciences and is known as *positivism*. The second school of thought opposes objectivity and affirms that "… observation is never objective but always affected by the social constructions of reality" (Poetschke, 2003:3). This position rejects positivism and refutes equating natural science methods with social science (Bryman & Teevan, 2005). This school of thought is known as *interpretivism*. Taylor (2010) argues that just as epistemology has opposing views of *rationalism* and *empiricism*, ontology has *positivism* and *interpretivism*.

This study adopts the first school of ontological thought, namely positivism. The subsequent sections detail the positivistic approach and by so doing outline the approach undertaken in the analysis of the study's data.

3.2.1.1 Positivism

The term *positivism* denotes a view that has dominated the natural and social sciences for the past 400 years (Guba & Lincoln, 1994). Positivism emerged as a philosophical paradigm in the 19th century with Auguste Comte who suggested that the most advanced form of thinking is the scientific form (Thomas, 2009). According to Poetschke (2003) positivism was developed from "... the empiricist tradition of natural science". *Empiricism* is the term given to the idea that knowledge comes from experience (Thomas, 2009). According to positivists, science is seen as the way to get at the truth, to understand the world in order to predict and control it (Trochim, 2006). Positivists therefore believe that observation and measurement is the core of scientific endeavour (Trochim, 2006).

Guba and Lincoln (1994) write that positivism focuses on efforts to "... verify or falsify *a priori* hypotheses stated as mathematical quantitative propositions". Guba and Lincoln (1994) maintain that these propositions are easily quantifiable and used to express cause and effect relationships. These are commonly found in the natural science field where the belief is that scientific endeavour is objective and value free

(Darlaston-Jones, 2007). Positivism strictly adheres to the scientific method as this method is designated as being universal; there is only one way of understanding phenomena (Scott, 2000). Positivism therefore advocates the following:

- Hypothesis testing
- Generalisation
- Objectivity
- Being value free
- Prediction and control

The testing of hypotheses implies that positivism does not seek to generate hypotheses but rather establishes the hypotheses before the research begins in order to investigate and prove the theory through tests and experiments (Cupchik, 2001). In generalisation findings can be applied to similar situations and settings in the broader population (Poetschke, 2003). Scott (2000) states that "... this model therefore makes law-like statements about the world and their methods therefore allow for replicability". Objectivity is deemed possible with positivists as they use quantitative methods as research tools, for these are objective and the results can then be generalised (Poetschke, 2003). This type of research ultimately seeks causal relationships and focuses on prediction and control (Poetschke, 2003). Kaboub (2008) points out that the criterion for evaluating the validity of a scientific theory is whether "... knowledge claims are verifiable", that is that the "... theory-based predictions are consistent with the information that can be obtained using the senses" (Kaboub, 2008:88).

However, it is important to place ontological assumptions into perspective. Bryman and Teevan (2005:9) write that determining a researcher's ontological stance is "… primarily [used] by methodologists and social theorists to try to describe and evaluate the theoretical assumptions underlying different approaches to research". Taylor, (2010:80) however, cautions that "… many studies in social science use a combination of positivist and interpretivist ideas, just as they use different research methods". It therefore follows that a researcher is neither strictly positivistic nor strictly interpretivistic but rather falls in a continuum of the two ontological assumptions depending on the purpose of the research.

This study, following the positivistic approach, takes the stance of objective and generalisable results. It is hoped that the results of the study can be replicated in similar studies.

3.2.2 Epistemology

The investigation into the theory and study of knowledge is called *epistemology* (Guba, 1990; Guba & Lincoln, 1994). Guba (1990:18) proposes that epistemology attempts to answer the question:

- *What is the nature of the relationship between the knower and the known*?

This is further elaborated by Guba and Lincoln (1994:108) when they add that epistemology attempts to answer the additional questions:

- … *what can be known*?
- *How can we come to accept that a research finding is true?*

Epistemology therefore attempts to answer these questions and in so doing exposes researchers' assumptions in the research approach with regard to the type of knowledge acquired. Bryman and Teevan (2005) write that determining one's epistemological perspective assists in providing ways to gather knowledge and the type of knowledge gained. Guba (1990) adds that similarly epistemology is concerned with determining what counts as valid knowledge. Bailie (2007:94) describes two opposing epistemological positions*, rationalism* or *idealism,* which appeals "… to rational and formal reasoning …" and e*mpiricism* which appeals "… to sensory perceptions". Bailie (2007:94) continues that "rationalists argued that reality could be reasoned logically by working from established concepts [whereas] in contrast, empiricists dispute the idea that *a priori* knowledge exists before sensory experience".

This is a secondary data analysis study and by implication does not follow the empiricist school of epistemology but rather the rationalist school of thought. Rationalism is described in detail.

3.2.2.1 Rationalism

Rationalism can be defined as "... attempts to show that a conclusion follows a set of premises or hypotheses" (Black, Brookes, Groves, Holmes, Hucker, McKeon & Summers, 2009:501). Rationalists therefore rely on logic and reason to make sense of the world. Meyers (2006), Bailie (2007) and Willis (2007) all make reference to *a priori* knowledge. *A priori* knowledge as Runes (1972:16) explains is "… a term applied to all judgements and principles whose validity is independent of all impressions of sense, [that is], whatever is pure *a priori* is unmixed with anything empirical". Rationalists believe that the notion of *a priori* presents an opportunity to construct logic and reason from an existing base line (Runes, 1972; Schwandt, 2007). Meyers (2006) and Black et al. (2009) reiterate the supposition of rationalists' aversion to reasoning with experience. Thus rationalists oppose empiricism. Rationalism can therefore be summarised using three distinct legs as depicted in Figure 3.1.

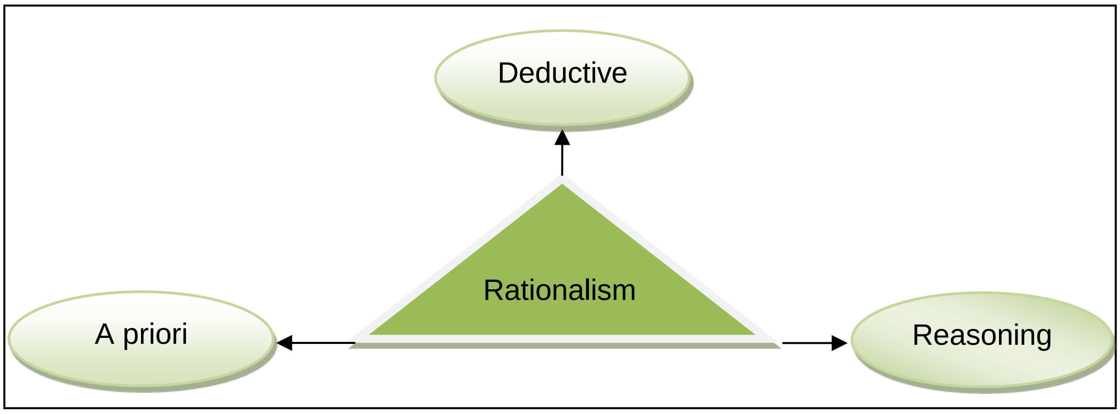

Figure 3.1: The three legs of rationalism

There are two main schools of rationalism: *moderate rationalism* and *radical rationalism* (Schwandt, 2007). Schwandt (2007:253) describes *moderate rationalism* as "... a belief in the value of critical discussion and valid argumentation". Moderate rationalists follow a more diluted approach to *rationalism* by taking into consideration contextual aspects of a situation or problem (Schwandt, 2007).

Schwandt (2007:253) describes *radical rationalism* as being more extreme in relation to *moderate rationalism* and "... equates [*radical rationalism*] with faith in the ability to reason unaided by perception, experiment or action". It is the radical rationalists that believe that intellect is *a priori* that assists in giving meaning to sense making (Schwandt, 2007). Willis (2007:36) concludes that "... rationalism supports the proposition that there are innate ideas humans already have in their minds when they are born ..."; therefore human beings build on these through *deductive reasoning* processes to ultimately solve problems.

3.2.3 Methodology/Methods

Creswell (1998:219) defines methodology as "the systematic study of methods that are, can be, or have been applied within a specific discipline". Methodology, unlike *methods,* which Pearsall and Trumble (2006:1089) define as having systematic details to a given procedure or process, does not describe specific techniques but rather refers to the rationale and/or the philosophical assumptions that underlie a particular study (Merriam, 2009). The terms *methodology* and *methods* are often used as synonyms. Table 3.2 summarises definitions of methods as defined by various authors (Guba, 1990; Guba & Lincoln, 1994; Payne & Payne, 2004; Caelli, Ray & Mill, 2008).

Table 3.1: Definitions of methods

Author	Definition
Guba	Methods attempt to answer the following question: "How should the inquirer go about finding out knowledge?" (1990:18).
Guba and Lincoln	Methods attempts to answer the question: "How can the inquirer (would-be knower) go about finding out whatever he or she believes can be known?" (1994:107).
Payne and Payne	"[Methods] refer to the principles and ideas on which researchers base their procedures and strategies" (2004:176).
Caelli, Ray and Mill	"[Methods] also represent theoretical frameworks that guide how the research should proceed and imply a concern for constructing a particular type of knowledge" (2008:6).

Methods, according to Guba (1990) and Guba and Lincoln, (1994) emphasise the knowledge-gathering process of research and furthermore how the *inquirer* goes about gathering this knowledge. Caelli et al. (2008) view methods as a *theoretical framework* that acts as a guide for the researcher whereas Payne and Payne (2004) view methods as sets of principles and ideas that assist researchers in the research process. The definitions summarised in Table 3.1 all characterise research methods as being an integral aspect of the research process that direct researchers regarding the type of data that will be collected in addition to how it will be collected. As this is a secondary data analysis study the methodological assumptions taken are those of the original study and the type of data collected. The type of data collected for SITES 2006 was categorical (as further defined in Section 3.3.2); hence the research design selected as detailed in the subsequent sections.

3.3 Research design

This secondary data analysis study explores data as collected for the Second Information Technology in Education Study 2006 (SITES 2006) by the International Association for the Evaluation of Educational Achievement (IEA) (SITES 2006, 2008). This study follows an integrated qualitative-quantitative research design (Srnka & Koeszegi, 2007). It entails transforming the qualitative data collected by IEA for SITES 2006 into numerical data that is then analysed, using quantitative analysis methods (Srnka & Koeszegi, 2007). Marying (2001) explains that this research design enables researchers to generalise qualitative data and make inferences from the results. The subsequent sections explain what is entailed in this research design.

3.3.1 Secondary data analysis

Devine (2007:285) defines secondary data analysis as "… the analysis of an existing dataset that had previously been collected by another researcher, usually for a different research question [and purpose]". Corti (2008) writes that secondary data offers researchers the ability to revisit previously collected data with new insights without the pressure of collecting similarly collected data. Devine (2007) points out the following four advantages of using secondary data as opposed to primary data:

- Savings on research costs
- Increased data quality
- Larger sample size
- Intellectual advancement

McGinn (2008) writes that primary data can be costly to collect due to the resources required, especially when there is a large sample size. By using pre-existing data the researcher would save on these costs with the advantage of avoiding duplicating research efforts and investments, according to McGinn (2008). Increased data quality implies that the researcher is exposed to a multitude of rich pre-existing archived material that includes "… large scale databases and data depositories, ready access to censuses, national and international educational assessments and other numeric data on a multitude of topics (McGin, 2008:803). It therefore proposes larger sample size availability to the researcher as all this data would be readily obtainable for the researcher to use. Intellectual advancement entails the enrichment of the researchers' research capabilities in terms of analysing data, with less pressure and consequently ease in collecting the required data.

However, Devine (2007) highlights four shortcomings of using secondary data. Secondary data use is influenced by the following:

- Understanding the dataset
- Different purposes of data collection
- Sample issues
- Data quality

Devine (2007) points out that before attempting to use the data the researcher should have an understanding of the nature and type of data available. This may also require an understanding of the background, the purpose and the statistical tests applied for the original use of the data. McGinn (2008:804) defines secondary data as "… pre-existing data that [was] collected for a different purpose or by someone other than the researcher". This implies that the secondary data is most likely not be a perfect fit for the researcher as the data was collected for a different purpose altogether. Since the researcher is confined to using this pre-existing data only, the researcher is unable to include a sample that is not in the secondary data in order to answer the research question/s. Secondary data therefore confines the researcher to the available dataset only. The quality of the data may be compromised depending on the source. Reliable and well known sources are thus essential in determining the usability and validity of the secondary data.

