The relationship between investment in ICT and mathematics achievement

by

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Declaration

I declare that the thesis, which I hereby submit for the degree Philosophiae Doctor (Computer Integrated Education) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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15 January 2018

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The author, whose name appears on the title page of this thesis, has obtained, for the research described in this work, the applicable research ethics approval. The author declares that he has observed the ethical standards required in terms of the University of Pretoria's *Code of ethics for researchers* and the *Policy guidelines for responsible research.*

Dedication

Ek dra hierdie navorsingstuk op aan my gesin.

Aan my ongeloofilke vrou, Emma, en ons twee wonderlike kinders, Emma en Ockie. Dankie vir julle onvoorwaardelike liefde, ondesteuning en verstaan die afgelope paar jaar. Dankie dat julle my die spasie en tyd gegun het om hierdie droom van my te bewaarheid.

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Abstract

Information and Communications Technologies (ICTs) are acknowledged as a vital ingredient for the transformation of any society. Since the late 1990's the Department of Education implemented several curriculum-based interventions aimed at improving the quality of education in South African schools. During this time there was also a gradual introduction of ICT in some schools, mainly because there seemed to be a belief that the integration of ICT in schools can transform education, reduce challenges, and lead to enhanced education in South Africa.

The data for this study originated from the TIMSS 2011 and TIMSS 2015 assessments conducted by the International Association for the Evaluation of Educational Achievement (IEA). This study investigated the relationship between the investment in ICT in South African schools and the mathematics achievement of the Grade 9 participants. The aim of the study was to identify trends in the use of ICT in schools, as well as the relationship between the use of ICT and mathematics achievement.

The findings from the study indicated a decrease in the availability of ICT for teaching and learning from 2011 to 2015. The study found that even where ICT was available, it was rarely used. At the same time Grade 9 participants reported an increase in the use of ICT for schoolwork outside of their school environment. While there was an increase in educator professional development focusing on the integration of ICT in education, the number of educators that used ICT for mathematics teaching and learning, decreased between 2011 and 2015. The research results suggested that educators seemed to battle to optimally use and implement new technologies.

A new model for improved integration of ICT in schools is therefore proposed. The proposed *IIIA-Model for the integration of ICT in Schools (IIIA-Model)* is based on an adaptation of the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2010) and the TIMSS

curriculum model (Mullis & Martin, 2013). The IIIA-Model aims to direct the implementation and integration of ICT in schools by identifying different zones of impact, role-players involved, as well as curriculum expectations during the process of ICT integration.

Key Terms:

Academic achievement, Educational technology, ICT, Mathematics, TIMSS

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TO WHOM IT MAY CONCERN

This is to confirm that the thesis titled ***"The relationship between investment in ICT and mathematics achievement "*** by Guillaume Matthys Kruger was proof read and edited by me in respect of language.

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List of Abbreviations

AAAS	American Association for the Advancement of Science
AAP	American Academy of Paediatrics
AISA	Africa Institute of South Africa
ANA	Annual National Assessments
BECTA	British Educational Communications and Technology Agency
CAPS	Curriculum and Assessment Policy Statements
DBE	Department of Basic Education
DHET	Department of Higher Education and Training
DOE	Department of Education
DPC	Data Processing and Research Center
EC	Eastern Cape province
FS	Free State province
GDE	Gauteng Department of Education
GP	Gauteng province
GPG	Gauteng Provincial Government
HSRC	Human Sciences Research Council
ICT	Information and Communications Technology
IEA	International Association for the Evaluation of Educational Achievement
IQCM	International Quality Control Monitor
ISCED	International Standard Classification of Education
IRT	Item Response Theory
ISTE	International Society for Technology in Education
KZ	KwaZulu-Natal province
LP	Limpopo province
MLA	Monitoring Learner Achievement
MOOC	Massive Open Online Course

MOS	Measure of school size
MP	Mpumalanga province
NC	Northern Cape province
NDP	National Development Plan
NRC	National Research Coordinator
NRI	Networked Readiness Index
NSC	National Senior Certificate
NW	North West province
OECD	Organisation for Economic Co-operation and Development
OLPC	One Laptop per Child project
PED	Provincial Education Department
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
PSU	Primary sampling unit
PV	Plausible value
ROI	Return on investment
RSA	Republic of South Africa
SACMEQ	Southern and Eastern African Consortium for Monitoring Educational Quality
SDA	Secondary data analysis
SITES	IEA Second Information Technology in Education Study
SMIRC	Science and Mathematics Item Review Committee
TAM	Technology Acceptance Model
TIMSS	Trends in International Mathematics and Science Study
SES	Socioeconomic status
SSU	Secondary sampling unit
UCT	University of Cape Town
UN	United Nations
WC	Western Cape province

WCED Western Cape Education Department

WEF World Economic Forum

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1. CHAPTER 1 – INTRODUCTION

"TIMSS participants share the conviction that comparing education systems in terms of their organization, curricula, and instructional practices in relation to their corresponding student achievement provides information crucial for effective education policy-making."

(International Association for the Evaluation of Educational Achievement [IEA], 2017a, para. 2)

1.1. Introduction

Prior to 1995 the only system available to track the quality of the South African national education system, was the annual Grade 12 National Senior Certificate (NSC) examination results (Howie, 2004; Spaull, 2013). However, this annual review of the Grade 12 results was problematic in that it focused mainly on one final assessment series in a 12-year education process. Additionally, a review of the NSC results did not take learners who did not reach Grade 12 into account. For example, by 2011 only 50% of learners that enrolled in Grade 1 reached Grade 12, and only 40% of those learners passed Grade 12, whilst only 12% qualified for access to university (Spaull, 2013).

The first opportunity to gain an overview of the education system as a whole, came in 1995 when South Africa participated in the third Trends in International Mathematics and Science Study (TIMSS) (Howie, 2004). South African schools, both public and private, took part in the 1995, 1999, 2003, 2011 and 2015 iterations of TIMSS (Reddy, Visser, et al., 2016). The 2015 iteration of TIMSS was therefore the fifth time that South African schools took part in the International Association for the Evaluation of Educational Achievement's (IEA) series of international assessments aimed at improving teaching and learning in mathematics and science (Human Sciences Research Council [HSRC], 2017).

Based on the achievement of South African Grade 8 learners in the 1995 and 1999 studies, the South African TIMSS National Research Coordinator (NRC) took a decision in 2002 to expand the TIMSS assessments to Grade 9 learners as well (Spaull, 2013). It was found from previous results that the TIMSS Grade 8 assessment was too difficult for South African Grade 8 learners and too many learners were performing on “guessing level” on the multiple choice items (Spaull, 2013, p. 16).

In view of South Africa’s unique education system, policies and procedures, the South African TIMSS NRC determined the TIMSS 2011 and 2015 assessments to be appropriate for South African Grade 9 learners only (Reddy, Arends, Juan & Prinsloo, 2016; Reddy et al., 2013). The TIMSS 2011 assessments were conducted in 45 countries (Mullis, Martin, Foy & Arora, 2012), while the TIMSS 2015 assessments were done in 39 countries worldwide (Mullis, Martin, Foy & Hooper, 2016).

South African learners’ mathematics achievement improved by 20 points on the TIMSS achievement scale, from 252 points in TIMSS 2011 to 272 points in TIMSS 2015 (Reddy, Visser, et al., 2016). If one further looks at the mathematics achievement of South African learners between 2003 and 2015, South African learners made the biggest improvement in mathematics achievement of all participating education systems worldwide (Department of Basic Education [DBE], 2016c). However, despite the improvement in mathematics achievement, South African learners still achieved the second lowest average score on the TIMSS achievement scale for 2015 (Mullis, Martin, Foy, et al., 2016).

On regional level, South Africa also participated in the Monitoring Learner Achievement (MLA) project for Grade 4 in 1999 (Chinapah, 2003) and the Southern and East African Consortium for Monitoring Educational Quality (SACMEQ) studies for Grade 6 in 2000, 2007 and 2013 (DBE, 2017c; Moloi & Chetty, 2011). At a national level, the Department of Basic Education

(DBE)[1] initiated several systemic studies for Grade 3 in 200 and, 2007, and for Grade 6 in 2004 (Reddy, Arends, et al., 2016). In 2011 the DBE introduced an annual national, standardised set of tests for literacy and numeracy in Grades 1 to Grade 9, the Annual National Assessments (ANA) (DBE, 2016b).

The ANA question papers were set and distributed by the DBE, while schools were responsible for conducting, marking and moderating the tests. The aim of the ANA was to measure learner achievement over time and to measure the improvement of the quality of the schooling system (DBE, 2016b). The ANA were population based and were designed to give immediate feedback to educators, parents, schools and the DBE on the state of education on classroom level in a specific school (Reddy, Arends, et al., 2016). However, the ANA were purely academic in nature and did not report on the school, educator or learner background.

Unfortunately these assessments all told the same story: that mathematics achievement of South African learners is lower than that of learners in most developing countries (Spaull & Kotze, 2015). Education in South Africa seems to be struggling, despite national interventions aimed at improving the skills and knowledge of educators (DBE & Department of Higher Education and Training [DHET], 2010; South African Council of Educators, 2011), and an ever-increasing national budget allocation (National Treasury, 2017a).

1.2. Background to the problem

Since the late 1990's the DBE implemented several interventions, such as curriculum reforms – namely the National Curriculum Statements in 2002 (Department of Education [DOE], 2002)

[1] The Department of Basic Education was formed in 2009 when the former National Department of Education (DOE) was split into two departments, namely the Department of Basic Education (DBE) and the Department of Higher Education and Training (DHET).

and the Curriculum and Assessment Policy Statements in 2012 (DBE, 2011) – and educator development programmes (DBE & DHET, 2010), aimed at improving the quality of education in South African schools. In order to fast-track the improvement of education in South Africa, the South African Government has been steadily increasing the spending on education to around 20% of the South African National budget in 2017 (National Treasury, 2017a).

The TIMSS assessment results allow for the comparison of South African learner achievement in mathematics and science with learner achievement in other countries using a standardised measuring instrument (Ndlovu & Mji, 2012). TIMSS also allows South African learner achievement in mathematics and science to be compared with achievement in previous iterations of the TIMSS study (Mullis, Martin, Ruddock, O'Sullivan & Preuschoff, 2009).

A worldwide trend that has emerged among TIMSS participant countries over the last decade, is the large scale implementation of educational technologies in schools in the hope that Information and Communications Technology (ICT) will improve the quality of education. According to the IEA, most countries that took part in TIMSS 2015 reported initiatives to integrate ICT in the mathematics curriculum (Mullis, Martin & Loveless, 2016). The IEA also found that most large scale initiatives to integrate ICT in education were fairly recent, with most initiatives starting after 2011. Additionally, 93% of participating countries reported special curriculum guidelines for the integration of ICT in mathematics education (Mullis, Martin & Loveless, 2016).

Despite interventions by the DBE and Provincial Education Departments (PEDs), the vast amount of money spent on education, and the fact that South African Grade 9 learners took part in TIMSS 2011 and TIMSS 2015, both of which were aimed at Grade 8 learners, the achievement of South African learners still ranked amongst the three lowest performing countries in both studies (Mullis, Martin, Foy, et al., 2012; Mullis, Martin, Foy, et al., 2016). The mathematics achievement of South African Grade 9 participants is depicted in Table 1.1.