3.3.2 Data types

There are two types of statistical data: *numerical* and *categorical* data (Willemse, 2009; Salkind, 2011). Numerical data is commonly affiliated to the quantitative theory of methods because the type of data used is described as being *continuous da*ta (Few, 2005). Willemse (2009:6) describes continuous data as data "… that has an infinite number of possible values". Continuous data can be categorised further into two groups, namely *interval data* and *ratio data* (Few, 2005; Willemse, 2009). Willemse (2009) describes interval data as "data which does not have an absolute zero"; Few (2005) adds that there is a meaningful value between any two values in interval data. The second category for continuous data is ratio data. Willemse (2009:8) describes ratio data as consisting of a true zero. Few (2005) adds that the value zero would denote an absence of that variable for ratio data.

Categorical data is associated with the qualitative theory of methods because this data is described as being discrete in nature (Few, 2005). Willemse (2009) defines discrete data as data with a finite number of possibilities. Few (2005) adds that discrete data has specific values that represent a limited number of variables. Discrete data is further divided into *nominal data*, "... where data is nam[ed], label[led] or categoris[ed] in no specific order" and *ordinal data* "... where objects are ranked in some order" (Willemse, 2009:7). This is the type of data collected by SITES 2006 for the IEA.

Maree (2008) and Salkind (2011) describe two groups of statistical tests where the different data types can be classified as *parametric tests* and *non-parametric tests*. Wagner (1991), Maree (2008) and Salkind (2011) state that parametric tests are undertaken in a study when the following conditions are met:

- Numerical data
- A large data set

- Normal distribution
- Homogeneous variance

Salkind (2011:285) explains that parametric tests are undertaken when the type of data collected is numerical, "... the sample is large enough to represent the population ..."; the characteristics of the data is known, i.e. normal distribution and "... the variances of each group [under study are] ... similar". Wagner (1991) emphasises that there are instances when normal distribution cannot be assumed. This refers to a distribution that may be skewed in addition to a small data set and the use of categorical data. In this case a parametric statistical test would not suffice, thus a non-parametric tests would be undertaken instead. The following conditions are thus necessary to conduct a non-parametric test:

- Categorical data
- Small data set
- Any type of distribution

Due to the nature of the sample of this study, non-parametric tests are computed to assess the data.

3.3.3 Instruments

The following four questionnaires were developed and implemented for SITES 2006:

- The national context questionnaire
- The principal questionnaire
- The teacher questionnaire
- The technical coordinator questionnaire

For the purpose of this study results as collected from the SITES 2006 teacher questionnaire, question 9 J (see Figure 3.2), question 20 C, 20 D, 20 E, 20 F, 20 G, 20 H, 20 I (see Figure 3.3) and question 29, 30, 31, 32,33, 34 and 36 (see Figure 3.4) are examined. Question 9 was used to draw the sample as only the Mathematics teachers who indicated *yes* to using ICT in the discovery of Mathematics principles and concepts (as circled in Figure 3.2) are considered.

9. In your teaching of the target class in this school year,
(a) How often is the scheduled learning time of the class used for the following activities?
(b) Has ICT been used when these activities took place?
Please mark only one choice for each of the two parts in each row.

		(a) How often is the scheduled learning time used for the following activities?				(b) ICT used?	
		1 Never	2 Sometimes	3 Often	4 Nearly always	1 No	2 Yes
A	Extended projects (2 weeks or longer) BTG09A1/BTG09A2	☐	☐	☐	☐	☐	☐
B	Short-task projects BTG09B1/BTG09B2	☐	☐	☐	☐	☐	☐
C	Product creation (e.g., making a model or a report) BTG09C1/BTG09C2	☐	☐	☐	☐	☐	☐
D	Self-accessed courses and/or learning activities BTG09D1/BTG09D2	☐	☐	☐	☐	☐	☐
E	Scientific investigations (open-ended) BTG09E1/ BTG09E2	☐	☐	☐	☐	☐	☐
F	Field study activities BTG09F1/BTG 09F2	☐	☐	☐	☐	☐	☐
G	Teacher's lectures BTG09G1/BTG09G2	☐	☐	☐	☐	☐	☐
H	Exercises to practice skills and procedures BTG09H1/ BTG09H2	☐	☐	☐	☐	☐	☐
I	Laboratory experiments with clear instructions and well-defined outcomes BTG09I1/BTG09I2	☐	☐	☐	☐	☐	☐
J	Discovering mathematics principles and concepts BTG09J1/BTG 09J2	☐	☐	☐	☐	☐	☐
K	Studying natural phenomena through simulations BTG09K1/BTG09K2	☐	☐	☐	☐	☐	☐
L	Looking up ideas and information BTG09L1/BTG 09L2	☐	☐	☐	☐	☐	☐
M	Processing and analyzing data BTG09M1/BTG 09M2	☐	☐	☐	☐	☐	☐

Figure 3.2: Discovering Mathematics principles and concepts questionnaire
[Source: Brese and Carstens (2009:112)]

In question 20 (Figure 3.3) seven (7) of fifteen (15) learning areas as indicated were selected as these represent the learning competencies as defined in Section 2.5.

20. To what extent has the use of ICT impacted your students in the target class in the following areas?
Please mark only one choice in each row.

		1 Decreased a lot	2 Decreased a little	3 No impact	4 Increased a little	5 Increased a lot
A	Subject matter knowledge BTG20A1 Dependent					
B	Learning motivation BTG20B1 Dependent					
C	Information-handling skills BTG20C1 Dependent					
D	Problem-solving skills BTG20D1 Dependent					
E	Self-directed learning skills BTG20E1 Dependent					
F	Collaborative skills BTG20F1 Dependent					
G	Communication skills BTG20G1 Dependent					
H	ICT skills BTG20H1 Dependent					
I	Ability to learn at their own pace BTG20I1 Dependent					
J	Self esteem BTG20J1 Dependent					
K	Achievement gap among students BTG20K1 Dependent					
L	Time spent on learning BTG20L1 Dependent					
M	School attendance BTG20M1 Dependent					
N	Assessment results BTG20N1 Dependent					
O	Digital divide (i.e., inequity between students from different socioeconomic backgrounds) BTG20O1 Dependent					

Figure 3.3: Learning competencies questionnaire
[Source: Brese and Carstens (2009:119)]

The last questions to be considered in this study are those related to teacher characteristics and background. Results as collected from questions 29, 30, 31, 32, 33, 34 and 36 are computed in this study as indicated in Figure 3.4. Question 35 was not considered as South Africa does not have a teacher licensing of certification system as is the case in other countries.

29. Do you have access to a computer at home?
BTG29A1 Filter
1 ☐ No → Please go to question 31.
2 ☐ Yes → Please continue.

30. Do you use this computer for the following activities?
Please mark only one choice in each row.

		1 No	2 Yes
A	Teaching related activities BTG30A1 Dependent	☐	☐
B	Connecting to the internet BTG30B1 Dependent	☐	☐

31. To what age group do you belong?
BTG31A1

1	2	3	4	5	6
Below 25	25–29	30–39	40–49	50–59	60 or above
☐	☐	☐	☐	☐	☐

32. What is your gender?
BTG32A1

1	2
Male	Female
☐	☐

33. What is your highest level of education?
BTG33A1
Please mark only one choice.

1	2	3	4
Secondary or high school	Post-secondary education (e.g., teachers college)	Bachelor's degree	Master's degree or above
☐	☐	☐	☐

34. Do you have a Bachelor's degree in Science or Mathematics?
BTG34A1
Please mark only one choice.

1	2	3	4
No	Degree in Mathematics only	Degree in Science Science only	Degree in both Mathematics and Science
☐	☐	☐	☐

35. Do you have a teaching license or certificate?
BTG35A1

1	2
No	Yes
☐	☐

36. How many years of experience do you have in teaching Mathematics or Science?
BTG36A1

1	2	3	4	5
Less than 2 years	2–4 years	5– 9 years	10–19 years	20 years or more
☐	☐	☐	☐	☐

Figure 3.4: Teacher characteristics questionnaire
[Source: Brese and Carstens (2009:124-125)]

3.3.4 South African SITES 2006 sample

The SITES 2006 population considered schools offering education to Grade 8 learners and the Mathematics and Science teachers teaching this target grade (SITES 2006, 2008). A total of 445 schools were sampled in South Africa, using stratified probability sampling (Carstens & Pelgrum, 2009). To ensure equal probability of the number of teachers sampled from each school "… the SITES 2006 research team implemented a sample design that involved … stratifying the school sample frame according to the school size" (Carstens & Pelgrum, 2009:50). Therefore between two and four Mathematics teachers and between two and four Science teachers were sampled in each school, depending on the school size (Carstens & Pelgrum, 2009). Additionally the level of ICT use of each school was taken into consideration, i.e. high, low and no use of ICT (Carstens & Pelgrum, 2009). A total of 666 Mathematics teachers were sampled for the study (Howie & Blignaut, 2009).

3.3.4.1 Sub-sample

The sub-sample of this study was drawn using question 9 JB (Figure 3.2). For the purpose of this study only the Mathematics teachers who indicated *yes* to using ICT in the discovery of Mathematics principles and concepts were sampled. A subset consisting of these teachers only was drawn from the original data set.

3.3.5 South African SITES 2006 data collection methods

Data collection for the South African leg of the study commenced in the year 2006, employing a survey method (Blignaut, Els & Howie, 2010:563). Two types of data collection methods were employed for SITES 2006, namely the paper-and-pencil method and the online data collection (ODC) method (Blignaut et al., 2010a). The majority of education systems opted for the ODC method; South Africa, however, was the only country to follow the paper-and-pencil method of data collection (Blignaut et al., 2010a). The software package WINDEM was used to capture data followed by the cleaning, processing and weighting of the data (Blignaut et al., 2010a). The International Research Centres (IRCs) analysed the data of the 22 participating countries and had compiled an initial draft report by April 2007. The IRCs released the final international SITES 2006 report in 2008 (Blignaut et al., 2010a). A subset of this data was extracted to include only the teachers that indicated using ICT as an educational tool in the discovery of Mathematics principles and concepts.

3.3.6 Data access

The South African SITES 2006 data set was retrieved from the IEA study data repository in SPSS format. The data repository options include which study to select, the year of the study, the type of file, the country and the type of format of which the data can be retrieved. It was through this process that the South African SITES 2006 data set in SPSS format was accessed for use in this study.

The applicability of the data for the purpose of the study was determined by conducting a preliminary data analysis for one of the learning competencies. This entailed piloting the statistical tests that would be conducted for the actual study on one research question. The results were then analysed to ascertain their plausibility in answering the research question. It was determined through this preliminary data analysis that the data was indeed applicable for the study.

3.3.7 Statistical tests

The bivariate Spearman correlation coefficient (r_s) is the statistical method selected for this study to test the data inferentially. The Spearman correlation coefficient (r_s) is a non-parametric test that is used to calculate the strength of a relationship between two or more variables (Motulsky, 2005; Maree, 2008). The Spearman correlation coefficient is used to answer the following questions, according to Altman (1991):

- Is there a relationship between variables?
- How strong is the relationship?
- What is the direction of the relationship?

Correlation coefficients range from -1.00 to +1.00 and indicate the strength and direction of a relationship (Altman, 1991). A positive sign indicates a positive relationship and negative sign indicates a negative one (Altman, 1991; Gay & Airasian, 2003). Table 3.2 illustrates the inference of each value of a correlation coefficient (Gay & Airasian, 2003).

Table 3.2: Interpretation of Spearman's correlation coefficient

r_s	Meaning
< $^{+}/_{-}$ 0.449	Low
$^{+}/_{-}$0.450 – $^{+}/_{-}$0.649	Medium
$^{+}/_{-}$ 0.650 >	High

The study adopted a Spearman correlation coefficient (r_S), with the p-value or significance value of either 0.01 or 0.05. The p-value determines the chance or probability that random sampling would result in a correlation coefficient with a value ranging from zero to one (Motulsky, 2005; Maree, 2008). If the p-value is small enough, that is closer to zero, the researcher can conclude that the difference between sample means is unlikely to be due to chance (Motulsky, 2005). If the researcher defines statistically significant to mean $p<0.05$ or $p<0.01$, then this implies that there is a 5% or 1% chance of no difference in the results (Motulsky, 2005). Table 3.3 indicates the significance of each p-value (Motulsky, 2005:18).

Table 3.3: Interpretation of p-value

p-value	Meaning	Summary
< 0.001	Extremely significant	***
0.001 to 0.01	Very significant	**
0.01 to 0.05	Significant	*
>0.05	Not significant	ns

3.3.8 Validity and Reliability

Cohen, Manion and Morrison (2007) write that in order to confirm the quality of the data and improve the generalisability of the results collected in research, validity and reliability must be achieved. Merriam (2009) reiterates the importance of making reference to validity and reliability for any given research in order to ensure trustworthiness in the researcher and more importantly, in the research. A brief definition of validity and reliability is given with the ways in which they were realised in this study highlighted in this section.