Table 1.1: Mathematics achievement in TIMSS 2011 and TIMSS 2015

Mathematics achievement in **TIMSS 2011**		
Country	**Average scale score[2]**	**Standard Error**
Korea, Rep of	613	2.9
Singapore	611	3.8
Chinese Taipei	609	3.2
Hong Kong SAR	586	3.8
Japan	570	2.6
Russian Fed.	539	3.6
Israel	516	4.1
Finland	514	2.5
United States	509	2.6
England	507	5.5
Hungary	505	3.5
Australia	505	5.1
Slovenia	505	2.2
Lithuania	502	2.5
TIMSS scale centrepoint (500)		
Italy	498	2.4
New Zealand	488	5.5
Kazakhstan	487	4
Sweden	484	1.9
Ukraine	479	3.9
Norway	475	2.4
Armenia	467	2.7
Romania	458	4.0
UAE	456	2.1
Turkey	452	3.9
Lebanon	449	3.7
Malaysia	440	5.4
Georgia	431	3.8
Thailand	427	4.3
Macedonia Rep	426	5.2
Tunisia	425	2.8
Chile	416	2.6
Iran	415	4.3
Qatar	410	3.1
Bahrain	409	2.0
Jordan	406	3.7
Palestinian NA	404	3.5
Botswana*	***397***	***2.5***
Saudi Arabia	394	4.6
Indonesia	386	4.3
Syrian Arab Rep	380	4.5
Morocco	371	2
Oman	366	2.8
South Africa*	***352***	***2.5***
Honduras*	***338***	***3.7***
Ghana	331	4.3
* - Grade 9 participants		

Mathematics achievement in **TIMSS 2015**		
Country	**Average scale score[2]**	**Standard Error**
Singapore	621	3.2
Korea, Rep. of	606	2.6
Chinese Taipei	599	2.4
Hong Kong SAR	594	4.6
Japan	586	2.3
Russian Fed.	538	4.7
Kazakhstan	528	5.3
Canada	527	2.2
Ireland	523	2.7
United States	518	3.1
England	518	4.2
Slovenia	516	2.1
Hungary	514	3.8
Norway*	***512***	***2.3***
Lithuania	511	2.8
Israel	511	4.1
Australia	505	3.1
Sweden	501	2.8
TIMSS scale centrepoint (500)		
Italy	494	2.5
Malta	494	1.0
New Zealand	493	3.4
Malaysia	465	3.6
UAE	465	2.0
Turkey	458	4.7
Bahrain	454	1.4
Georgia	453	3.4
Lebanon	442	3.6
Qatar	437	3.0
Iran	436	4.6
Thailand	431	4.8
Chile	427	3.2
Oman	403	2.4
Kuwait	392	4.6
Egypt	392	4.1
Botswana*	***391***	***2.0***
Jordan	386	3.2
Morocco	384	2.3
South Africa*	***372***	***4.5***
Saudi Arabia	368	4.6
* - Grade 9 participants		

Adapted from Mullis, Martin, Foy, et al. (2012) and Mullis and Martin (2013)

[2] Average score achieved by Grade 8 learners on the TIMSS achievement scale.

Van Staden (2010) warns against viewing the participation in international comparative studies, such as TIMSS, as a competitive exercise to determine a country's standing in relation to other countries' performance on the IEA assessment scales. The focus should rather be on assessing what was intended with a country's curriculum over the last four years, which parts of the curriculum were implemented over the last four years, and what learners attained over the last four years (Van Staden, 2010).

In order to deliver on the promise of quality education for all South Africans, the DBE and some of the PEDs, notably the Gauteng Department of Education (GDE) and the Western Cape Education Department (WCED), started looking towards technology to assist with the provision of high quality teaching and learning to schools in the late 1990's (Gauteng Provincial Government [GPG], 2008; Isaacs, 2007; Western Cape Education Department [WCED], 2004). By 2002 there were 34 different ICT-related programmes and projects aimed at schools in South Africa (Isaacs, 2007). Two of these projects, namely the GautengOnline project started by the GDE in 2001, and the Khanya Project started by the WCED in 2003, were aimed at rolling out ICT to all schools in these two provinces (Du Toit, 2005; Petjé et al., 2002). Vandeyar (2013) sees these two projects as the first real education-centred ICT projects in Africa.

A question that remains largely unanswered though, is whether the investment in ICT in schools in South Africa has led to an improvement in the teaching and learning in schools? This study, therefore, explored the relationship between the investment in ICT in schools and the mathematics achievement of South African learners.

1.3. Research questions

The research questions that guided this study were a response to various reports of huge amounts of money spent on establishing ICT in South African schools (DBE, 2015; Gauteng

Department of Education [GDE], 2013; National Treasury, 2017a; WCED, 2007a) and anecdotal evidence that seemed to suggest that establishing ICT in South African schools had little effect on improved learner achievement (Alfreds, 2015; Blignaut, Els & Howie, 2010; Vilakati, 2014).

Based on the problem statement, the two research questions that guided the study were:

Research question 1: What is the relationship between the investment in ICT in South African schools, and the mathematics achievement of the Grade 9 learners who participated in TIMSS 2011 and TIMSS 2015 respectively?

In order to focus the study and align it to the theoretical framework selected for the study, the first research question was expanded into two sub-questions:

a) To what extent was ICT available to South African learners as reported in TIMSS 2011 and 2015 in relation to the:

- School context,
- Classroom and educator context, and
- Learner context?

b) What was the relationship between the ICT-related variables and the mathematics achievement in TIMSS 2011 and 2015 in relation to the:

- School context,
- Classroom and educator context, and
- Learner context?

Research question 2: How can the integration of ICT in South African schools be improved to show an increased educational return on investment (ROI)?

1.4. Nature of the study

Positivism produces research questions that can be tested against the reality in which research participants exist (McMillan & Schumacher, 2014). Positivism expects theory to provide a set of absolute rules through which to explore and predict this reality (Howell, 2012). However, this type of rigid exploration and prediction is extremely difficult to attain in the social sciences, consequently positivism was rejected as philosophical stance for this study. On the other hand, while post-positivist theory also produces research questions that can be tested against the reality in which research participants exist, it accepts that while this reality or truth exists, it "…could only be understood imperfectly or probabilistically" (Howell, 2012, p. 42) and that no common truth exists (Panhwar, Ansari & Shah, 2017). This study acknowledged that TIMSS 2011 and 2015 covered the whole of South Africa and a single reality probably did not exist for all South African participants. Post-positivism was therefore selected as philosophical position for this study.

This study followed a deductive approach where the research project started off with a number of research questions that were to be answered (McMillan & Schumacher, 2014). This study also followed a quantitative research approach in an attempt to establish the relationship between the investment in ICT in education and the mathematics achievement of South African learners. The TIMSS datasets are available in the public domain and can be retrieved from the IEA website (IEA, 2015). The IEA assured that a representative sample of South African participants were selected (Joncas & Foy, 2012; LaRoche, Joncas & Foy, 2016). This study, therefore, used purposive sampling in that the full datasets of TIMSS 2011 and 2015 were used in this study – the study focused on all 11 969 participants in TIMSS 2011, and all 12 514 participants in TIMSS 2015.

The study relied on a secondary data analysis (SDA) of the South African TIMSS datasets. Descriptive and inferential statistical analyses were used to describe each of the identified ICT-related variables in order to examine the relationship between the variables and the mathematics achievement of learners that took part in TIMSS 2011 and 2015. Post-positivism emphasises "multiplicity and complexity as hallmarks of humanity" (Ryan, 2006, p. 16) and this approach fits with the TIMSS research design of including contextual data with mathematical achievement results.

1.5. Purpose of the study

The purpose of this study was to investigate whether the investment in ICT in South African schools made any difference to the mathematics achievement of the learners. In order to gain insight to this question, the availability of ICT in South African schools was explored using responses from South African school principals, educators and learners to ICT-related questions in the TIMSS context questionnaires. These responses were compared with the average mathematics achievement of South African Grade 9 learners that participated in the 2011 and 2015 Trends in International Mathematics and Science Studies.

The results of this study may possibly contribute to the fields of mathematics education, education policy, educational technologies in schools, as well as educational planning and the setting of standards for schools. The study aimed to identify the following:

- School-related ICT elements that may have had an influence on learner achievement in mathematics.
- Educator- and classroom-related ICT elements that may have had an influence on learner achievement in mathematics.
- Learner-related ICT elements that may have had an influence on learner achievement in mathematics.

1.6. Conceptual framework of the study

Learner achievement in schools can be influenced by a variety of elements (Creemers, Stoll, Reezigt & ESI Team, 2007; Scheerens, 1990). The TIMSS studies used context questionnaires in order to collect data from sampled schools, educators and learners (Martin, Mullis &

Hooper, 2016). In order to be able to identify specific factors influencing learner achievement in TIMSS, Mullis et al. (2009) identified four distinct areas of research on which the TIMSS context questionnaires focus:

1. The mathematics curriculum as set out by the participating country's department of education.
2. The school context in which both the learner and educator function – this includes aspects such as the availability of resources and the socioeconomic status (SES) of the community in which the school is situated.
3. The background of the educator and the influence of the educator on teaching and learning effectiveness in the classroom context – this includes aspects such as the educational background of the educator, teaching techniques of the educator as well as application of learning in the classroom, perceived safety at school and perceived support from school management.
4. The context in which the learner functions – this includes learner-related information such as the learner's home environment, the learner's academic motivation and application, as well as background on the learner's parents and support available at home.

The four distinct areas of research of the TIMSS context questionnaires relate closely with the four levels of education effectiveness factors identified in the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2010), which attempts to define the dynamic factors associated with educational effectiveness. The Dynamic Model focuses on four distinct, but connected levels in the structure of education effectiveness – context-related factors (e.g. national and regional educational departments and policies), school-related factors (e.g. school policies for teaching and learning), classroom and educator-related factors, and learner-related factors (Antoniou, Kyriakides & Creemers, 2011).

In order to customise the study for the South African context, an adaptation of the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2010) was used as basis for the conceptual framework for the study. The conceptual framework supported the notion that the elements related to achievement in mathematics are most likely diverse for different learners. The conceptual framework that guided this study is discussed in Chapter 2.

1.7. Concepts used in the study

A number of concepts used in this thesis have specific meaning in the context of this study. These concepts are therefore clarified so that their intended meaning may be understood in the context of the study.

1.7.1. ICT (Information and Communications Technology)

In the context of this study, 'ICT' refers to any information or communications technology that has been made available to educators and learners for use during teaching and learning. The term ICT is therefore used as an alternative to the term educational technologies. Examples of ICT in schools include computers or tablets, computer software and data projectors. In this study ICT in schools does not refer to ICT used for administrative purposes.

1.7.2. Investment

The concept 'Investment' is common in business and is conceptually linked to 'Return on investment' (ROI) which implies a financial investment and the subsequent returns or profits made from the investment (Krueger, 2013). The education system is not in the business of making profit and the ROI on the investment of ICT in education can therefore not be quantified in rands and cents. In the context of this study, investment should be seen as the making available of ICT in schools without expecting returns in monetary terms. The value of the investment of ICT in education "…should be defined by its educational return, not its financial return" (Krueger, 2013, p. 25).

1.7.3. South African provinces

The Republic of South Africa is divided into nine provinces, each with its own provincial premier and provincial legislative authority (Republic of South Africa [RSA], 2017). The nine South African provinces are Eastern Cape (EC), Free State (FS), Gauteng (GP), KwaZulu-Natal (KZ), Limpopo (LP), Mpumalanga (MP), Northern Cape (NC), North West (NW) and Western Cape (WC). This study examined the involvement of South African participants in TIMSS 2011 and 2015 in relation to the province in which their schools were situated.

1.7.4. Structure of the South African government

The government of the Republic of South Africa is structured into three spheres, namely national government, provincial government and local government (RSA, 2017). Each of these spheres of government have executive and legislative authority in their own sphere and are described in the South African Constitution as "…distinctive, interdependent and interrelated" (RSA, 1996a, p. 1267).

This study examined ICT-related elements in education in South Africa and grouped participants according to the province in which their schools were situated. Although the DBE provides broad, national policy guidelines and strategies for the realisation of educational goals in the country, responsibility for implementing these national guidelines and strategies is decentralised to nine provincial departments of education, who then have the responsibility to manage schools in that particular province (DBE, 2016d). Consequently, there is very little uniformity in the approach to education-related matters in the nine South African provinces.

1.8. Assumptions of the study

The following assumptions were made in this study:

1. The study assumed that the IEA data for the TIMSS assessments in South Africa was valid and reliable. During the development of TIMSS items, the IEA and the local TIMSS NRC put measures in place to ensure that the questionnaires were valid, reliable and applicable to the South African context.
2. Incomplete data was removed from the data sets. The study assumed that this did not have an impact on the validity and reliability of the data due to the large size of the sample group available for research.

1.9. Delimitations of the study

The following delimitations were applicable to this study:

1. South African learner achievement in TIMSS was not compared to learner achievement in other participating countries.
2. The study focused only on the mathematics achievement of South African Grade 9 learners in TIMSS 2011 and TIMSS 2015.
3. This study did not focus on all of the South African data available in the TIMSS data sets, but focused on ICT-related variables in the school context, in the educator and classroom context, and in the learner context.

1.10. Limitations of the study

The following limitations were applicable to this study:

1. At the time of the study, the TIMSS 2015 data set was the most current data set available. The limitation is that this data may not accurately reflect the current reality of South African schools and learners.
2. The study followed a secondary data analysis approach. Accordingly many detailed contextual questions remain unanswered and were indicated as possible areas of future research in Chapter 8.

1.11. Ethical considerations

All TIMSS datasets are managed by the IEA Data Processing and Research Center (DPC). The IEA website states that "There are a number of resources available to support researchers interested in secondary analysis of IEA data. The datasets are managed by the IEA Data Processing and Research Center (DPC) and are available in the public domain" (IEA, 2017d, para. 1). Specific permission to use the South African data from TIMSS 2011 and TIMSS 2015 was, nonetheless, received from Dr Cas Prinsloo of the Education and Skills Development Unit at the Human Sciences Research Council of South Africa (HSRC) on 17 July 2015 (see Appendix 1: Permission to use data from the South African TIMSS studies).

The privacy of participants in the TIMSS study is protected by the IEA DPC and it was not possible to identify any participants from the data sets. The only identifiable data used in this study was an indication in which one of the nine South African provinces the schools, educators and learners were situated.

Additionally, all rules and regulations as stipulated by the University of Pretoria's Faculty of Education Ethics Committee were abided by and permission to commence with the fieldwork of the study was granted on 11 August 2016 (see Appendix 2: University of Pretoria Faculty of Education Ethics Committee permission to commence with the study). At the conclusion of the study, the University of Pretoria Research Ethics Committee issued Ethics Clearance Certificate number SM16/06/02 on 16 October 2017 (see Ethical Clearance Certificate on p.ii of this thesis) to confirm that all ethical considerations were abided by during this study.

1.12. Chapter outline

This thesis is organised in eight chapters. The outline of the different chapters in the thesis is as follows:

Chapter 1: This chapter serves as an introduction to the study by presenting the background to the research problem, an overview of the research questions and the purpose of the study. Additionally, the chapter provides definitions of central concepts used throughout the study, as well as background information on the limitations, delimitations and ethical considerations of the study.

Chapter 2: This chapter provides an overview of literature related to the use of ICT in teaching and learning. The chapter explores existing literature on the benefits and challenges to schools, educators and learners when using ICT for teaching and learning. Additionally the roles and responsibilities of the different role players in the integration of ICT in education are discussed. An overview of the state of affairs of education in South Africa is provided. The conceptual framework used to guide the study is presented and discussed.

Chapter 3: This chapter provides an overview of the research design and research methods used in the study. Firstly, the research design and research methods followed for the TIMSS 2011 and 2015 studies are discussed. Sampling of participants, the development of the TIMSS research instruments, data collection during the rollout of TIMSS 2011 and 2015, and general background to the IEA research approach are unpacked. Secondly, the research design and research methods followed for this study are explained. Data sources used for this study, participant selection, instruments and variables used in the study, as well as background to secondary data analysis is provided.

Chapter 4: The background to the data analysis of the identified ICT-related variables from the TIMSS 2011 and 2015 context questionnaires and reporting thereof is discussed in this chapter. Specific mention is made of the selection of variables and data sources for inclusion in the study.

Chapter 5: Chapter 5 presents the data analysis and results of the identified ICT-related variables in the 2011 and 2015 Eighth Grade *School* Questionnaires. Six ICT-related variables (three from 2011, and three from 2015) are examined and reported on.

Chapter 6: Chapter 6 presents the data analysis and results of the identified ICT-related variables in the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires. Fourteen ICT-related variables (seven from 2011, and seven from 2015) are examined and reported on.

Chapter 7: Chapter 7 presents the data analysis and results of the identified ICT-related variables in the 2011 and 2015 Eighth Grade *Student* Questionnaires. Nine ICT-related variables (four from 2011, and five from 2015) are examined and reported on.

Chapter 8: Chapter 8 presents a summary of the research project in terms of a reflection on the literature, the theoretical framework and the research methodology. The results from the three TIMSS context questionnaires are interpreted in order to attempt to provide answers to the research questions. Recommendations for further research, suggestions for improved ICT-related policy making in education, as well as suggestions for improved ICT integration in education, are made. Additionally, Chapter 8 presents a proposed new model for improved ICT integration in schools, the *IIIA-Model for the integration ICT in Schools (IIIA-Model)*. The IIIA-Model is aimed at improving the integration of ICT in schools in order to demonstrate an increased educational return on investment (ROI).

1.13. Summary

Chapter 1 provided an introduction to the background and rationale of this study. The nature of the study was discussed and the theoretical framework that guided the study was introduced. Key concepts used in the study were clarified and the assumptions, limitations and delimitations of the study were stated. Adherence to the ethical prescripts of the University of Pretoria Research Ethics Committee during the study was discussed. Finally, an outline of the chapters in this thesis was provided.

Chapter 2 will provide background to the literature that was consulted prior to the start of the study. The literature review guided the design and implementation of the study.

2. CHAPTER 2 – LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

"South Africa needs to ensure that ICT becomes an enabler in the country. On the skills front, many young people from historically disadvantaged backgrounds come out of the basic education system, never having been exposed to ICTs. This impacts their performance in institutions of higher learning, as well as their ability to adapt and become competent in the use of ICTs."

President Jacob Zuma[3], President of the Republic of South Africa (Chiles, 2012, p. 1)

"We must admit that the transformation of our education system into 21st century learning environments that provide our learners with the skills they need to succeed in today's information age economy is long overdue."

Ms Angie Motshekga[4], Minister of Basic Education (RSA, 2015, p. 1)

2.1. Introduction

After the dawn of democracy in 1994, the South African Government identified education reform as one of its priorities for the upliftment of a large number of South Africans disadvantaged by previous policies of segregation in the country (Isaacs, 2007; Organisation for Economic Co-operation and Development [OECD], 2008; RSA, 1996b). A number of education legislation, policy and curriculum reforms have changed the South African education landscape over the past twenty years. The most important change has been the establishment of a single education department to replace the racially segregated education departments that existed before 1994 (Lundall & Howell, 2000; RSA, 1996a; RSA, 1996b). However, since 1994 the education system in South Africa has faced huge challenges, such as poor learner achievement, diminished labour market relevance (OECD, 2008) and the redress

[3] Keynote address at the 53rd African National Congress National Policy Conference in Midrand.
[4] Keynote address at the second phase of the "Big Switch On – Paperless Classrooms Programme" in Gauteng.

of differences in resources between poor and privileged schools (Chisholm, 2005; Du Toit, 2005)

Worldwide, Information and Communications Technology (ICT) is acknowledged as a crucial ingredient for the transformation of any society (DOE, 2004; OECD, 2010; Plomp, Pelgrum & Law, 2007). Since the late 1990’s the DBE implemented several interventions aimed at improving the quality of education in South African schools. While these interventions, such as frequent curriculum reforms – the National Curriculum Statements in 2002 (DOE, 2002) and the Curriculum and Assessment Policy Statements in 2012 (DBE, 2011) – and professional development programmes for South African educators were received well (DBE & DHET, 2010). However, concern still exists about the quality of education in South Africa (Howie & Hughes, 1998; Reddy, 2006; Spaull, 2013). In the Education at a Glance 2016 study conducted by the Organisation for Economic Co-operation and Development (OECD) on education in South Africa, a clear relationship between higher levels of education and improved social outcomes was identified (OECD, 2016). According to this study, educational achievement seemed to have a significant influence on the perceptions of life fulfilment of South African individuals aged 25 to 64.

In order to fast-track the improvement of education in South Africa, the South African government has been steadily increasing government spending on education. Between 2011 and 2017, the national budget allocation for education has increased from R198 billion in the 2011/12 financial year to around R320.5 billion in the 2017/18 financial year (National Treasury, 2017a; Statistics South Africa, 2015). In the 2017/18 financial year the expenditure on education reached around 20% of the total South African government budget (National Treasury, 2017a). Despite this increase in expenditure on education, the South African government still spent significantly less than the OECD average per South African learner in 2016 – the 2016 expenditure on South African secondary school learners was US$ 2 513 per learner, while the OECD average for the same year was US$ 9 811 per learner (OECD, 2016).

However, the South African government budget is severely constrained and in the 2017 Medium Term Budget and Policy Statement (National Treasury, 2017b) the Minister of Finance revised the budget allocation for education downward to R249.8 billion. In a media statement, Equal Education, a lobby group of education activists promoting improved education in South Africa, expressed concern at the decrease in actual budget allocation to education and advocated for increased government spending to improve the basic infrastructure which is still lacking in many South African schools (Equal Education, 2017). The burden to do more with less is a daily reality in South African schools (Equal Education, 2017; Spaull & Kotze, 2015) and the (incorrect) idea that a once-off investment in ICT may alleviate the pressure seems to be reason enough for education leaders to seriously consider supporting the integration of ICT in schools .