3.3.8.1 Validity

Validity according to Merriam (2009) is concerned with whether an instrument measures what it is supposed to measure. There are two constructs of validity: internal and external validity (Merriam, 2009). SITES 2006 ensured internal validity during the process of designing instruments (Martin, Rust & Adams, 1999). Martins et al. (1999) explain that validity was ensured by conducting small-scale field tests which assisted in refining and wording the questions during the development of the questionnaire. Furthermore, Martin et al. (1999) continue that field testing was reviewed by content experts, test development experts, editorial specialists and proof readers to check the performance of questionnaire items. Shenton (2004) adds that one of the key criteria addressed by positivist researchers is that of internal validity, that is, seeking to ensure that their study measures or tests what is actually intended.

Merriam (2009:197) suggests that external validity "… is concerned with the extent to which the findings of one study can be applied to other situations". Sinkovics, Penz and Ghauri (2008) refer to this as the transferability of the research methodology. Shenton (2004) suggests two ways in which researchers can achieve transferability. Firstly, by adopting well established research methods and secondly by examining previous research findings (Shenton, 2004). The former was achieved in this study with the attempt at using well-documented research methods that provide the study with a blueprint on how to conduct the research. The latter was achieved through a thorough critique and assessment of literature (see Chapter 2) on previous project's results and findings. This exercise was vital in ensuring comparability of research methods and the findings of this study with those reported previously.

3.3.8.2 Reliability

Reliability is the measure for the consistency of instruments (Cohen, Manion & Morrison, 2007). Reliability therefore involves ensuring two major aspects: dependability and confirmability (Shenton, 2004). Dependability refers to "… [whether], if the work were repeated, in the same context, with the same methods and with the same participants, similar results would be obtained" (Shenton, 2004:71). In order to address dependability Shenton (2004) suggests a detailed account of the study that would enable future researchers to replicate the research.

Confirmability relates to the ability of the instruments utilised in the study deriving objective results (Shenton, 2004). Both these facets were attained in this study by what Shenton (2004) refers to as the *data-oriented* approach. This entails allowing the data to lead the study to the eventual discussion of the findings as well as the development of recommendations of the research as is described in detail in Chapter 4 (Shenton, 2004).

3.3.9 Ethical considerations

As with all studies undertaken by IEA, SITES 2006 follows the international code of ethics as well as the national code of ethics as stipulated by each participating institution and/or country (Brese & Carstens, 2009). Therefore the South African leg of the study had to comply with the National Research Coordinator's (NRC) code of ethics in South Africa. Permission was therefore obtained from each provincial department of education (PDOE) to conduct the study in each respective school (Blignaut et al., 2010a).

For the purpose of this study the research ethics requirements of the University of Pretoria were adhered to. This process included obtaining permission from the ethics committee of the institution in addition to getting approval from the National Research Coordinator of SITES 2006 for South Africa. This was to ensure that the researcher used the data in a responsible, moral and professional manner following the guidelines as stipulated by the University of Pretoria. As this study is a secondary data analysis study, full anonymity and confidentiality were adhered to as no names of schools and/or teachers were disclosed in any aspect of the study. The original data is referred to in the study but only the findings of this study are outlined and discussed at length in this document; no additional ethical concerns arose in the course of the research.

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.1 Introduction

This chapter describes the data analysis procedure undertaken for this study. The data drawn from the South African SITES 2006 was analysed closely, using both descriptive and inferential statistics as is explicitly described in this chapter. The first section describes the descriptive analysis and specifically details the sub-sample teachers' characteristics using frequencies as percentages. The second section highlights the inferential statistics undertaken in the study. The inferential analysis was conducted by calculating the correlation coefficient using Spearman's correlation analysis. A summary of the findings concludes the chapter.

4.2 Descriptive analysis

Pedagogical practices are influenced by a variety of factors, one of which is the teacher's characteristics and background. This study focuses on the possible influences of teacher characteristics and background on a learner and ultimately on the learner's learning competencies as depicted in the conceptual framework. This section presents information about the characteristics and background of the teachers sampled for this investigation. An overall view of the teachers' characteristics and background is highlighted in this section using descriptive analysis. The descriptive analysis is presented in the form of frequencies as percentages, pie charts and bar graphs. The following teacher characteristics are analysed and described in this section:

- Gender
- Age group
- Highest level of education
- Degree obtained
- Years of teaching experience
- Access to a computer at home
- The uses of the computer at home

The sub-sample for this study consisted of a total of 82 Mathematics teachers. These were Mathematics teachers that indicated using ICT in the discovery of Mathematics principles and concepts. However, in most cases there was missing data. The descriptive analysis that follows excludes the missing data. However, Table 4.1 shows the total number of Mathematics teachers who responded to each respective teacher characteristic as well as the missing data. Data was regarded missing for the following reasons (Carstens & Pelgrum, 2009):

- If the respondent chose not to respond to a question it was regarded as *omitted.*
- If the respondent did not have time to reach the question in the instrument it was regarded as *not reached.*
- If the previous filter question was answered in a way that made a response to dependent questions logically impossible it was regarded as *logically not applicable.*

Table 4.1: **Missing data**

	Number of respondents	**Total missing**	**Missing data type**
Gender distribution	78	4	1 *not reached* 3 *omitted*
Age group distribution	78	4	1 *not reached* 3 *omitted*
Highest level of education	79	3	1 *not reached* 2 *omitted*
Bachelor degree obtained	80	2	2 *omitted*
Years of teaching experience	81	1	1 *not reached*
Access to a computer at home	63	19	11 *not reached* 8 *omitted*
Teaching-related activities	48	34	1 *not applicable* 9 *omitted* 24 *logically not applicable*
Connecting to the Internet	48	34	9 *omitted* 1 *not applicable* 24 *logically not applicable*

4.2.1 Gender distribution

Figure 4.1 illustrates the gender distribution of the sub-sample teachers who indicated using ICT as an educational tool in the discovery of Mathematics principles and concepts. Figure 4.1 shows that 55% of the sample consisted of male teachers and 45% of female teachers. When the gender distribution of the sub-sample is compared to that of the South African SITES 2006 sample (see Figure 4.2) it can be seen that the latter consisted of more female teachers (52%) than male teachers (48%).

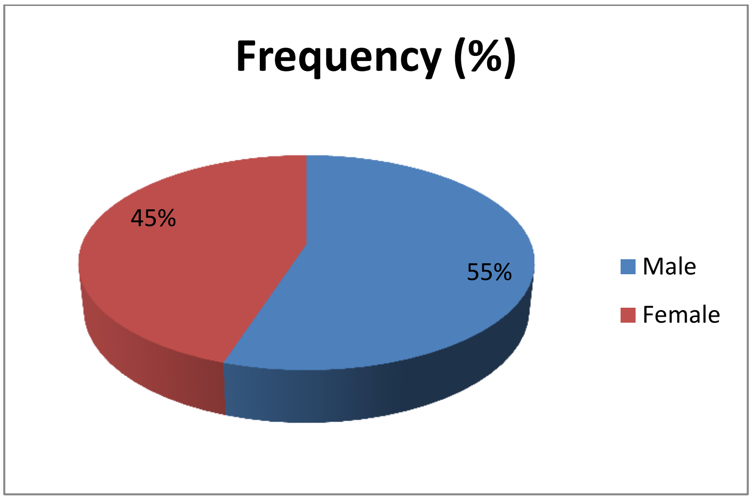

Figure 4.1: Gender distribution of the sub-sample

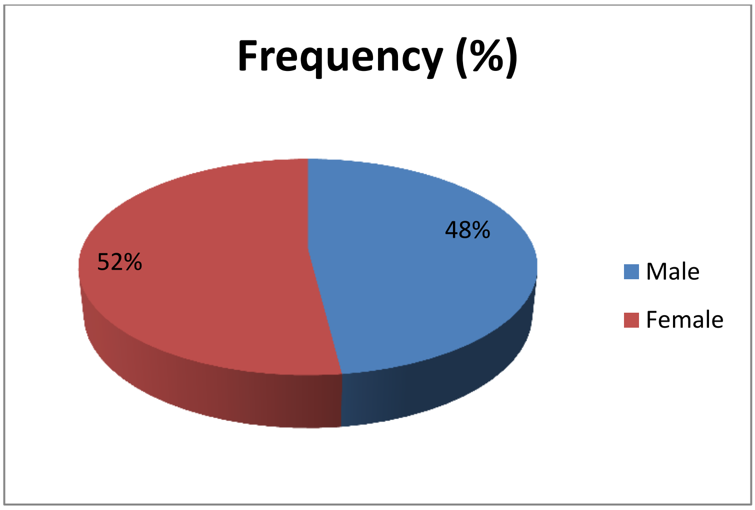

Figure 4.2: Gender distribution of the SITES 2006 sample

4.2.2 Age group distribution

The age group distribution of the sub-sample teachers is illustrated in Figure 4.3. It is evident that the age of the majority of teachers ranged from 30 to 39 years (40%) and the ages of 40 to 49 (37%). Very few teachers (12%) were in the age group 25 to 29 and the age group 50 to 59 (10%). A negligible 1% of the teachers fell in the age group below 25 years.

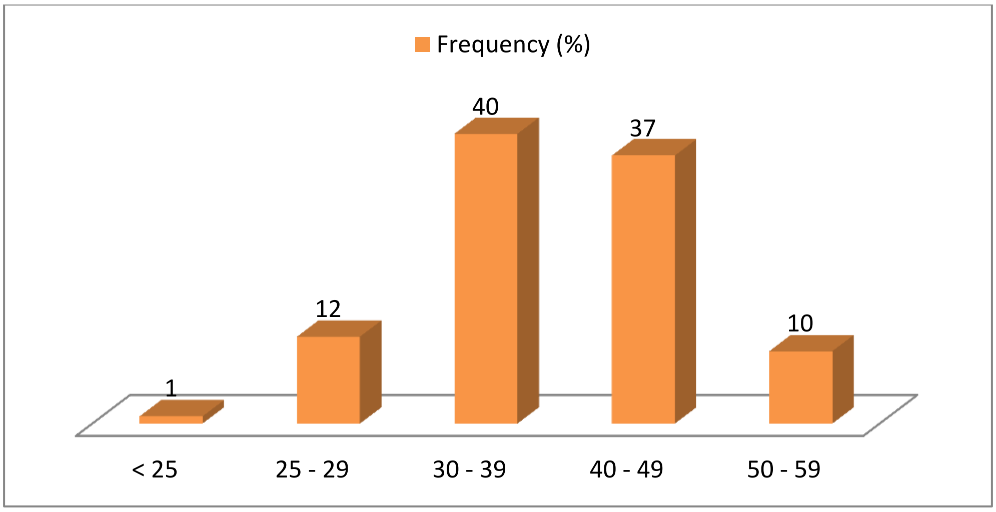

Figure 4.3: Age group distribution

4.2.3 Highest level of education

Figure 4.4 depicts the highest level of education obtained by the sub-sample teachers. It is clear that the bulk of the teachers (51%) had obtained post-secondary school education; 33% of the teachers held a Bachelor's degree and 15% had a Master's degree or a qualification beyond this. Very few teachers (1%) had a secondary or high school certificate only.

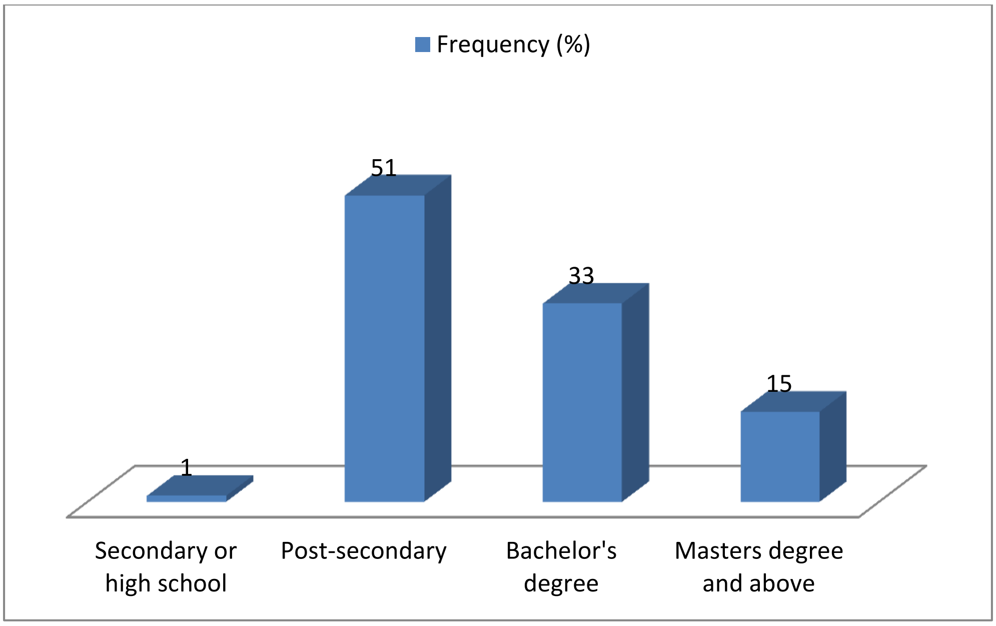

Figure 4.4: Highest level of education

Teachers were asked what type of Bachelor’s degree they had obtained, the results of which are illustrated in Figure 4.5. Of the 24 teachers who indicated having obtained a Bachelor’s degree, 14% held a Bachelor’s degree in Mathematics only, 11% held a degree in both Mathematics and Science and 4% indicated obtaining a degree in Science only as indicated in Figure 4.5. Seventy one (71) % of teachers did not hold a Bachelor’s degree in the areas indicated.