2.2. ICT in the context of education

ICT is a central concept used in this study and it is therefore necessary to further unpack how ICT is understood in the context of education. The White Paper on e-Education identifies three separate aspects when it comes to ICT in education:

> *Enriching the learning environment through the use of ICT is continuum; it's a process that takes learners and teachers through* learning about ICTs *(exploring what can be done with ICTs),* learning with ICTs *(using ICTs to supplement normal processes or resources) and* learning through the use of ICTs *(using ICTs to support new ways of teaching and learning).* (DOE, 2004, p. 19)

"Learning with ICTs" can be defined as using ICT as a tool to support teaching and learning in a traditional classroom (Webb, 2002, p. 238). The use of educational software for the drill-and-practise of mathematics tables is a good example of learning with ICT. "Learning through the use of ICTs" can be defined as situations where ICT functions as the total learning environment – the provision of learning materials, the teaching, the testing and the assessment is conducted inside the environment created by ICT (Webb, 2002, p. 238). A good example of learning through the use of ICT is the use of Massive Open Online Courses (MOOCs) where learners from anywhere in the world log into a learning site and complete their learning there.

A number of studies found the availability of ICT for personal use to be closely linked to a country's levels of economic and social development – the more ICT available for personal use, generally the higher a country's levels of economic and social development (Bialobrzeska & Cohen, 2005; Plomp et al., 2007; World Bank, 2016). Fuchs and Woessmann (2004) identified the use of ICT to be beneficial for the economic prospects of an individual. Their research showed that computer skills may impact positively on the productivity and income of individuals, and the labour market prospects of individuals may widen when ICT is used to learn new skills.

The availability of ICT for personal use in South Africa has slowly increased over the recent past. It is interesting to note that Statistics South Africa only started to include computers as indicator of household assets in the *2012 General Household Survey* (Statistics South Africa, 2013) when 19.5% of households in South Africa indicated that they possess at least one computer. By 2016 the number of South African households with at least one computer increased slightly to 21.4% (Statistics South Africa, 2017).

In this study the use of ICT as a tool for teaching and learning in the context of mathematics education in South Africa was explored. Data collected during the 2011 and 2015 iterations of the TIMSS studies was used. This study therefore focused on ICT as tool for teaching and learning in South African schools and does not enter into debate on whether ICT should be integrated into the curriculum of other subjects at South African schools.

2.3. General benefits of the use of ICT

The benefits and potential power of ICT in the private business sector have long been accepted (International Society for Technology in Education [ISTE], 2016; Law, Pelgrum & Plomp, 2008; World Economic Forum [WEF], 2015). Integrating ICT in teaching and learning in order to harness its potential power and application for education is becoming more prevalent (Mullis, Martin & Loveless, 2016). At the turn of the century, Imison and Taylor (2001) already identified ICT as catalyst in extending the boundaries of traditional teaching and learning.

Emerging economies, like South Africa, face many demographical, political and social challenges and these challenges demand an ICT friendly education environment which will prepare learners for participation in the modern economy (Stols et al., 2015; WEF, 2015). There is a general agreement that the global economy is changing from a predominantly industrial economy to a knowledge economy (Gudmundsdottir, 2010; United Nations, 2015; WEF, 2015). Anderson (2008) sees the concept of knowledge economy as economic systems where knowledge and concepts function as commodities. Two of the features of a knowledge economy that are relevant for education, are that technology simplifies the sharing of knowledge and that knowledge now functions as a commodity in the economy of a country (Anderson, 2008).

In their 2016 Standards for Students, the International Society for Technology in Education (ISTE) identified seven ICT-related skills and qualities that learners need to engage in a modern, digitally connected world (ISTE, 2016). The seven ICT-related skills needed to engage in a modern, digitally connected world are: to be an empowered learner, a digital citizen, a knowledge constructor, an innovative designer, a computational thinker, a creative communicator and a global collaborator. These ICT-related skills are unpacked in Table 2.1.

Table 2.1: ICT-related skills required to engage in a modern, digitally connected world

ICT-related skill	Application in a modern, digitally connected world
Empowered learner	Use ICT to take an active role in selecting, accomplishing and demonstrating their attainment of their learning outcomes.
Digital citizen	Recognise the rights, responsibilities and opportunities of an interconnected digital world.
Knowledge constructor	Use ICT to construct knowledge, produce artefacts and have meaningful learning experiences for themselves and others.
Innovative designer	Use ICT to creatively identify and solve problems by creating new, innovative solutions.
Computational thinker	Use ICT to understand problems and develop and test solutions to those problems.
Creative communicator	Communicate clearly and express themselves using the ICT tools appropriate for the situation.
Global collaborator	Use ICT to broaden their perspectives and enrich their learning by collaborating effectively.

ISTE (2016)

The seven skills identified by the ISTE (ISTE, 2016) correlate closely with the skills and learning strategies required for optimal functioning in a knowledge society as identified by Anderson (2008). The skills and learning strategies required to function in a knowledge society are depicted in Table 2.2.

Table 2.2: Skills and learning strategies required in a knowledge society

Demands from society	Skills required	Learning strategies
Use knowledge as a commodity.	Able to construct knowledge.	Constructivism; inquiry; project-based learning.
Able to adapt to rapid change.	Adaptability.	Relearn; just-in-time learning; self-directed learning.
Able to deal with large amounts of new information.	Find, retrieve and organise information. Use ICT to manage information.	Multiple sources of information.
Able to deal with badly organised information.	Information management. Use ICT to manage information.	Design and implement a personal database of organised information.
Able to distinguish between valid and non-valid information.	Critical thinking.	Problem solving through critical evaluation of information.
Knowledge sharing.	Teamwork.	Collaborative learning.

Anderson (2008, p. 7)

Countries' need to be globally competitive and improve social conditions of its citizens, is often used to justify investment in educational and developmental improvement programmes that utilise the power and application of ICT (Butcher, 2011; Draper, 2010; Lundall & Howell, 2000). In a fast changing world, schools need to prepare learners for jobs that may not yet exist – the ability to effectively use ICT is therefore recognised as an essential competency to prepare learners to function in the twenty first century (Draper, 2010; ISTE, 2016).

In 2007 the ISTE recommended that young children should acquire basic technology skills by their fifth birthday (ISTE, 2007). The ISTE stated that basic ICT skills lay the foundation for more advanced ICT literacy skills later in life. These skills prepare young people for critical thinking and the use of technology in the future. This was corroborated by a study by Bonaveri, Blanco, Calvo and Cepeda (2015) that found that the integration of ICT in classrooms offered Grade 10 and Grade 12 learners access to ICT skills required to succeed later in life.

In a globalised world people increasingly rely on ICT to communicate, access information, and stay connected with each other (OECD, 2010; WEF, 2015). In most developed countries, ICT features prominently in primary and secondary education and most educators and learners will use various forms of ICT for teaching and learning activities (Law et al., 2008). Educators have the huge task of preparing their learners for "jobs that may not exist yet, where they will use technologies that may still need to be invented, to solve problems that we don't even know are problems yet" (Esteves, 2016, 2:26).

At the United Nations (UN) Millennium Summit in September 2000 a gathering of world leaders adopted the UN Millennium Development Goals, a set of eight targets to reduce extreme poverty in the world by 2015 (United Nations, 2002). Universal access to primary school education was identified as the second most important goal, after eradicating hunger and extreme poverty. The UN identified the use of ICT as one of the major enablers for ensuring universal access to primary school education and the eradication of abject poverty (United Nations, 2015).

It is not only in developing countries that the use of ICT in education has gained momentum – in the United States, the National Association for the Education of Young Children, which was traditionally sceptical regarding the use of technology for the education of young children, released a position statement in 2012 that supported the use of technology in early childhood education as long as the technology could be deemed developmentally appropriate (National Association for the Education of Young Children, 2012). Since 2000 the American Academy of Paediatrics (AAP) warned parents against any screen time for young children (Blackwell, Lauricella & Wartella, 2016). However, in 2015 the AAP also revised its position to acknowledge research showing that high quality educational technologies may have positive effects on the social and mental development of young children (Shifrin, Brown, Hill, Jana & Flinn, 2015).

The AAP also acknowledged that modern teens use technology to become more independent, validate their identities and build connections and that adolescent development more and more involves the use of technology (Shifrin et al., 2015). Additionally the National Institute for Literacy in the United States compared the importance of early digital literacy skills to the importance of early book handling skills (National Institute for Literacy, 2008).

In the 1990's Jonassen (1996, p. 24) coined the phrase "cognitive tools" or "mindtools". Jonassen (1996) saw cognitive tools as an overarching concept of how to use technology in class. The idea was that the technology should not be the goal, but the means to reach a goal. Jonassen (1996) encouraged the use of technology to allow learners to construct knowledge themselves through critical and analytical thinking. This ties in with studies by Flynn (1999) that demonstrated a worldwide increase in IQ over years. Flynn (1999) suggested that this increase could be linked to the modernisation of society and the increasing complexity that people have to deal with on a day-to-day basis. Inside and outside their comfort zones, learners are confronted with changing ways of acting and interacting with others and information, and this seems to have a direct impact on human development and cognitive growth (Gauvain & Munroe, 2009).

Law (2009) stated that in classrooms where the use of ICT was integrated in the development of skills, the classrooms tended to be more learner-centred in their approach as opposed to educator-centred learning environments in traditional classrooms. Law (2009) also found that these learner-centred learning environments stimulated problem-solving skills that learners could apply beyond the walls of the classroom. Jenkins, Purushotma, Weigel, Clinton and Robison (2009) identified a range of skills that children need for their development in a modern world. These skills include improvisation, experimentation, simulation, multitasking, networking and the ability to evaluate diverse sources of information. The integration of ICT in education seems to be especially valuable when trying to develop these non-academic skills in learners (Lee & Wu, 2013).

It is therefore becoming increasingly important to expose learners to ICT in schools in order to prepare them for the modern job market. In a developing country like South Africa, where the vast majority of learners do not have access to ICT at home (Statistics South Africa, 2017), a huge responsibility thus lies with the education sector to empower learners in the use of ICT.

2.4. Educational benefits of using ICT

The integration of ICT in education is seen as an encouraging approach to assist disadvantaged learners and schools to improve access to quality education across the world (Bai, Mo, Zhang, Boswell & Rozelle, 2016; Higgins, Xiao & Katsipataki, 2012; Mlitwa & Koranteng, 2013). However, even in developed countries the integration of ICT in education is seen as a way to improve the quality of education, and in Norway the Ministry of Education and Research regards digital literacy as a basic skill, along with speaking, reading, writing and mathematics (Røkenes & Krumsvik, 2016).

There is a general belief among proponents of ICT in education that integrating ICT in education can replace 'bad' educators and that learners will still learn (Bai et al., 2016). The belief is also that ICT programmes in schools can be rolled out more cost effectively than educator development, due to the limited human resource requirements of ICT programmes (Rahimi & Yadollahi, 2011). Rahimi and Yadollahi (2011) also found that the belief exists that ICT will improve teaching regardless of the quality of teaching or the effort put into teaching by the educator.