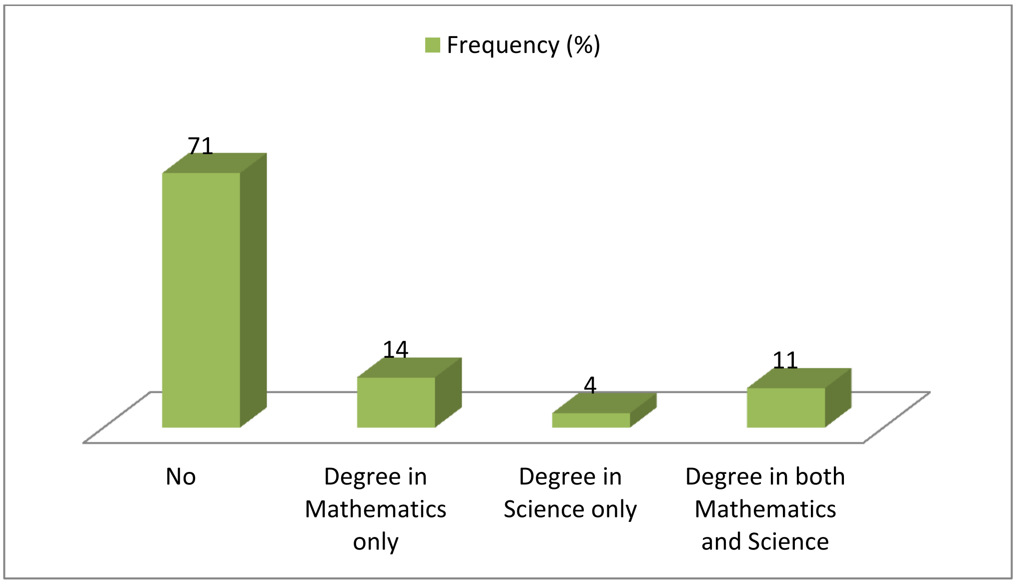

Figure 4.5: Bachelor’s degree obtained

4.2.4 Years of teaching experience

The number of years of teaching experience of the Mathematics teachers is illustrated in Figure 4.6. From Figure 4.6 it is evident to see that the majority of the teachers in this sub-sample had teaching experience of between 10 and 19 years (36%). This was followed by teachers who had teaching experience of between five to nine years (23%). The teachers with teaching experience of between two to four years and 20 years and more were on par with a frequency percentage of 17%. Teachers with less than two years' teaching experience were in the minority with 7%.

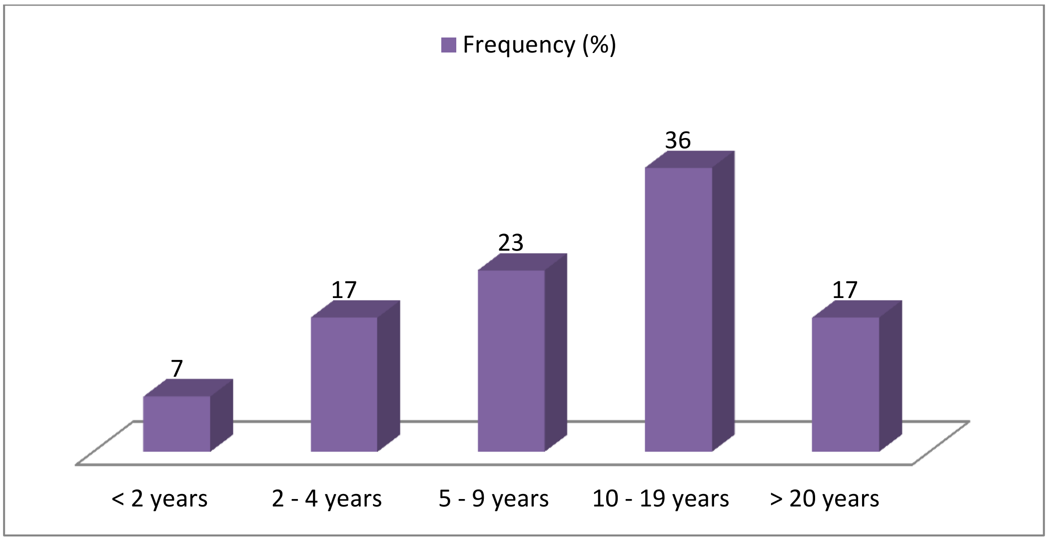

Figure 4.6: Years of teaching experience

4.2.5 Access to a computer at home

The Mathematics teachers were asked to indicate whether or not they had access to a computer at home as the results show in Figure 4.7. This question was then followed up with teachers asked firstly to indicate whether they use this computer for teaching-related activities (Figure 4.8) or secondly, whether they use this computer to access the Internet (Figure 4.9). The vast majority of the teachers (62%) indicated that they did indeed have access to a computer at home in comparison to 38% of the teachers that did not have access to a computer at home.

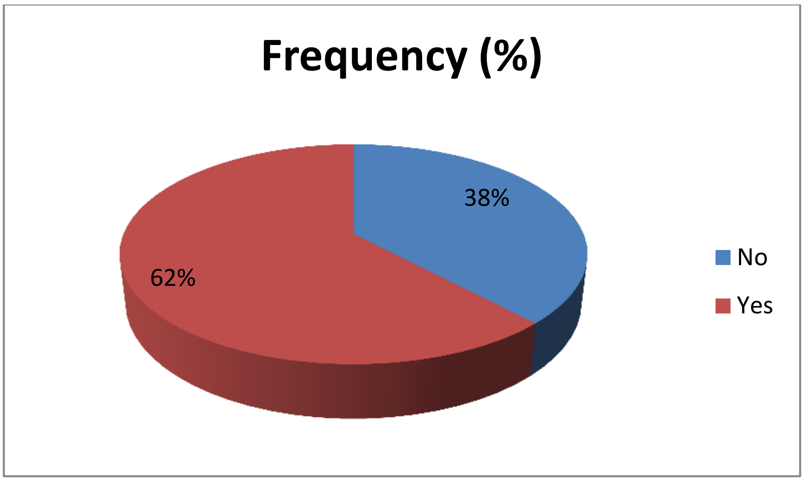

Figure 4.7: Access to a computer at home

Figure 4.8 is an illustration of the first follow-up from the teachers who indicated having a computer at home. The teachers were asked whether they use the computer at home for teaching-related activities. From Figure 4.8 it is clear to see that the vast majority of the teachers (83%) indicated using their computer for teaching-related activities as opposed to a minor 17% of the teachers indicating not using their computer for teaching-related activities.

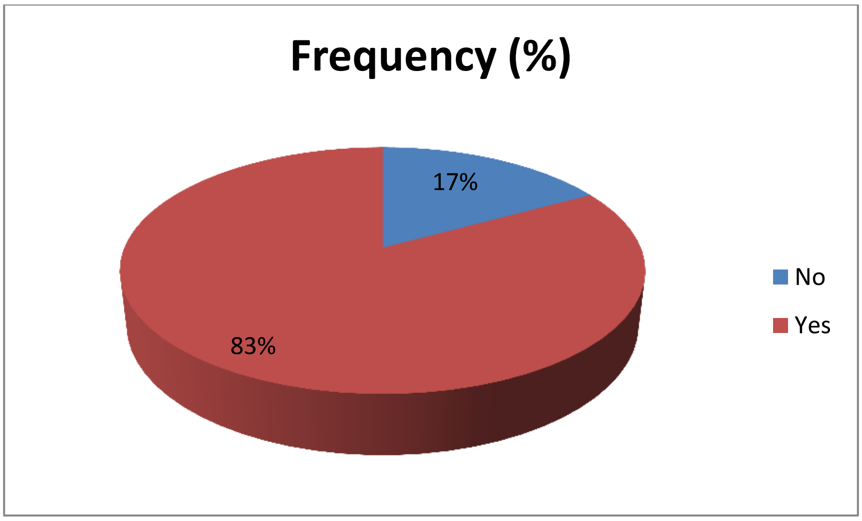

Figure 4.8: Teaching-related activities

Figure 4.9 shows the second follow-up results, specifically whether the teacher who indicated having a computer at home used this computer to connect to the Internet. Of the 48 teachers who responded to this question, slightly more teachers (56%) indicated that they have access to the Internet at home than teachers who do not have access to the Internet at home (44%).

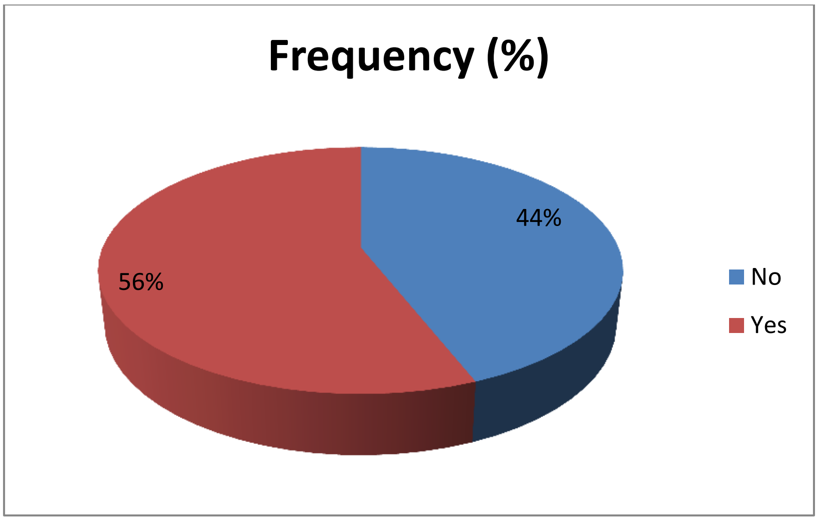

Figure 4.9: Access to the Internet

4.2.6 Overview of teacher characteristics

A total of 666 Mathematics teachers took part in the South African SITES 2006 study of which 82 Mathematics teachers were sub-sampled for the purpose of this study. The demographics of this sub-sample show that there were slightly more male teachers (55%) than female teachers (45%) in the sample. The majority of the teachers (77%) were in the age group 30 to 49 years. Just over half of the teachers (51%) indicated their highest level of education was post-secondary schooling; a third (33%) of the teachers' highest level of education was a Bachelor's degree with a Master's degree or higher qualification at 15%. Of the teachers that had obtained a Bachelor's degree, 14% had a Bachelor's degree in Mathematics only, 11% had a Bachelor's degree in both Mathematics and Science and 4% had a Bachelor's degree in Science only. Over a third (36%) of the teachers had teaching experience of between 10 and 19 years, 23% between five and nine years and teachers who had teaching experience of between two and four years and over 20 years had the same percentage of 17% respectively. In terms of access to a computer at home, 62% of the teachers indicated having access in comparison to 32% who did not have access to a computer at home. Of these teachers who had access to a computer at home, 83% used their computer for teaching-related activities and a just over half (56%) had access to the Internet at home.

4.3 Inferential analysis

In this section the inferential statistical analysis conducted for this study is presented. Data was analysed inferentially by calculating the correlation coefficient using Spearman's correlation and the p-value in SPSS. The Spearman's correlation coefficient was computed to assess the relationship between the use of ICT in discovering Mathematics principles and concepts with each of the seven learning competencies. This section is further sub-divided according to each of the learning competencies that were assessed. For each learning competency all teacher characteristics were analysed by determining the correlation coefficient (r_s), the p-value and whether there was significance. A brief description of the results in each sub-section is given, using the American Psychological Association (APA) method of reporting. Only the teacher characteristics with a medium to high correlation coefficient (between 0.450 and 1.000) and a significant p-value ($p<0.01$ and $p<0.05$) are discussed. Correlation coefficients are indicated with either a coloured background and/or use of an asterix (* if correlation is significant at 0.05 level and ** if correlation is significant at 0.01 level). The following key is applicable:

Very significant	Significant	Not significant (Medium to high r_s)

As data was missing in all instances for each of the teacher characteristics as depicted in Table 4.1 this by default implies that there is additional missing data in the correlation of the variables. This is because SPSS, when computing correlations, only considers observations with complete valid data for all variables (IDRE Research Technology group, 2012). The tables that follow indicate data that could not be computed with a (-). All SPSS outputs are in included in the CD ROM that accompanies this dissertation.

4.3.1 Information handling skills

A Spearman's correlation coefficient was computed to assess the relationship between the use of ICT in discovering Mathematics principles and concepts, and information handling skills. The results are detailed on the included CD ROM and summarised in Table 4.2.

Table 4.2: Correlation between the discovery of Mathematics principles and concepts, and information handling skills

			Number of respondents	r_s	p-value	Significance
Discovery of Mathematics principles and concepts	**Teacher characteristics**	All data	42	0.252	0.107	No
	Gender	Male	22	0.101	0.654	No
		Female	19	0.495*	0.031	Yes
	Age group	< 29 years	6	0.500	0.312	No
		30 - 49 years	31	0.326	0.073	No
		50 years >	4	-0.258	0.742	No
	Highest level of education	Secondary school or high school	1	-	-	-
		Post-secondary	21	0.119	0.608	No
		Bachelor's degree	12	0.269	0.398	No
		Master's degree	6	0.567	0.241	No
	Bachelor's degree	None	31	0.287	0.118	No
		Mathematics only	3	0.500	0.667	No
		Science only	2	-	-	-
		Both Mathematics and Science	5	-0.028	0.965	No
	Years of teaching experience	< 9 years	19	0.267	0.269	No
		> 10 years	23	0.212	0.331	No
	Access to a computer at home	No	11	0.013	0.970	No
		Yes	19	0.559*	0.013	Yes
	Teaching-related activities	No	5	-0.152	0.807	No
		Yes	22	0.451*	0.035	Yes
	Connecting to the Internet	No	11	0.243	0.471	No
		Yes	16	0.508*	0.045	Yes

* Correlation is significant at 0.05 level (2-tailed) ** Correlation is significant at 0.01 level (2-tailed)

In general, for all the data there was no correlation between the use of ICT in discovering Mathematics principles and concepts, and information handling skills [r_s (42) = 0.252, p=0.107]. However, there was a statistically significant correlation for the female Mathematics teachers [r_s (19) = 0.495, p<0.05]; the teachers who had access to a computer at home [r_s (19) = 0.559, p <0.05]; the teachers who used their computer at home for teaching-related activities [r_s (22) = 0.451, p<0.05] and the teachers that could connect to the Internet at home [r_s (16) = 0.508, p <0.05]. A medium correlation was discovered for teachers under the age of 29 years old [r_s (6) = 0.500, p=0.312]; teachers with a Master's Degree [r_s (6) = 0.567, p=0.241] and teachers that had obtained a degree in Mathematics only [r_s (3) = 0.500, p=0.667]. This was, however, not statistically significant as p>0.05.

4.3.2 Problem-solving skills

A Spearman's correlation coefficient was computed to assess the relationship between the use of ICT in discovering Mathematics principles and concepts, and problem-solving skills, the results of which are indicated in Table 4.3.

Table 4.3: Correlation between the discovery of Mathematics principles and concepts, and problem solving skills

			Number of respondents	r_s	p-value	Significance
Discovery of Mathematics principles and concepts	**Teacher characteristics**	All data	42	0.259	0.098	No
	Gender	Male	22	0.249	0.264	No
		Female	19	0.290	0.228	Yes
	Age group	< 29 years	6	-0.055	0.918	No
		30 - 49 years	31	0.338	0.063	No
		50 years >	4	0	0	No
	Highest level of education	Secondary school or high school	1	-	-	-
		Post-secondary	21	0.051	0.825	No
		Bachelor's degree	12	0.408	0.188	No
		Master's degree	6	0.429	0.396	No
	Bachelor's degree	No	31	0.282	0.125	No
		Mathematics only	3	-	-	-
		Science only	2	-	-	-
		Both Mathematics and Science	5	0.556	0.331	No
	Years of teaching experience	< 9 years	19	0.218	0.369	No
		> 10 years	23	0.282	0.192	No
	Access to a computer at home	No	11	0.223	0.510	No
		Yes	19	0.492*	0.032	Yes
	Teaching-related activities	No	5	-0.162	0.794	No
		Yes	22	0.374	0.086	No
	Connecting to the Internet	No	11	0.288	0.390	No
		Yes	16	0.354	0.179	No

* Correlation is significant at 0.05 level (2-tailed) ** Correlation is significant at 0.01 level (2-tailed)

In general, for all the data there was no correlation between the use of ICT in discovering Mathematics principles and concepts, and problem-solving skills [r_s (42) = 0.259, p=0.098]. Only one statistically significant correlation was discovered for the teachers who had access to a computer at home [r_s (19) = 0.492, p <0.05]. Furthermore, a medium non-significant correlation is apparent for teachers with a degree in both Mathematics and Science [r_s (5) = 0.556, p=0.331].

4.3.3 Self-directed learning skills

Spearman's correlation coefficient was computed to assess the relationship between the use of ICT in discovering Mathematics principles and concepts, and self-directed learning skills. The results are shown in Table 4.4.

Table 4.4: Correlation between the discovery of Mathematics principles and concepts, and self-directed learning skills

			Number of respondents	r_s	p-value	Significance
Discovery of Mathematics principles and concepts	Teacher characteristics	All data	42	0.219	0.164	No
	Gender	Male	22	0.150	0.505	No
		Female	19	0.341	0.154	No
	Age group	< 29 years	6	0.310	0.550	No
		30 - 49 years	31	0.296	0.106	No
		50 years >	4	-0.544	0.456	No
	Highest level of education	Secondary school or high school	1	-	-	No
		Post-secondary	21	0.084	0.718	No
		Bachelor's degree	12	0.374	0.230	No
		Master's degree	6	0.254	0.627	No
	Bachelor's degree	No	31	0.217	0.240	No
		Mathematics only	3	1.000**	-	-
		Science only	2	-	-	-
		Both Mathematics and Science	5	0.054	0.931	No
	Years of teaching experience	< 9 years	19	0.270	0.264	No
		> 10 years	23	0.103	0.640	No
	Access to a computer at home	No	11	0.289	0.389	No
		Yes	19	0.486*	0.035	Yes
	Teaching-related activities	No	5	-0.162	0.794	No
		Yes	22	0.328	0.136	No
	Connecting to the Internet	No	11	0.057	0.868	No
		Yes	16	0.415	0.110	No

* Correlation is significant at 0.05 level (2-tailed) ** Correlation is significant at 0.01 level (2-tailed)

In general, for all the data there was no correlation between the use of ICT in discovering Mathematics principles and concepts, and self-directed learning skills [r_s (42) = 0.219, p=0.164]. Only one statistically significant correlation was discovered for the teachers who had access to a computer at home [r_s (19) = 0.486, $p < 0.05$]. A perfect correlation [r_s (3) = 1.000] was detected for teachers with a Bachelor's degree in Mathematics only. However, as the p-value was not computed, statistical significance could not be confirmed.

4.3.4 Collaborative skills

Spearman's correlation coefficient was computed to assess the relationship between the use of ICT in discovering Mathematics principles and concepts, and collaborative skills, the results of which are indicated in Table 4.5.

Table 4.5: Correlation between the discovery of Mathematics principles and concepts, and collaborative skills

			Number of respondents	r_s	p-value	Significance
Discovery of Mathematics principles and concepts	**Teacher characteristics**	All data	42	0.325*	0.036	Yes
	Gender	Male	22	0.034	0.880	No
		Female	19	0.608**	0.006	Yes
	Age group	< 29 years	6	0.898*	0.015	Yes
		30 - 49 years	31	0.317	0.082	No
		50 years >	4	-0.544	0.456	No
	Highest level of education	Secondary school or high school	1	-	-	-
		Post-secondary	21	0.133	0.564	No
		Bachelor's degree	12	0.398	0.200	No
		Master's degree	6	0.493	0.321	No
	Bachelor's degree	No	31	0.317	0.082	No
		Mathematics only	3	0.806	0.333	No
		Science only	2	-	-	-
		Both Mathematics and Science	5	0	1.000	No
	Years of teaching of experience	< 9 years	19	0.568*	0.011	Yes
		> 10 years	23	0.105	0.635	No
	Access to a computer at home	No	11	0.058	0.867	No
		Yes	19	0.430	0.066	No
	Teaching-related activities	No	5	-0.361	0.550	No
		Yes	22	0.611**	0.003	Yes
	Connecting to the Internet	No	11	0.178	0.601	No
		Yes	16	0.667**	0.005	Yes

* Correlation is significant at 0.05 level (2-tailed) ** Correlation is significant at 0.01 level (2-tailed)

In general, for all the data there was a statistically significant correlation between the use of ICT in discovering Mathematics principles and concepts, and collaborative skills [r_s (42) = 0.325, $p<0.05$]. For the specific teacher characteristics, statistically significant correlations were discovered for the female teachers [r_s (19) = 0.608, $p<0.01$]; teachers under the age group of 29 [r_s (6) = 0.898, $p<0.05$]; teachers with teaching experience of less than nine years [r_s (19) = 0.568, $p<0.05$]; teachers who used their computer at home for teaching-related activities [r_s (22) = 0.611, p<0.01] and teachers who had access to a computer at home [r_s (16) = 0.667, p <0.01]. Additionally there was a statistically insignificant medium negative correlation for teachers above the age of 50 years [r_s (4) = -0.544, p=0.456]. Moreover, statistically insignificant medium correlations were discovered for teachers with a Master's degree [r_s (6) = 0.493, p=0.321] and a statistically insignificant high correlation for teachers with a degree in Mathematics only [r_s (3) = 0.806, p=0.333].

4.3.5 Communication skills

Spearman's correlation coefficient was computed to assess the relationship between the use of ICT in discovering Mathematics principles and concepts, and communication skills, the results of which are indicated in Table 4.6.

Table 4.6: Correlation between the discovery of Mathematics principles and concepts, and communication skills

			Number of respondents	r_s	p-value	Significance
Discovery of Mathematics principles and concepts	Teacher characteristics	All data	43	0.341*	0.025	Yes
	Gender	Male	22	0.394	0.070	No
		Female	20	0.276	0.238	No
	Age group	< 29 years	6	0.730	0.099	No
		30 - 49 years	32	0.259	0.152	No
		50 years >	4	0.333	0.667	No
	Highest level of education	Secondary school or high school	1	-	-	-
		Post-secondary	22	0.139	0.539	No
		Bachelor's degree	12	0.613*	0.034	Yes
		Master's degree	6	0.188	0.722	No
	Bachelor's degree	No	32	0.256	0.157	No
		Mathematics only	3	0.866	0.333	No
		Science only	2	-	-	-
		Both Mathematics and Science	5	0.825	0.086	No
	Years of teaching experience	< 9 years	19	0.552*	0.014	Yes
		> 10 years	24	0.181	0.396	No
	Access to a computer at home	No	11	0.347	0.295	No
		Yes	20	0.369	0.110	No
	Teaching-related activities	No	5	-0.361	0.550	No
		Yes	23	0.436*	0.038	Yes
	Connecting to the Internet	No	11	0.161	0.635	No
		Yes	17	0.513*	0.035	Yes

* Correlation is significant at 0.05 level (2-tailed) ** Correlation is significant at 0.01 level (2-tailed)

In general, for all the data there was a statistically significant correlation between the use of ICT in discovering Mathematics principles and concepts, and communication skills [r_s (43) = 0.341, $p<0.05$]. Specifically, the statistically significant correlations were discovered for teachers with a Bachelor's degree [r_s (12) = 0.613, $p<0.05$]; teachers with teaching experience of less than nine years [r_s (19) = 0.552, $p<0.05$]; teachers who used their computer at home for teaching-related activities [r_s (23) =

0.436, $p<0.05$] and teachers who had access to a computer at home [r_s (17) = 0.513, $p <0.05$]. Moreover, strong statistically insignificant correlations were apparent for teachers under the age of 29 years [r_s (6) = 0.730, p=0.099]; teachers with a degree in Mathematics only [r_s (3) = 0.866, p=0.333] and teachers with a degree in both Mathematics and Science [r_s (5) = 0.825, p=0.086].

4.3.6 ICT skills

Spearman's correlation coefficient was computed to assess the relationship between the use of ICT in discovering Mathematics principles and concepts, and ICT skills. The results are highlighted in Table 4.7.