In research conducted for the Africa Institute of South Africa (AISA) in the South African context, Mdlongwa (2012) identified specific learner-related benefits when integrating ICT in education. He saw increased motivation, participation, creativity, collaboration and an increase in responsibility and self-esteem among the learners that took part in the study. He also documented improved knowledge and skills of learners in the subjects where ICT was integrated in the teaching and learning process. This was confirmed in a South African study by Vandeyar (2013) that found educators saw similar benefits emerge when using ICT in their teaching and learning. In a study conducted in Colombia, Bonaveri et al. (2015) also found an increase in motivation, self-esteem and self-confidence in the Grade 10 and Grade 12 groups they investigated.

Mdlongwa (2012) also looked at the benefits of integrating ICT in schools as identified by educators in the study. Educators identified improved administration, such as better record keeping and lower administrative costs (e.g. photocopying), as some of the main benefits to them. Educators indicated that they were able to respond to changes in the curriculum more effectively when using ICT in the classroom. Educators also indicated that they felt that their learners had access to better quality learning materials when using ICT. The use of data projectors specifically, allowed educators to show disadvantaged learners real-life situations that they would not normally be able to experience. In their study in Colombia, Bonaveri et al. (2015) also found that ICT provided educators with opportunities for expanding teaching beyond the classroom. An interesting observation made by educators in the Mdlongwa (2012) study, is that learners acquire a variety of non-academic skills, such as typing skills, skills in

Microsoft Word and Microsoft Excel, as well as general computer literacy skills that could be used outside of the classroom as well.

In research conducted on the One Laptop per Child (OLPC) project in Ethiopia in 2012, Hansen et al. (2012) found that the primary impact of the 5 800 laptops of the OLPC project was on the learners' cognitive performance rather than on their school performance. Hansen et al. (2012) found that access to a laptop did not directly affect academic skills which are routinely examined in the school context, such as writing skills and mathematics. They did however find that the laptops impacted on the learners' cognitive performance and reasoning abilities, both of which are essential for effective learning.

Hansen et al. (2012) found that disadvantaged learners in the OLPC project had to learn how to operate a laptop from scratch, which in itself was a learning encounter that was likely to have a positive intellectual impact. Using ICT in developing countries develop new skills and make new demands on the learners' abstract reasoning skills – learners are constantly required to expand their existing understanding and apply their understanding to a new environment (Maria De Fátima & Alves, 2007).

This finding corresponds with findings from a study Mayer (1997) did on multimedia learning. Mayer (1997) found that humans engage in three distinct cognitive processes when confronted with multimedia technology – select, organise and integrate the verbal and visual information. Hansen et al. (2012) postulates that in order to engage in these three cognitive processes, learners needed fall back on familiar situations to interpret the new unfamiliar situation and processes presented by the laptop. Learners therefore applied their reasoning abilities in order to explore the activities provided by the laptop. This finding is supported by research done in South Africa by Sujee (2015) that found that the use of ICT led to the creation of a challenging learning environment that was conducive to the development of higher order thinking skills and deep learning. This was, furthermore corroborated by a study, done by Condie and Munro (2007) in Britain, that found while the use of ICT increased motivation in learners, the increase in motivation did not directly lead to improved academic performance.

Condie and Munro (2007) linked the use of ICT with the development of learner autonomy, higher order thinking skills, metacognitive skills and self-regulation. Condie and Munro (2007) postulated that the development of these skills, and not the use of ICT, led to improved learning and performance. In a study comparing four communities in Belize, Kenya, Nepal and American Samoa, Gauvain and Munroe (2009, p. 1630) found that learners who were exposed to what they called "modernisation (information stimuli, such as mass media)", achieved better results on all cognitive measures in the study. They found that these changes were measurable and comparable in societies who were at the same point of modernisation.

Hansen et al. (2012) postulate that for learners in developing countries the laptop was a source of new experiences in a milieu where their experience of new information was usually very restricted. In many developing countries, education have a tendency to be educator-led and seems to be focused on the attainment of concrete skills (Glewwe & Kremer, 2006). In many of these countries there seemed to be a lack of learning materials and this meant that learners did not get adequate opportunities to independently explore significant quantities of new information (Hansen et al., 2012).

Hansen et al. (2012) found that the effect of the OLPC project in Ethiopia appeared to be quite large when compared with the limited effect of similar programmes on learners in developed countries (Penuel, 2006; Zucker & Light, 2009). The large effect in the Grade 6 and Grade 7 groups of the study seemed to be due to the fact that for Ethiopian learners the laptop was a completely new experience, different from anything they have experienced before. Hansen et al. (2012) argue that the use of laptops improved their abstract reasoning since learners needed to draw parallels between activities and information offered by the laptop and information that was familiar to them. The positive effect was strongest among older learners who used the laptop intensively and explored a wider variety of activities. The skills gained by interacting with the laptop activities seemed to enhance learners' ability to identify, explore and interpret consistencies and structures in the world around them (Hansen et al., 2012).

The findings by Hansen et al. (2012) supported earlier research done by Gauvain and Munroe (2009) that suggested that using ICT in education could be related to improved abstract reasoning abilities in school going children. This tied in with research done by Wurst, Smarkola and Gaffney (2008) that found that the main aim of educators integrating new technologies in education was the belief that the ICT could assist in making teaching and learning more effective and efficient. While Wurst et al. (2008) stated that using ICT devices in class provided learners with new tools to explore and understand the subject matter, Ferrer, Belvís and Pàmies (2011) found that integrating ICT in the curriculum also assisted learners with barriers to learning to become more confident in expressing their own ideas and thoughts.

However, in a longitudinal study of 3 345 Australian learners, Hatzigianni, Gregoriadis and Fleer (2016) found no significant impact on these learners' social-emotional outcomes. In these schools ICT was used as an important resource to support learners' creativity, but Hatzigianni et al. (2016) found that while computers can and do increase learners' exposure to new things, the interventions only seem to have impact if both the situational and personal characteristic of the learners are taken into consideration.

In a research project on the influence of the use of ICT on youth from lower SES environments, Shank and Cotten (2014) found an unexpected negative correlation between owning a computer and mathematical self-efficacy. Shank and Cotten (2014) speculated that not owning a computer may have forced learners to collaborate among one another. This speculation is supported by a study by Springer, Stanne and Donovan (1999) that suggested that mathematics is better learned in small groups.

Interesting to note is that Hansen et al. (2012) found that only 2.8% of learners surveyed indicated that they used their laptop in class. Hollow (2009) made a similar observation while monitoring the implementation of this project in Ethiopia – if educators used the laptops in class it was mainly to access the electronic versions of existing textbooks. In a study conducted in state sponsored schools in Chile, Hinostroza, Labbé, Brun and Matamala (2011) found that educators in high performing Chilean schools used ICT more frequently than educators in low performing schools. While Hinostroza et al. (2011) conceded that the difference might be due to contextual factors, such as educator competencies, it is important to note that the ratio of learners per computer (22 learners to one computer) was the same for both groups. They also found no statistically significant differences between the means of frequencies between the two groups of schools for educator training in ICT, educator self-perception of ICT skills, or in the use of ICT for classroom- and school management-related activities.

Hinostroza et al. (2011) found that learners from high performing schools reported a lower frequency of the use of ICT in most of the activities, as opposed to learners from lower performing schools that reported a higher frequency of the use of ICT in class. The only activity where learners from high performing schools reported a higher frequency, was with the activity of presenting information to others. This is corroborated by Higgins et al. (2012) who found that although the use of ICT engaged learners, there was only an advantage to learning if the activity was aligned to what needed to be learned.

Hinostroza et al. (2011) also found that learners from high and low performing schools in Chile used ICT to perform different learning activities. On the other hand educators used ICT for similar teaching activities in both high and low performing schools.

A long-term research project by the American Association for the Advancement of Science (AAAS), namely Project 2061, aims to improve science education to ensure literacy in mathematics, science and technology (American Association for the Advancement of Science [AAAS], 2016). A research paper by the AAAS stated that while the use of ICT may not be the end of curriculum problems, it should be used to transform the curriculum closer to the intended outcomes of the curriculum (AAAS Project 2061, 2001).

In a research study by Owusu, Monney, Appiah and Wilmot (2010) on the effect of the use of ICT on learner performance in biology in Ghana, they found that although high and low achieving learners believed they benefitted from the intervention, the performance of the low achievers in the group was more enhanced.

Interestingly, Owusu et al. (2010) noted no significant difference in the average achievement between the group that used ICT and the group that used traditional teaching methods, except for the low achieving learners in the ICT group that performed significantly better. This is corroborated by a study in Spain by Ferrer et al. (2011) that found that learners with low academic performance and who are from low SES households benefitted more from interventions using ICT. They found that while there was no significant difference in the use of ICT between boys and girls, the boys in the group showed the most improvement after the ICT intervention. Ferrer et al. (2011) reasons that this may be because the boys in the group had a significantly lower baseline academic performance than the girls. In this study the introduction of ICT reduced the performance gap between the boys and girls in the group and brought about a reduction of inequality between the groups.

In an Italian study, Pagani, Argentin, Gui and Stanca (2016) also found a significant increase in academic performance for learners with low academic performance and learners from low socioeconomic households. An important observation made by Bai et al. (2016) was that learners with low academic performance only benefitted from the introduction of ICT when their educators integrated ICT into the curriculum. When educators implemented ICT as standalone interventions they recorded no benefit to learners with low academic performance.

A global body of evidence exists on the positive impact of ICT on the learning and development of learners with special needs (Condie & Munro, 2007). A range of assistive technologies are specifically designed to support learners with disabilities that have special learning needs. Many mainstream ICT devices, such as computers and smart phones, integrate seamlessly with these assistive devices to support these learners. The introduction of ICT in classrooms led to the development of innovative strategies to deal with diversity in the classroom.

In their study on the implementation of ICT, Ferrer et al. (2011) saw a positive impact on the learning processes and academic performance of immigrant learners. They also saw an improvement in the integration of the immigrant learners with the other learners in the group.

Higgins et al. (2012) identified six lessons learned from their study for the British Education Endowment Foundation. The co-operative use of ICT was more effective than individual use. ICT was more powerful in increasing learner performance when used as a short, focused intervention. Lower performing learners, learners with special educational needs and learners from disadvantaged backgrounds benefitted from the remedial and tutorial use of ICT. ICT in classrooms had more impact when used in blended learning environments. Learner performance in mathematics and science benefitted more than other subjects, e.g. literacy. Educators needed at least one full day's training in the use and implementation of technology in their classrooms.

As globalisation increases, South African tertiary institutions and workplaces are becoming more technologically advanced and the preparation of school leavers to function in this digital environment becomes more important (Sujee, 2015). The question facing the 21st century learner is no longer what technology to use, but how to select and use the appropriate technology for a task (Higgins et al., 2012; Mentz & Mentz, 2003).

2.5. The role of governments in the integration of ICT in education

There seems to be a general perception that Africa lags behind developed countries where the use of ICT is concerned (United Nations, 2015; WEF, 2015). Kozma (2008) sees national ICT-related education policies and programmes as two important aspects when countries aim to harness the power of technology for teaching and learning. National ICT-related education policies have an important role to play by providing

> *…a rationale, a set of goals, and a vision for how education systems might be with the introduction of ICT, and how students, teachers, parents and the general population might benefit from its use in schools* (Kozma, 2008, p. 1084).