Table 4.7: Correlation between the discovery of Mathematics principles and concepts, and ICT skills

			Number of respondents	r_s	p-value	Significance
Discovery of Mathematics principles and concepts	**Teacher characteristics**	All data	43	0.037	0.813	No
	Gender	Male	22	-0.062	0.785	No
		Female	20	0.193	0.414	No
	Age group	< 29 years	6	0.018	0.973	No
		30 - 49 years	32	0.099	0.590	No
		50 years >	4	0	1.000	No
	Highest level of education	Secondary school or high school	1	-	-	-
		Post-secondary	22	-0.186	0.407	No
		Bachelor's degree	12	0.313	0.322	No
		Master's degree	6	0.164	0.756	No
	Bachelor's degree	No	32	-0.018	0.922	No
		Mathematics only	3	0.500	0.667	No
		Science only	2	-	-	-
		Both Mathematics and Science	5	0.304	0.619	No
	Years of teaching experience	< 9 years	19	0.191	0.433	No
		> 10 years	24	-0.112	0.601	No
	Access to a computer at home	No	11	-0.179	0.599	No
		Yes	20	0.205	0.387	No
	Teaching-related activities	No	5	-0.361	0.550	No
		Yes	23	0.302	0.161	No
	Connecting to the Internet	No	11	0.016	0.962	No
		Yes	17	0.392	0.120	No

* Correlation is significant at 0.05 level (2-tailed) ** Correlation is significant at 0.01 level (2-tailed)

In general, for all the data there was no correlation between the use of ICT in discovering Mathematics principles and concepts, and ICT skills [r_s (43) = 0.037, p=0.0.813]. Furthermore, only a medium statistically insignificant correlation was detected for teachers with a degree in Mathematics only [r_s (3) = 0.500, p=0.667].

4.3.7 Ability to learn at their own pace

Spearman's correlation coefficient was computed to assess the relationship between the use of ICT in discovering Mathematics principles and concepts, and the ability of the learners to learn at their own pace. The results are indicated in Table 4.8.

Table 4.8: Correlation between the discovery of Mathematics principles and concepts, and the ability of the learners to learn at their own pace

			Number of respondents	r_s	p-value	Significance
Discovery of Mathematics principles and concepts	**Teacher characteristics**	All data	43	0.345*	0.023	Yes
	Gender	Male	22	0.245	0.271	No
		Female	20	0.473*	0.035	Yes
	Age group	< 29 years	6	0.500	0.312	No
		30 - 49 years	32	0.412*	0.019	Yes
		50 years >	4	-0.544	0.456	No
	Highest level of education	Secondary school or high school	1	-	-	-
		Post-secondary	22	0.308	0.163	No
		Bachelor's degree	12	0.421	0.173	No
		Master's degree	6	0.283	0.586	No
	Bachelor's degree	No	33	0.352*	0.048	Yes
		Mathematics only	3	1.000**	-	-
		Science only	2	-	-	-
		Both Mathematics and Science	5	0.028	0.965	No
	Years of teaching experience	< 9 years	19	0.507*	0.027	Yes
		> 10 years	24	0.221	0.300	No
	Access to a computer at home	No	11	0.611*	0.046	Yes
		Yes	20	0.301	0.196	No
	Teaching-related activities	No	5	-0.162	0.794	No
		Yes	23	0.328	0.328	No
	Connecting to the Internet	No	11	0.278	0.409	No
		Yes	17	0.303	0.236	No

* Correlation is significant at 0.05 level (2-tailed) ** Correlation is significant at 0.01 level (2-tailed)

In general, for all the data there was a statistically significant correlation between the use of ICT in discovering Mathematics principles and concepts, and the ability of the learners to learn at their own pace [r_s (43) = 0.345, $p<0.05$]. Specifically, statistically significant correlations were discovered for the female teachers [r_s (20) = 0.473, $p<0.05$]; teachers between the age groups of 30 and 49 [r_s (32) = 0.412, $p<0.05$]; teachers with no Bachelor's degree in Mathematics or Science [r_s (33) = 0.352, $p<0.05$]; teachers with teaching experience of less than nine years [r_s (19) = 0.507, $p<0.05$] and teachers who do not have a computer at home [r_s (11) = 0.611, $p<0.05$]. A statistically insignificant medium correlation was discovered for teachers under the age of 29 years [r_s (6) = 0.500, $p=0.312$]. A statistically insignificant negative medium correlation was discovered for teachers over the age of 50 years [r_s (4) = -0.544, $p=0.456$]. Lastly, a perfect correlation [r_s (3) = 1.000] was discovered for teachers with a degree in Mathematics only; however, as the p-value was not computed, statistical significance cannot be confirmed.

4.3.8 Summary of results

This section summarises all the results obtained from the previous section as illustrated in Table 4.9. The descriptions of the results that follow are further sub-divided into three categories: very significant correlations; significant correlations and correlations with no significance. The following key is applicable to Table 4.9:

- Very significant
- Significant
- Correlation with no significance
- Not significant

Table 4.9: Summary of the results

		Learning competencies	Information handling skills	Problem-solving skills	Self-directed learning skills	Collaborative skills	Communication skills	ICT skills	Ability to learn at their own pace
Discovery of Mathematics principles and concepts	Teacher characteristics	All data	r_s (42) = 0.252, p=0.107	r_s (42) = 0.259, p=0.098	r_s (42) = 0.219, p=0.164	r_s (42) = 0.325, p<0.05	r_s (43) = 0.341, p<0.05	r_s (43) = 0.037, p=0.813	r_s (43) = 0.345, p<0.05
Discovery of Mathematics principles and concepts	Gender	Male	r_s (22) = 0.101, p=0.654	r_s (22) = 0.249, p=0.264	r_s (22) = 0.150, p=0.505	r_s (22) = 0.034, p=0.880	r_s (22) = 0.394, p=0.070	r_s (22) = -0.062, p=0.785	r_s (22) = 0.245, p=0.271
Discovery of Mathematics principles and concepts	Gender	Female	r_s (19) = 0.495, p<0.05	r_s (19) = 0.290, p=0.228	r_s (19) = 0.341, p=0.154	r_s (19) = 0.608, p<0.01	r_s (20) = 0.276, p=0.238	r_s (20) = 0.193, p=0.414	r_s (20) = 0.473, p<0.05
Discovery of Mathematics principles and concepts	Age group	< 29 years	r_s (6) = 0.500, p=0.312	r_s (6) = -0.055, p=0.918	r_s (6) = 0.310, p=0.550	r_s (6) = 0.898, p<0.05	r_s (6) = 0.730, p=0.099	r_s (6) = 0.018, p=0.973	r_s (6) = 0.500, p=0.312
Discovery of Mathematics principles and concepts	Age group	30 - 49 years	r_s (31) = 0.326, p=0.073	r_s (31) = 0.338, p=0.063	r_s (31) = 0.296, p=0.106	r_s (31) = 0.317, p=0.082	r_s (32) = 0.256, p=0.152	r_s (32) = 0.099, p=0.590	r_s (32) = 0.412, p<0.05
Discovery of Mathematics principles and concepts	Age group	50 years >	r_s (4) = -0.258, p=0.742	r_s (4) = 0 p=0	r_s (4) =-0.544, p=0.456	r_s (4) =-0.544, p=0.456	r_s (4) = 0.333, p=0.67	r_s (4) = 0 p=1.000	r_s (4) = -0.544, p=0.456
Discovery of Mathematics principles and concepts	Highest level of education	Secondary school or high school	r_s (1)	r_s (1)	r_s (1)	r_s (1)	r_s (1)	r_s (1)	r_s (1)
Discovery of Mathematics principles and concepts	Highest level of education	Post-secondary	r_s (21) = 0.119, p=0.608	r_s (21) = 0.051, p=0.825	r_s (21) = 0.084, p=0.718	r_s (21) =0.133, p=0.564	r_s (22) = 0.139, p=0.539	r_s (22) = -0.186, p=0.407	r_s (22) = 0.308, p=0.163
Discovery of Mathematics principles and concepts	Highest level of education	Bachelor's degree	r_s (12) = 0.269, p=0.398	r_s (12) = 0.408, p=0.188	r_s (12) = 0.290, p=0.230	r_s (12) =0.398, p=0.200	r_s (12) = 0.613, p<0.05	r_s (12) = 0.313, p=0.322	r_s (12) = 0.421, p=0.173
Discovery of Mathematics principles and concepts	Highest level of education	Master's degree	r_s (6) = 0.567, p=0.241	r_s (6) = 0.429, p=0.396	r_s (6) = 0.254, p=0.627	r_s (6) = 0.254, p=0.627	r_s (6) = 0.188, p=0.722	r_s (6) = 0.164, p=0.756	r_s (6) = 0.283, p=0.586

Table 4.9: Summary of the results (continued…)

Discovery of Mathematics principles and concepts	Teacher characteristics \ Learning competencies		Information handling skills	Problem-solving skills	Self-directed learning skills	Collaborative skills	Communication skills	ICT skills	Ability to learn at their own pace
	Bachelor's degree	No	r_s (31) = 0.287, p=0.118	r_s (31) = 0.282, p=0.125	r_s (31) = 0.217, p=0.240	r_s (31) = 0.317, p=0.082	r_s (32) = 0.256, p=0.157	r_s (32) = -0.018, p=0.922	r_s (33) = 0.352, p<0.05
		Mathematics only	r_s (3) = 0.500, p=0.667	r_s (3)	r_s (3) = 1.000	r_s (3) = 0.806, p=0.333	r_s (3) = 0.866, p=0.333	r_s (3) = 0.500, p=0.667	r_s (31) = 0.296, p=0.106
		Science only	r_s (2)	r_s (2)	r_s (2)	r_s (2)	r_s (2)	r_s (2)	r_s (2)
		Both Mathematics and Science	r_s (5) = -0.028, p=0.965	r_s (5) = 0.556, p=0.331	r_s (5) = 0.054, p=0.931	r_s (5) = 0 p=1.000	r_s (5) = 0.825, p=0.086	r_s (5) = 0.304, p=0.619	r_s (5) = 0.054, p=0.931
	Years of teaching experience	< 9 years	r_s (19) = 0.267, p=0.269	r_s (19) = 0.218, p=0.369	r_s (19) = 0.270, p=0.264	r_s (19) = 0.568, p<0.05	r_s (19) = 0.552, p<0.05	r_s (19) = 0.191, p=0.433	r_s (19) = 0.507, p<0.05
		> 10 years	r_s (23) = 0.212, p=0.331	r_s (23) = 0.282, p=0.192	r_s (23) = 0.103, p=0.640	r_s (23) = 0.105, p=0.635	r_s (24) = 0.181, p=0.396	r_s (24) = -0.112, p=0.601	r_s (24) = 0.221, p=0.300
	Access to a computer at home	No	r_s (11) = 0.013, p=0.970	r_s (11) = 0.223, p=0.510	r_s (11) = 0.289, p=0.389	r_s (11) = 0.058, p=0.867	r_s (11) = 0.347, p=0.295	r_s (11) = -0.179, p=0.599	r_s (11) = 0.661, p<0,05
		Yes	r_s (19) = 0.559, p <0.05	r_s (19) = 0.492, p <0.05	r_s (19) = 0.486, p <0.05	r_s (19) = 0.430, p=0.066	r_s (20) = 0.369, p=0.110	r_s (20) = 0.205, p=0.387	r_s (20) = 0.301, p=0.196
	Teaching-related activities	No	r_s (5) = -0.152, p=0.807	r_s (5) = -0.162, p=0.794	r_s (5) = -0.162, p=0.794	r_s (5) = -0.361, p=0.550	r_s (5) = -0.361, p=0.550	r_s (5) = -0.361, p=0.550	r_s (5) = -0.162, p=0.794
		Yes	r_s (22) = 0.451, p<0.05	r_s (22) = 0.374, p=0.086	r_s (22) = -0.328, p=0.136	r_s (22) = 0.611, p<0.01	r_s (23) = 0.436, p<0.05	r_s (23) = 0.302, p=0.161	r_s (23) = 0.328, p=0.328
	Connecting to the Internet	No	r_s (11) = 0.243, p=0.471	r_s (11) = 0.288, p=0.390	r_s (11) = 0.057, p=0.868	r_s (11) = 0.178, p=0.601	r_s (11) = 0.161, p=0.635	r_s (11) = 0.016, p=0.962	r_s (11) = 0.278, p=0.409
		Yes	r_s (16) = 0.508, p <0.05	r_s (16) = 0.354, p=0.179	r_s (16) = 0.415, p=0.110	r_s (16) = 0.667, p <0.01	r_s (17) = 0.513, p <0.05	r_s (17) = 0.392, p=0.120	r_s (17) = 0.303, p=0.236

4.3.8.1 Very significant correlations

The very significant correlations were the correlations with $p < 0.01$ with a medium to high coefficient (between 0.450 and 1.000). As illustrated in Table 4.9, only one learning competency, namely collaborative skills, revealed very significant relationships for three varying teacher characteristics. The teacher characteristics were female teachers, teachers using their computer at home for teaching-related activities and teachers with access to a computer at home.

4.3.8.2 Significant correlations

The significant correlations were the correlations with $p < 0.05$ with a medium to high coefficient (between 0.450 and 1.000). Table 4.9 clearly illustrates that for all the data only three significant relationships existed between the uses of ICT in discovering Mathematics principles with the following learning competencies: collaborative skills, communication skills and the ability of the learners to learn at their own pace.

The results showed that for information handling skills the following teacher characteristics indicated the existence of a significant relationship: female teachers, teachers with access to a computer at home, teachers who used this computer for teaching-related activities and could connect to the Internet.

For the learning competency problem-solving skills, only one significant relationship was discovered for teachers with access to a computer at home. This was similar for self-directed learning skills.

In addition to all the data having a relationship for collaborative skills, significant relationships were discovered for teachers under the age of 29 years and teachers with less than nine years teaching experience.

Similarly, in addition to all the data having a relationship with communication skills, significant relationships were found for the following teacher characteristics: teachers with a Bachelor's degree, teachers with teaching experience of less than nine years, teachers who use their computer at home for teaching-related activities and teachers with access to a computer at home.

Lastly, for the learning competency ability of the learners to learn at their own pace, relationships were discovered for female teachers, teachers between the age groups of 30 and 49 and teachers with teaching experience of less than nine years. Surprisingly, these two variables revealed relationships for the teachers with no Bachelor's degree in Mathematics or Science and the teachers who do not have a computer at home.

4.3.8.3 Correlations with no significance

The correlations with no significance were the ones where $p > 0.05$ with a medium to high coefficient (between 0.450 and 1.000). The results show that for information handling skills, the following teacher characteristics indicated an existence of a non-significant relationship: teachers under the age of 29 years, teachers with a Master's degree and teachers with a degree in Mathematics only.

The learning competency problem-solving skills revealed a non-significant relationship for teachers with a degree in both Mathematics and Science only.

Self-directed learning skills were identified as having two non-significant relationships for teachers over the age of 50 years and teachers with a degree in Mathematics only. It should be noted that correlation for the teachers above 50 years of age was a negative correlation (See Table 4.9).

Collaborative skills revealed three non-significant relationships for the following teacher characteristics: teachers over the age of 50 years, teachers with a Master's degree and teachers with a degree in Mathematics only. Likewise, the correlation for the teachers over 50 years was negative (See Table 4.9).

Communication skills also revealed three non-significant relationships for the following teacher characteristics: teachers under the age of 29 years, teachers with a degree in Mathematics only as well as teachers with a degree in both Mathematics and Science.

Surprisingly the results showed only one non-significant relationship for ICT skills for teachers with a degree in Mathematics only.

The ability of learners to learn at their own pace displayed three non-significant relationships for teachers less than 29 years old, teachers over the age of 50 years and teachers with a degree in Mathematics only. As with all other learning competencies, a negative correlation was exhibited for the teachers over the age of 50 years.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This final chapter begins with an overview of the study and consolidates all the significant aspects from each of the preceding chapters. It is followed by a discussion that attempts to answer the research and sub-research questions. Conclusions based on the findings of the study with recommendations on how the results of the study are beneficial follow directly. Suggestions for further research close the chapter.

5.1.1 Overview of the study

The purpose of the study is to explore the relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which ICT assists in improving learning competencies. The investigation was directed by the primary research question:

> *What is the relationship between the use of ICT as an educational tool and the extent to which ICT assists in improving learning competencies?*

Feeding into the primary research question were the following learning competencies that were explored in this study:

- Information handling skills
- Problem-solving skills
- Self-directed learning skills
- Collaborative skills
- Communication skills
- ICT skills
- Ability to learn at the learners' own pace

Since each learning competency was investigated, it constituted an individual sub-research question with the resultant null and alternative hypotheses. To provide answers to these research questions and hypotheses, a conceptual framework to determine the role of ICT as an educational tool in Mathematics classrooms was generated using the underlying principles of Activity Theory and the SITES 2006 conceptual framework. As indicated in the conceptual framework, teacher characteristics are just one of the crucial components that play a vital role in determining the effectiveness of ICT as an educational tool in Mathematics classrooms. The teacher characteristics were added as layer variables to add a dimension to the study. Thus, in addition to investigating the learning competencies, the following teacher characteristics were examined:

- Gender
- Age group
- Highest level of education
- Degree obtained
- Years of teaching experience
- Access to a computer at home
- The uses of the computer at home

Major findings from the literature have revealed that although ICT integration in Mathematics has become synonymous with technological advancements, very few initiatives have been made in South Africa as most provinces are still in the early stages of introducing ICT into their schools. Blignaut et al. (2010b) in their study found most South African schools are still concentrating their computers in laboratories instead of placing them in classrooms where teachers or learners have access to them. Additionally, more than half (62%) of schools still do not provide universal access to ICT in education to their learners (Howie & Blignaut, 2009). Statistics show that ICT integration is still predominant in two provinces in the country, namely the Western Cape and Gauteng Province.

Similarly, Mathematics achievement in most provinces is considered under par, with the Western Cape and Gauteng Province performing relatively well in comparison. A suggestion put forward by Reddy (2006) is the respectively high human development index (HDI) in these two provinces. The initiatives to introduce ICT into schools have not had the desired effect; instead, the country continues to underperform in comparison to the majority of both African and international countries in studies undertaken in these regions. Whereas studies internationally primarily focus on investigating pedagogical practices of teachers, Howie (2010) writes that the research available in South Africa still focuses predominantly on policy documents and the intentions of the Government and not on the actual implementation of ICT in education.

This study used data from the SITES 2006 South African Mathematics teachers' questionnaire and sampled a total of 82 Mathematics teachers. The sub-sample consisted of the Mathematics teachers who indicated using ICT in the discovery of Mathematics principles and concepts. Descriptive and inferential analyses were identified and used to address the research questions. Descriptive analysis was presented in the form of frequencies as percentages whereas the inferential analysis was determined by calculating the correlation coefficient using Spearman's correlation coefficient and the p-value. An overview of the results from the inferential analysis is illustrated in Table 5.1, with a tick (✓) representing the relationships discovered among the variables in this study.

Table 5.1: Overview of the results

		Learning competencies	Information handling skills	Problem-solving skills	Self-directed skills	Collaborative skills	Communication skills	ICT skills	Ability to learn at their own pace
Discovery of Mathematics principles and concepts	**Teacher characteristics**	All data				✓	✓		✓
	Gender	Male							
		Female	✓			✓			✓
	Age group	< 29 years				✓			
		30 - 49 years							✓
		50 years >		✓					
	Highest level of education	Secondary school or high school							
		Post-secondary							
		Bachelor's degree					✓		
		Master's degree							
	Bachelor's degree	No							✓
		Mathematics only							
		Science only							
		Both Mathematics and Science							
	Years of teaching experience	< 9 years				✓	✓		✓
		> 10 years							
	Access to a computer at home	No							✓
		Yes	✓	✓	✓				
	Teaching-related activities	No							
		Yes	✓			✓	✓		
	Connecting to the Internet	No							
		Yes	✓			✓	✓		

5.2 Answering the sub-research questions

In this section the sub-research questions and the hypotheses are addressed. This section is therefore structured by each sub-research question and its respective null and alternative hypothesis. A tick (✓) represents which hypothesis was accepted.

Research question	Hypotheses	
1. What is the relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' information handling skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' information handling skills.	✓
	H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' information handling skills.	

The study has revealed that overall a relationship does not exist between the use of ICT in discovering Mathematics principles and the extent to which it improves learners' information handling skills. The null hypothesis is therefore accepted. However, given the layer variables – teacher characteristics – four relationships were found to exist. Relationships were found for the following teacher characteristics: female teachers, teachers who have a computer at home, teachers who use this computer for teaching-related activities and can connect to the Internet. Although statistically significant relationships exist for the afore-mentioned teacher characteristics, in all these cases the correlation coefficient is in the medium range, implying that the relationship is not strong. Additionally relationships between the use of ICT in discovering Mathematics principles and concepts, and information handling skills were detected for teachers who are under the age of 29 years old, teachers who hold a Master's degree and teachers that have a degree in Mathematics only. However, these relationships are not statistically significant.

Research question	Hypotheses	
2. What is the relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' problem-solving skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' problem-solving skills.	✓
	H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' problem-solving skills.	

In general, the results show that there is no relationship between the use of ICT in discovering Mathematics principles and concepts, and problem-solving skills. The null hypothesis is therefore accepted. However, a relationship was discovered for teachers who have access to a computer at home. Additionally, a non-significant correlation was also discovered for teachers with a degree in both Mathematics and Science.

Research question	Hypotheses	
3. What is the relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' self-directed skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' self-directed skills.	✓
	H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' self-directed skills.	

No relationship was found to exist in general between the use of ICT in discovering Mathematics principles and concepts, and self-directed skills. The null hypothesis is therefore accepted. Only one statistically significant relationship was discovered for the teachers who have access to a computer at home. A non-significant relationship was found to exist for teachers with a Bachelor's degree in Mathematics only.

Research question	Hypotheses	
4. What is the relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' collaborative skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' collaborative skills.	
	H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' collaborative skills.	✓

The results show that there is a statistically significant relationship in general between the use of ICT in discovering Mathematics principles and concepts, and collaborative skills. The null hypothesis is rejected. Furthermore, very strong statistically significant relationships exist for a varying number of teacher characteristics: female teachers, teachers under the age group of 29, teachers with teaching experience of less than nine years, teachers who use their computer at home for teaching-related activities and teachers who have access to a computer at home. Additionally, statistically insignificant medium correlations were discovered for teachers with a Master's degree and a statistically non-significant high correlation for teachers with a degree in Mathematics only. An interesting result is that there is a statistically non-significant medium negative correlation for teachers above the age of 50 years.

Research question	Hypotheses	
5. What is the relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' communication skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' communication skills.	
	H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' communication skills.	✓

In general, the results show that there is a statistically significant relationship between the use of ICT in discovering Mathematics principles and concepts, and communication skills. The null hypothesis is therefore rejected. Specifically, very strong statistically significant relationships were discovered for the female teachers, teachers under the age of 29, teachers with teaching experience of less than nine years, teachers who used their computer at home for teaching-related activities and teachers who have access to a computer at home. Moreover, strong statistically non-significant correlations are apparent for teachers under the age of 29 years, teachers with a degree in Mathematics only and teachers with a degree in both Mathematics and Science.

Research question	**Hypotheses**	
6. What is the relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' ICT skills?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' ICT skills.	✓
	H_1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' ICT skills.	

Surprisingly, the results show that there is no relationship between the use of ICT in discovering Mathematics principles and concepts, and ICT skills. The null hypothesis is therefore accepted. Furthermore only a medium statistically non-significant relationship was detected for teachers with a degree in Mathematics only.

Research question	Hypotheses	
7. What is the relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves the learners' ability to learn at their own pace?	H_0: There is no relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' ability to learn at their own pace.	
	H1: There is a relationship between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it improves learners' ability to learn at their own pace.	✓

In general the results show that there is a statistically significant relationship between the use of ICT in discovering Mathematics principles and concepts, and the ability of the learners to learn at their own pace. Therefore the null hypothesis is rejected. Specifically statistically significant relationships were discovered for female teachers, teachers between the age groups of 30 and 49 and teachers with teaching experience of less than nine years. Surprisingly, these two variables revealed statistically significant relationships for the teachers with no Bachelor's degree in Mathematics or Science and the teachers who do not have a computer at home. Additionally, statistically non-significant medium relationships were discovered for teachers under the age of 29 years. Interestingly, a statistically non-significant negative medium relationship was discovered for teachers over the age of 50 years. Lastly, a perfect non-significant relationship was discovered for teachers with a degree in Mathematics only.

5.3 Conclusion

So what influence do teacher characteristics and background have on learning competencies? The following conclusions can be drawn from the present study. Although there were slightly more male teachers (55%) in the sample of this study, the results indicate that generally female teachers compared to male teachers are more likely to support learners' information handling skills and ability to learn at their own pace when using ICT in the discovery of Mathematics principles and concepts. Additionally, female teachers are even more influential in assisting the development of their learners' collaborative skills when engaged in the discovery of Mathematics principles and concepts while using ICT. The findings of this study support Krieg (2005), who in his study found that that most learners (be they male or female) learn best when taught by a female teacher. However, evidence from this study is not conclusive as different contexts were used for either study. Firstly, Krieg's (2005) study did not specifically investigate the subject Mathematics or the use of ICT. In terms of Mathematics, this study contradicts Warwick and Haroona's 1994 study that found that Mathematics learners are more likely to learn from a male teacher.