While many developing countries have good ICT policies and services in place, most of these countries fail to fully harness the power of technology due to implementation challenges on grassroots level (Owusu et al., 2010). Additionally, Howie (2010) suggested that another obstacle for the implementation of technology in developing countries was that most of the global discussions on ICT-related education policies took place in the context of well-resourced, developed educational conditions.

In order to be implementable, Kozma (2008) suggests five specific operational components to be included in national ICT-related education policies: infrastructure development (this includes any budget allocations for ICT-related resources), educator training (this includes continuous professional development programmes for educators focusing on the specific skills that need to be acquired), technical support (this includes specifying which hardware and software support will be provided), pedagogical and curriculum-related change management (this includes identifying required ICT-related changes in the curriculum, in educational practice, and in assessment practices), and content development (this includes identifying any required digital content development where needed). Only when these operational components are in balance will the ICT-related education policies lead to the effective pedagogical use of ICT in teaching and learning (Kennisnet Foundation, 2015).

The South African Government responded proactively by adopting the concept of ICT in education on both policy and political level by creating a supportive policy environment for the integration of ICT in the South African society as a whole – the *Electronic Communications and Transactions Act* was promulgated in 2002 (RSA, 2002) and a *White Paper on e-Education: Transforming learning and teaching through information and communication technologies* was published in 2004 (DOE, 2004). Both these documents aimed to pave the way for the integration of ICT in South African society.

The White Paper on e-Education acknowledged the need to prepare learners with the knowledge, skills, attitudes and values required for an ever-changing world, while increasing the effectiveness of the education system and keeping costs at a minimum. Through the White Paper the Department of Education (DOE)[5] expressed the belief that access to ICT in schools will lead to the increased quality of teaching and learning, the creation of access to quality learning interventions and the redress of past inequalities:

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

The White Paper on e-Education gave PEDs the mandate to provide schools with both professional ICT support, as well as and technical ICT support. As a result of this policy directive, eLearning directorates were established at provincial and district level in order to support schools with the implementation of the objectives of the White Paper (Vandeyar, 2013).

Draper (2010) found that the potential of ICT to assist with the improvement of education in South Africa had a direct effect on policy development and the prioritisation of the DOE's expenditure on ICT-related projects. Implementation of Education-related policies lies with the nine PEDs (Isaacs, 2007). South Africa has a comprehensive and enabling ICT policy environment, but the objectives of the policies are not yet visible in most South African classrooms (Czerniewicz & Hodgkinson-Williams, 2005; Howie & Blignaut, 2009; Mlitwa & Koranteng, 2013).

[5] The former National Department of Education (DOE) was split into two departments in 2009, namely the Department of Basic Education (DBE) and the Department of Higher Education and Training (DHET).

The World Economic Forum (WEF) releases an annual Global Information Technology Report that contains a Networked Readiness Index (NRI) ranking. The NRI details 143 countries in terms of their ability to "prepare for, use and leverage ICT" (WEF, 2015, p. xiii). The NRI looks amongst others at factors such as the political and regulatory environment, infrastructure, digital content and the use of ICT, in order to calculate the overall NRI ranking of a country. In the 2015 WEF NRI, South Africa slipped five places to 75th place overall. South Africa is now placed third in Africa, behind Mauritius in 45th place and Seychelles in 74th place (WEF, 2015). Experts agree that while South Africa has a sound regulatory and policy environment, the implementation of these policies and regulations are slowing ICT expansion in the country (Van Zyl, 2015).

Vandeyar (2013) found a lack of understanding of the implications of the White Paper on e-Education (DOE, 2004) among South African educators. He indicated that there seems to be a need for an inclusive approach from the DBE when developing policy and implementing ICT in schools. The White Paper on e-Education envisaged that a large number of South African schools would have significantly changed teaching and learning environments by 2013 (DOE, 2004).

Unfortunately most of the planned Phase 3 outcomes envisaged by the White Paper on e-Education, such as educators and learners competent in the use of ICT, curriculum integration of ICT at schools, the use of high quality educational software and the involvement of communities in ICT at schools, have not yet been achieved (Vandeyar, 2015). Vandeyar (2015) suggested that a reason for the low impact of the 2004 White Paper on e-Education could be that the policy has always existed in isolation from the national curriculum statements – first the Revised National Curriculum Statement (DOE, 2002) in 2004, and currently the Curriculum and Assessment Policy Statements (CAPS) (DBE, 2011).

2.6. The role of schools and educators in the integration of ICT in education

The responsibility for creating a focused vision and strategy for ICT implementation in schools and encouraging teaching staff to collaborate in the development of ICT-friendly materials lies to a large extent with the school's management itself (Lakkala & Ilomäki, 2015). On the other hand, the responsibility for the material implementation of national education policies and guidelines in the classroom, lies with the educator in the class (Bryderup, Larson & Trentel, 2009).

Educators have to prepare learners for participation in a knowledge society – learners need to be prepared to be able to acquire new knowledge and the requisite ICT skills to function in a knowledge society (Anderson, 2008). Learners need to be able to "access, analyse, evaluate, integrate, present and communicate" information (DOE, 2004, p. 14).

The levels of success achieved by educators when communicating information using ICT relies heavily on human factors rooted within the educator (Drent & Meelissen, 2008; Kennisnet Foundation, 2015). Rahimi and Yadollahi (2011) identified educator behaviour as one of the foremost issues linked with the unsuccessful integration and adoption of ICT into the South African curriculum. They found that educators inadvertently function in a way that undermined the usefulness of the ICT that was brought in to assist with teaching and learning. Rahimi and Yadollahi (2011) also found that a big challenge was that educators used ICT software and materials without matching the software with the educational levels of the learners. Rahimi and Yadollahi (2011) also found that if ICT is not integrated in the curriculum, learner performance could actually be harmed.

In an effort to operationalise a definition of digital competence for educators, Krumsvik (2014) developed a model, describing the digital competencies needed by modern educators. The Model of Digital Competence for Educators is depicted in Figure 2.1.

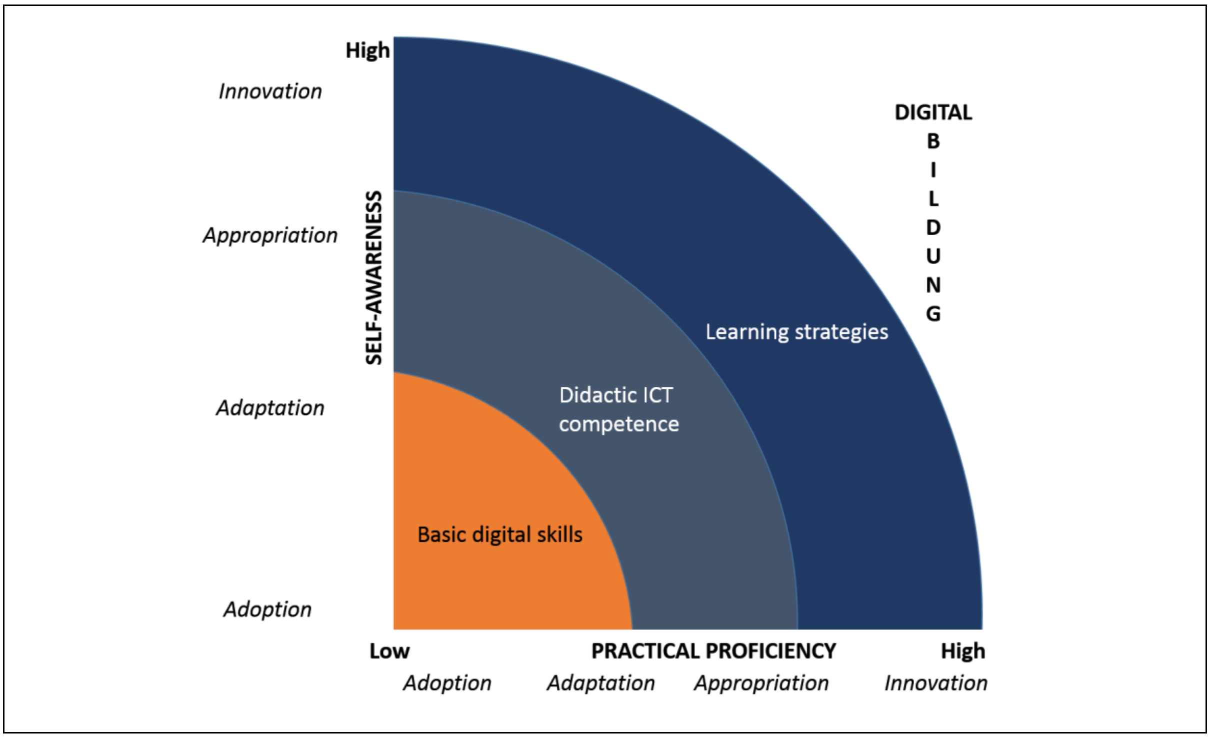

Figure 2.1: Model of Digital Competence for Educators (Krumsvik, 2014)

The Krumsvik (2014) model consists of two axes that emphasise the practical and intellectual aspects of digital competence development: self-awareness and practical proficiency. Both axes start with Adoption and Adaptation – a stage when the educator possesses basic digital skills and is largely ignorant of the opportunities and restrictions of using ICT for teaching and learning. The educator is preoccupied with mastering the how-to of ICT. As the educator becomes more experienced and mindful of the opportunities afforded by the use of ICT, they reach the Appropriation and Innovation phases. Here they gradually become aware, and are able to recognise, the opportunities and restrictions of using ICT in teaching and learning. In these two stages, Røkenes and Krumsvik (2016) identified tension between identifying a tool and incorporating it in a specific teaching and learning context. It is, therefore, possible that an educator could master the basic digital skills and was able to identify the affordances of ICT, but never made the use of ICT seamless in the classroom.

The centre area of the model focuses on the educational use of ICT. Krumsvik (2014) identifies four components of digital competence: basic digital skills, didactic ICT competence, learning strategies and digital *Bildung*. Basic digital skills refer to the basic use of ICT for communication, basic administrative software in the work environment and the use of basic technical ICT tools in schools. Didactic ICT competence refers to the awareness of the possibilities and limitations in subject specific contexts. It also refers to the educational use and integration of ICT in topic specific contexts. Learning strategies refer to an awareness of the scaffolding processes involved in the development of knowledge construction, learning strategies and metacognition by learners. Digital *Bildung* refers to an awareness of the social implications and ethical considerations that the use of ICT has on human development. Digital *Bildung* also refers to the discussion of the development of positive behaviour and possible ethical dilemmas that learners with an increasing digital life may face.

Educators are increasingly faced with a situation where technology is delivered to their classrooms or schools and they are required to seamlessly integrate it into their teaching (Mullis, Martin & Loveless, 2016). Bai et al. (2016) found an increase in the workload of educators implementing ICT-related activities in their classrooms. This increase in workload revolved mainly around increased preparation, planning and organisation of the ICT programme. In their study, Bai et al. (2016) identified the current workload of educators identified for ICT integration programmes as a predictor of the success of such a programme – an educator with a heavy workload at school may be unable or unwilling to properly plan and integrate ICT-related activities in their classrooms. On the other hand, research conducted by Bonaveri et al. (2015), Condie and Munro (2007) and Nomass (2013) suggest that when ICT-related activities are well implemented in the curriculum, it assists learners to learn and complements traditional teaching, the workload required from the educator in order to improve learner performance could actually decrease.

Following their study in rural China, Bai et al. (2016) state that the usefulness of the integration of ICT programmes in the school curriculum may also depend on the basic knowledge level of the learners. The findings of Bai et al. (2016) are corroborated by earlier findings by Krashen (1987) that learning takes place optimally if the difficulty level of new learning materials are set in relation to the learner's current knowledge level. Krashen (1987) suggested that new learning materials needed to be set at a level just outside the learner's current level of capability. Condie and Munro (2007) found that the impact of the implementation of ICT in a classroom is greatest if it is an integral part of the day-to-day learning experiences of the learners. Bai et al. (2016) therefore postulate that the implication for ICT integration in the curriculum is that any ICT-related activities should be readily understandable to learners in order to be effective. Bai et al. (2016) suggest that learners should have a minimum amount of understanding of the subject area before an ICT-related intervention will be of benefit to them. Bai et al. (2016) state that ICT-related activities cannot be efficiently used by learners to learn a new subject that is completely unfamiliar to them.

Blackwell et al. (2016) found that ICT-related interventions were most effective if they utilised ICT to support learner-centred teaching and learning. The use of ICT enabled educators to shift the focus to content, pace and learning activities most appropriate for their learners' interests and abilities. Carneiro and Gordon (2013) suggested that educators create flexible, learning-centred learning environments in order to support scaffolding by the learners. It is therefore important that educators use technology in innovative ways in order to address the specific contextual needs of their learners. However, research conducted by Eteokleous (2008), found that most educators still utilised ICT like a traditional didactic tool, where learners utilise ICT to acquire basic educational skills through drill and practice. This may explain why many educators feel that ICT do not really add value to their classroom practice.

An often overlooked aspect of using ICT in teaching and learning is the prerequisite for direction from the educator when it comes to the organisation of information. Accessing new information is easier than ever before, as is the independent publishing of any information by anybody. All sources of information are not equal and learners need to be guided in the sourcing and evaluating of digital resources (Kolikant, 2012; Siddiq, Scherer & Tondeur, 2016).

2.7. Barriers and challenges to the implementation of ICT in education

Research has revealed a number of categories of challenges that education faces when trying to implement ICT in schools. These challenges can be broadly divided into school-related ICT challenges, educator-related ICT challenges, and learner-related ICT challenges (British

Educational Communications and Technology Agency [BECTA], 2004; Law et al., 2008; OECD, 2010).

South Africa took part in the Second Information Technology in Education Study (SITES) conducted by the IEA in 20 countries in 2006 (Blignaut et al., 2010; IEA, 2017i). In the SITES 2006 study, South Africa was identified as the country with the lowest ICT integration in mathematics (18%) and science (16%) of all participating countries (Vilakati, 2014). Unfortunately, South Africa has not participated in further iterations of SITES since 2006 and a national overview of the use of ICT for teaching and learning is not available. Both the SACMEQ III study of 2007 (DBE, 2010) and the SACMEQ IV study of 2013 (DBE, 2017c) included questions regarding the availability of computers in the sampled schools. In the SACMEQ III study, 76.9% of respondents indicated the availability of at least one working computer in the sampled schools (DBE, 2010, p. 33). In the SACMEQ IV study, the availability of at least one working computer in the sampled schools increased to 97.6% (DBE, 2017c, p. 24). However, the SACMEQ questions referred to the availability of “a computer in usable condition” (DBE, 2017c, p. 25) and did not specify whether computers were available for administrative use or for teaching and learning. Spaull (2012) noted that there was an average of 13 working computers available in South African schools in the SACMEQ III study.

2.7.1. School-related challenges

Starkey (2010) found that educators involved in the implementation of ICT in schools need the encouragement and support of school management, as well as the support of a like-minded mentor with relevant pedagogical content knowledge. This is supported by research conducted by Goktas, Gedik and Baydas (2013) where Turkish educators rated a lack of skills for ICT integration and a lack of in-service training as their main concerns. Similarly, South African mathematics educators believed that they would benefit from observing other educators presenting ICT-based lessons (Stols et al., 2015). In another South African study, Vandeyar (2013) found that educators in the study previously indicated a need for ICT support, and when they did not receive adequate ICT support from formal structures within the school, they established informal ICT-related communities of practice as support mechanism among themselves.

School-related challenges include a lack of access to ICT in the school and a lack of technical ICT support (BECTA, 2004; Stols et al., 2015; Vandeyar, 2013). In South Africa, educators indicated physical challenges, such as unpredictable electricity supply and lack of access to ICT in their classrooms, as some of their main challenges (Mdlongwa, 2012; Mofokeng & Mji, 2010; Stols et al., 2015). These educators also indicated a need to teach in safe, well-resourced classrooms where it would be easy to access the ICT needed for a specific lesson.

Funding for ICT infrastructure in schools remains one of the biggest obstacles to the successful implementation of ICT in schools (Elletson & Burgess, 2015; Hassan & Geys, 2016; Mdlongwa, 2012). The financial implications of ICT implementation are not limited to the acquisition of new hardware alone – the maintenance of hardware and network infrastructure, software updates, and educator empowerment all add to the cost of ICT at schools (Elletson & Burgess, 2015; Hassan & Geys, 2016). South Africa is by no means unique when it comes to the lack of access to ICT in schools. In a comparative study that ran in Turkey from 2005 to 2011, Goktas et al. (2013) also found the lack of ICT hardware and software as some of the top challenges to the integration of ICT in Turkish classrooms.

However, merely adding ICT resources to classrooms, without a clear plan to integrate ICT in the teaching and learning in the classrooms will not improve the quality of education in the classroom (Byrom & Bingham, 2001; Gudmundsdottir, 2010). South Africa has a comprehensive policy environment that supports the integration of ICT in the classroom (DOE, 2004; RSA, 2002; Vandeyar, 2015), but it seems as if schools struggle to make ICT available for teaching and learning (Blignaut et al., 2010; Stols et al., 2015).

2.7.2. Educator-related challenges

Educator-related challenges concerning the integration of ICT in education may include the level of confidence of educators to use ICT, inappropriate integration of ICT into the curriculum, limited time to prepare for lessons where they use of ICT is integrated, and a resistance to change long established (and often proven as working well in the context) teaching practices (BECTA, 2004; OECD, 2010). Thompson, Higgins and Howell (1991) suggest a negative correlation between the perceived and actual difficulty in using technology – if a person perceive technology as difficult to use, they will shy away from using it at all. Several studies identified a negative correlation between educator age and their opinion towards the integration of ICT in their classrooms – older educators seem less likely to use ICT in their classes (Aesaert, Van Nijlen, Vanderlinde & Van Braak, 2014; O'Bannon & Thomas, 2014; Scherer, Siddiq & Teo, 2015). This finding is especially relevant for South Africa with a large cohort of older educators.

In their study, Law et al. (2008) found that South African educators felt that the lack of resources and the inflexibility of the school system was less of a challenge, than a lack of ICT knowledge and skills and a lack of time for preparation. Other studies in the South African context also found that the perceived lack of ICT skills acted as a barrier for the implementation of ICT in mathematics classrooms (Mofokeng & Mji, 2010; Stols et al., 2015).

The British Educational Communications and Technology Agency (BECTA, 2004) states that educators need time for both formal training and for self-directed exploration of the affordances of new technologies. Fullan (1992) warns educational policy makers that the implementation of ICT in the classroom is fundamentally different from simple changes in the curriculum. Educators implementing ICT in their classroom “start from base zero” (Fullan, 1992, p. 33) and need to be supported in terms of training and time for experimentation. This view is supported by research done by Blackwell et al. (2016) who found educator attitude towards ICT and knowledge about the affordances of ICT to be the strongest educator-related predictors for the use of ICT in the classroom. Educators seem to align their use of ICT with their perceived usefulness of ICT in their teaching. These findings correspond with the Technology Acceptance Model (TAM) developed by Davis (1985).

The original TAM was expanded by Davis, Bagozzi and Warshaw (1989) and relies on user perception of the system or technology in question in order to forecast the real use of the system or technology. The Technology Acceptance Model is depicted in Figure 2.2.

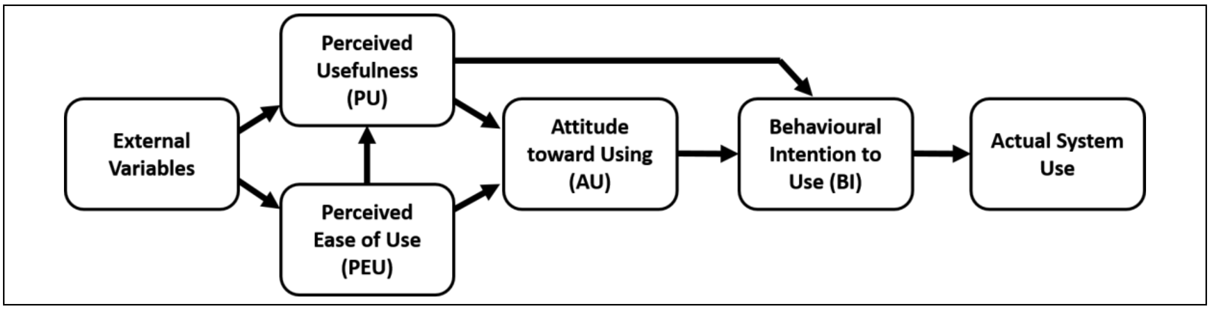

Figure 2.2: The Technology Acceptance Model (Davis et al., 1989)

Davis et al. (1989) identified two important perceptions that influence technology use: *perceived usefulness (PU)* and *perceived ease of use (PEU)*. *Perceived usefulness (PU)* is defined as the “prospective user’s subjective probability that using a specific application system will increase his or her job performance” (Davis et al., 1989, p. 985). *Perceived ease of use (PEU)* on the other hand is defined as “the degree to which the prospective user expects the target system to be free of effort” (Davis et al., 1989, p. 985). Chuttur (2009) found that PEU has a direct impact on the PU, because if an educator is uncomfortable using technology they may avoid using it. Additionally, Mac Callum and Jeffrey (2014) identified technology and pedagogy as skills needed to integrate technology into education. Mac Callum and Jeffrey (2014) also identified a further three aspects that restricted the integration of technology in education namely digital literacy, ICT anxiety and ICT self-efficacy.

In the SITES 2006 study, fewer than 8% of the South African educators interviewed, indicated that they have attended ICT-related professional development interventions (Law et al., 2008). The educators indicated that ICT-related professional development interventions were not readily available to them. The same lack of professional development opportunities available to South African mathematics educators was also identified by Stols et al. (2015). Krumsvik (2008) found that conventional professional development interventions are seldom effective because new knowledge and practice need to be applied in authentic teaching situations. South African mathematics educators indicated that the sourcing of relevant ICT-enabled subject content was a challenge to their use of ICT in the classroom (Stols et al., 2015).

The confidence to use ICT is a significant indicator of educators' willingness to use ICT in their classroom (Goktas et al., 2013; Pelgrum, 2001). A lack of confidence may lead to educators perceiving ICT use as difficult and complicated. This lack of confidence is often the result of a lack of training to implement ICT in the classroom (Draper, 2010). South African educators interviewed in the SITES 2006 study, was rated lowest for their general ICT skills and second lowest for their pedagogical competence to implement ICT in their classes (Blignaut et al., 2010; Law et al., 2008).