With regard to age group, evidence from the results supports the fact that teachers under the age of 29 are most probably going to use ICT in the discovery of Mathematics principles and concepts to enhance learners' collaborative skills. In comparison teachers between the ages of 30 and 49 are more likely to use ICT in the discovery of Mathematics principles and concepts to improve the ability of the learners to learn at their own pace.

In terms of the highest level of education, only teachers with a Bachelor's degree were found to be able to develop their learners' communication skills when using ICT in the discovery of Mathematics principles and concepts. Interestingly enough, the teachers with neither a Bachelor's degree in Mathematics nor in Science are more likely to develop the ability of the learners to learn at their own pace when using ICT in the discovery of Mathematics principles and concepts. This implies that teachers with a Bachelor's degree in Mathematics or Science or both do not use ICT in the discovery of

Mathematics principles and concepts to improve any of the learning competencies. The level of education and the type of degree held by the teacher have revealed very few relationships as illustrated in Table 5.1, contrary to the evidence as discussed in the literature.

Overwhelming evidence from the results as illustrated in Table 4.9 and Table 5.1 maintains that teachers with teaching experience of less than nine years are anticipated to develop the following learning competencies: collaborative skills, communication skills as well as the ability of learners to learn at their own pace when engaged in the discovery of Mathematics principles and concepts while using ICT. The results of this study therefore contradict those in literature (Goldhaber & Anthony, 2004; Zhang, 2008). This study has found that teachers with fewer years of experience are more likely to enhance learner competencies. But once again, this study unlike previous studies takes into account ICT which can change the dynamics somewhat, compared to the studies discussed in the literature.

The results of this study have revealed that teachers with access to a computer at home are inclined to develop the following learning competencies: information handling skills, problem-solving skills and self-directed learning skills. Additionally, teachers who have access to a computer at home and use this computer for teaching-related activities and access the Internet will most likely develop their learners' information handling skills and communication skills. Moreover, these teachers will most certainly develop their learners' collaborative skills. The majority of teachers (62%) in this sample indicated having access to a computer at home of which 83% use their computer at home for teaching-related activities and just over half (56%) have access to the Internet at home. Evidence from this study supports claims in the literature that teachers that have access to a computer at home are more likely to use them in their classrooms as suggested by Sime and Priestly (2005). Surprisingly, the results show that teachers that do not have access to a computer at home are most probably also the teachers that develop their learners' ability to learn at their own pace.

The main research question relates to a relationship between a number of variables:

What is the relationship between the use of ICT as an educational tool and the extent to which ICT assists in improving learning competencies?

Findings of the study expose just how complex the relationships among these variables are. Taken together, the findings of the study suggest that certain teacher characteristics (female teachers, access to a computer at home, using the computer at home for teaching-related activities, and access to the Internet at home) do indeed influence the probability of the teacher developing the learners' learning competencies in a Mathematics activity while using ICT. ICT in this instance is essentially just a tool the teacher uses to mediate the transformation process. Similarly, the findings show that of the seven learning competencies investigated in this study, three relationships were found to exist for the following learning competencies: collaborative skills, communication skills and the ability of learners to learn at their own pace. As van Joolingen (1999) suggests, skills should not be seen as a bi-product of the discovery learning process but as learning outcomes in themselves as these skills are essential for all aspects of learning. Using the conceptual framework, the findings of the study can be illustrated as in Figure 5.1.

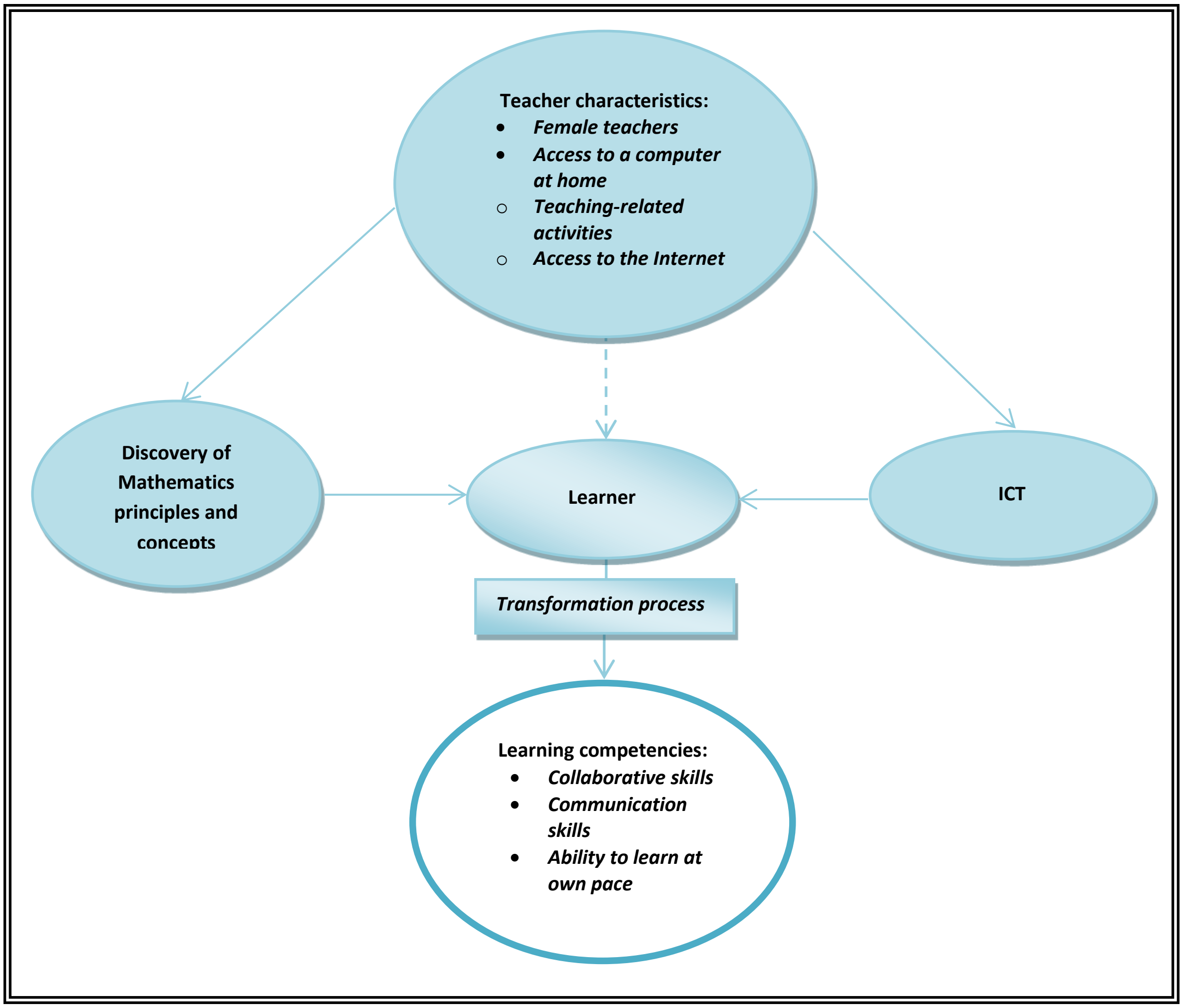

Figure 5.1: Findings from the study

5.4 Recommendations

Recommendations for further research can be made on two bases: firstly from insights drawn from the literature review and secondly from the findings of the study. Of the 666 Mathematics teachers that took part in SITES 2006, only 82 teachers indicated using ICT in the discovery of Mathematics principles and concepts; this number constitutes a mere 12% of the total sample. Although this is certainly not indicative for all activities that use ICT, with all the various initiatives being undertaken in each PDOE to equip schools with computers, measures should be put in place to ensure that teachers are actually using them as planned, i.e. as teaching and learning tools in the classrooms. The emphasis should therefore not be predominantly only on equipping schools with computers but also on ensuring that teachers are supported adequately in the integration of these technologies as educational tools in their classrooms. This calls for professional development activities with better technical support and greater universal access for teachers both in and out of schools. Increasing universal access entails the move from locating computers in school laboratories or libraries to all classrooms (Blignaut et al., 2010b).

Recommendations that emanate from the findings of the study include that professional development opportunities with regard to ICT for Mathematics teachers should be:

- Administered as early in the teacher's career as possible.
- Male teachers should in particular be encouraged to attend and participate in such activities.

Additionally, teachers should be assisted where possible in gaining access to a computer at home with the sole purpose of completing and enhancing teaching-related activities.

5.5 Suggestions for further study

As this study was a secondary data analysis study, it is advised that an empirical study be conducted to verify its findings.

As Howie (2010) fittingly writes, research available in South Africa still focuses predominantly on policy documents and the intentions of the Government and not on the actual implementation of ICT in education. Research in South Africa therefore desperately requires an increase in the number of studies with the primary focus on investigating the pedagogical practices of teachers. This is the general theme of most studies internationally as is clearly evident in the literature.

This study has revealed various relationships between the discovery of Mathematics principles and concepts and the teacher's age group. Some of these relationships are positive (teachers younger than 29 years and teachers between 30 to 49 years) while others are negative (teachers older than 50 years). However, there is very little or no literature that addresses the impact of the teacher's age on learner achievement. Further research is therefore suggested to investigate this possibility, specifically in the computer integrated education realm.

A surprising finding from the study is the lack of relationships discovered between the use of ICT in discovering Mathematics principles and concepts, and the extent to which it assists ICT skills-development. It would make for an interesting study to determine teacher perceptions of using ICT as a teaching and learning tool in developing their learners' ICT skills. The research has given rise to questions in need of further investigation and clarification in this area. Moreover, it would be beneficial to conduct a holistic study that investigates in addition to teacher perceptions, the learners' perceptions examined. Figure 5.2, using the conceptual framework, illustrates areas of possible further research with an asterix (*).

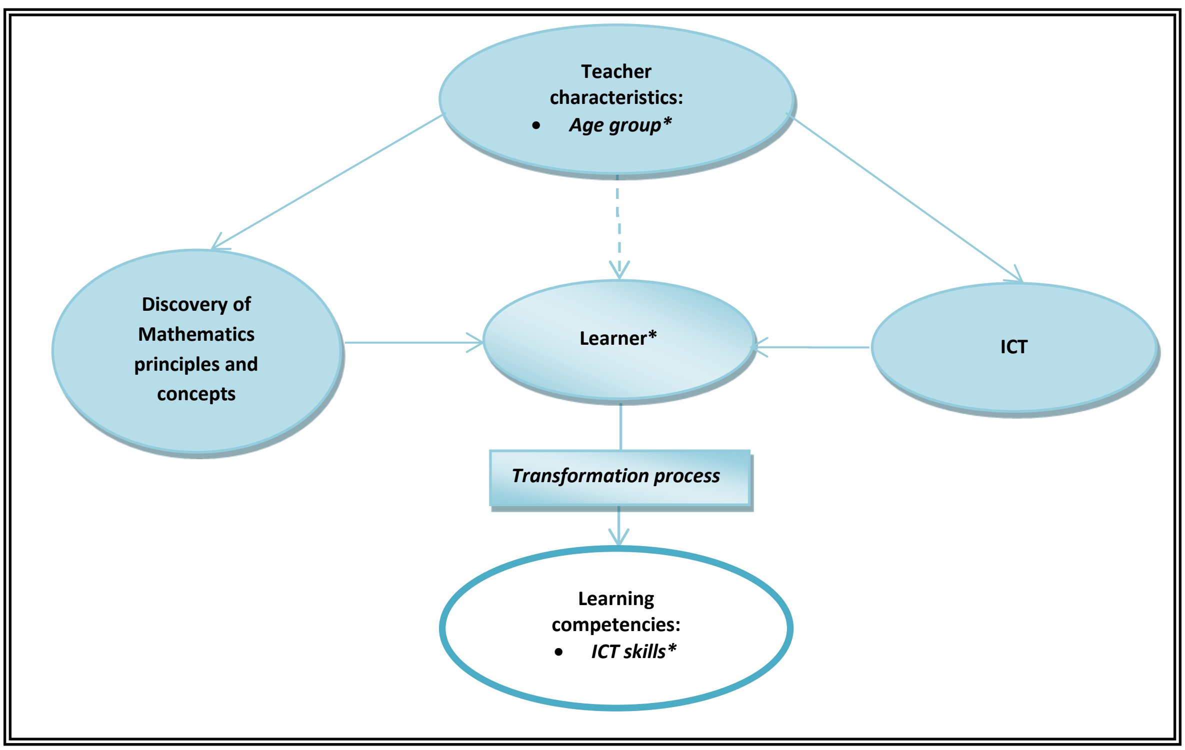

Figure 5.2: Suggestions for further research

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