Interesting to note is that Jita, Ndlalane and Maree (2008) found that the majority of South African science educators that participated in a professional development intervention, displayed inadequate subject content knowledge as well. This finding is corroborated by a study aimed at finding the ICT needs of South African mathematics educators (Stols et al., 2015). Educators in this study indicated that they found the field of ICT overwhelming and that they had very little time for experimentation with ICT due to the large quantity of curriculum content they had to cover while also struggling with inadequate mathematics subject content knowledge.

Although educators acknowledged a need for a paradigm shift away from traditional teaching methods to an approach that include modern trends in teaching and learning, they simply did not feel empowered to make the shift. A study by Rahimi and Yadollahi (2011) yielded similar results in that educators indicated that they perceived ICT as an extra burden in their already busy schedule. In the AISA study, Mdlongwa (2012) also found that educators were reluctant to change the way they have been teaching because they were worried they would not be able to cope with the new technologies in their classrooms.

Educators are the implementers of ICT in the classroom and the curriculum. If they are not adequately prepared and supported to manage ICT in their own classes and curricula, ICT projects in education stand a real chance of failing, not due to a lack of finances, but due to lack of integration in the classroom (Comi, Argentin, Gui, Origo & Pagani, 2017).

2.7.3. Learner-related challenges

Learner-related challenges centre mainly around a lack of ICT skills and the lack of access to ICT inside and outside the school (Law et al., 2008). It is interesting to note that South African educators that took part in the Law et al. (2008) study, put the lack of ICT skills and the lack of access to ICT outside the school as their top learner-related challenges.

A challenge that most developing countries face when implementing ICT in education, is the issue of a language barrier between the users of the technology (the learners, educators and administrators) and the technology itself (Bai et al., 2016; Mdlongwa, 2012). In most developing countries English is not the first language of most of the population and this may hinder the effective use of ICT software, most of which is in English. The development of local digital content in local languages should be prioritised as it may assist with the successful integration of ICT in schools (Butcher, 2011).

Kolikant (2012) warns of a possible disconnect between the current digital generation of learners and traditional teaching styles and materials. Modern learners seem to easily disconnect from the teaching and learning process if they cannot identify with the subject matter. Digital content therefore needs to be carefully selected so that learners can still identify with the subject matter and the learning process (Blackwell et al., 2016; Kolikant, 2012).

The first two major ICT in education projects in South Africa, GautengOnline and the Khanya Project, focused on implementing ICT in the classroom and empowering educators to use the ICT as teaching and learning tools (Du Toit, 2005; Petjé et al., 2002). Many people believe that because today's learners grew up with technology, they take to ICT naturally and need minimal support in order to use ICT for teaching and learning (Barrera-Osorio & Linden, 2009).

However, the skills to use ICT optimally for knowledge construction is different from simply using ICT for relaxation, and these education-related ICT skills need to be acquired (ISTE, 2016; Pagani et al., 2016). Educators therefore also need to be empowered to assist learners with acquiring these skills and factor learner empowerment into any ICT implementation project they plan for their classrooms (Comi et al., 2017).

2.8. Background to the education system in South Africa

The Constitution of the Republic of South Africa (RSA, 1996a) guarantees the right to basic education for South African children. The South African Schools Act (RSA, 1996b) stipulates compulsory education for all South African children from ages seven to 15. As such, there were 12 932 565 learners, taught by 418 613 educators, in 25 574 schools in South Africa in 2017 (DBE, 2017a).

School-based education in South Africa functions on a two-tier model where the DBE is responsible for setting policy guidelines and strategies for implementation of education on a national level (DBE, 2016d). The responsibility of implementing national policies and strategies is decentralised to nine PEDs who in turn manage the schools in that province (Botha, 2013; Isaacs, 2007). The South African Schools Act (RSA, 1996b, p. 6) stipulates that "…nothing in this Act prevents a provincial legislature from enacting legislation for school education in a province in accordance with the Constitution." The responsibilities of provincial departments include, among other, provincial educational policies and legislation, provincial finances, the provision of books and the provision of physical facilities and computer services for schools (Lundall & Howell, 2000; Vandeyar, 2015).

In terms of the South African Schools Act (RSA, 1996b), schools in South Africa are awarded some degree of autonomy in order to address the needs of a very diverse learner population across the country. Areas like the physical school buildings, human and financial resources, time allocation through timetabling and relations between the school and community are all part of the school's responsibilities (Botha, 2013).

Using the Gauteng Department of Education (GDE) and the Western Cape Education Department (WCED) as examples, Figure 2.3 depicts the complex nature of education provision in South Africa.

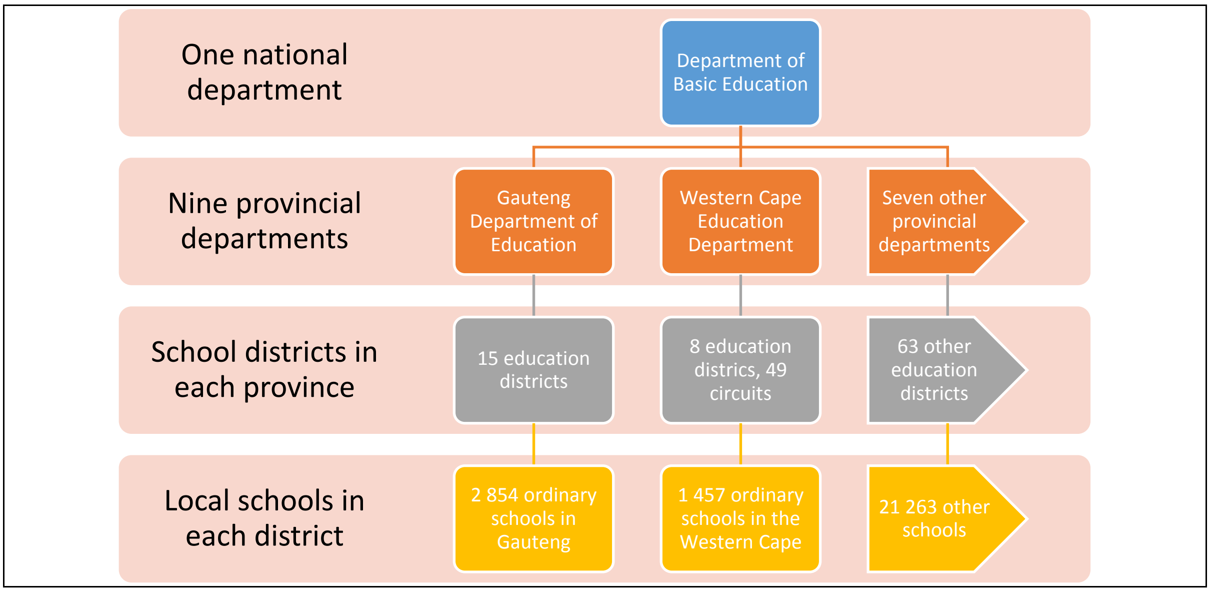

Figure 2.3: Graphic representation of the Education System in South Africa (DBE, 2017a; GDE, 2017; WCED, 2016; WCED, 2017)

In a study completed in 2014, Magano (2014) found that while PEDs do take guidelines set by the DBE into account when implementing national policies and strategies on a provincial level, the implementation is often far removed from the original intent as envisaged by the DBE. This is demonstrated by the difference in results attained by Grade 12 learners from different provinces in the final Grade 12 National Senior Certificate (NSC) exam – while the national pass rate in the 2016 NSC exam was 72.5%, the provincial pass rates ranged from 59.3% in the Eastern Cape to 88.2% in the Free State (DBE, 2017b).

Magano (2014) further recommends the collection of quality education management data by both the DBE and PEDs in order to inform planning and decision-making. One of the main objectives of the TIMSS project is the belief that by comparing education systems in terms of organisation, curriculum, teaching practice and learner achievement, crucial information for effective education policy- and decision-making is provided to participating education systems (IEA, 2017h).

2.8.1. Overview of ICT in education in South Africa

Globally a belief exists that the availability of ICT in schools may assist with improving the teaching and learning of basic skills (Bonaveri et al., 2015). Similarly, in South Africa there seems to be an expectation that the integration of ICT in teaching and learning in South African classrooms can transform education (DOE, 2004), improve the skill levels of learners, and prepare learners for participation in a modern information and knowledge society (Butcher, 2011). The expectation is that the introduction of ICT in schools should reduce the challenges experienced by South African schools and lead to enhanced education in the country (Lundall & Howell, 2000; Mdlongwa, 2012).

Starkey (2010) identifies enabling school policies and structures that promote ICT and ensure access to ICT, as important aspects that have an impact on the implementation of ICT in schools. The DBE is tasked with the development of a national ICT competency framework for educators, school managers as well as school administrators (Vandeyar, 2015). These competencies are aimed at facilitating the innovative use of technology in schools. However, in research conducted by Vandeyar (2015) he found the ICT competency levels of South African educators to be considerably lower than expected.

Mdlongwa (2012) found that after 1994, the focus of the South African government was on the rollout of basic services to communities and consequently ICT implementation in schools were not really prioritised on a national level. Hence, the allocation of financial resources for education on national level was primarily aimed at the redress of educational disparities in the country (DBE, 2016e; Lundall & Howell, 2000). The implication is that a large portion of government spending on education is still channelled to the most disadvantaged schools and at these schools the funding is used to fund basic educational needs, such as stationary and books (DBE, 2014; Lundall & Howell, 2000). This disparity seems to have a negative influence on the ability of PEDs to implement ICT for teaching and learning.

By 2002 there were over 200 ICT in education projects running in Africa, mostly funded by development agencies and not the countries' governments themselves (Petjé et al., 2002). In research conducted for infoDev, Isaacs (2007) identified that by 2002 there were 34 different ICT in education programmes and projects aimed at schools in South Africa. Isaacs (2007) identified close coordination between ICT in education programmes as a requisite for success. However, most of the programmes identified by Isaacs (2007) do not exist anymore and thus their impact on education in South Africa remains questionable.

In order to deliver on the promise of quality education for all South Africans, the DBE and some of the PEDs (notably the GDE and the WCED), started looking towards technology to assist with the provision of high quality teaching and learning in schools in the late 1990's (Isaacs, 2007; Mahlong, 2009; WCED, 2007a). Vandeyar (2013) sees these two projects, namely GautengOnline by the GDE and the Khanya Project by the WCED, as the first education centred ICT projects in Africa.

In 2001 the WCED launched the Khanya Project after approval by the Western Cape Provincial Government. The word Khanya comes from a Xhosa verb, 'ukukhanya', which means to brighten or to enlighten. The focus of the Khanya Project was to put ICT in reach of all learners in the Western Cape by 2012 (Du Toit, 2005). The main motives behind the WCED's investment in the Khanya Project was a critical shortage of suitably qualified and experienced educators, the expanding digital divide in the province and the need for reparation of the in resource imbalances between underprivileged and privileged schools (Draper, 2010; Du Toit, 2005; Mlitwa & Koranteng, 2013).

The WCED identified a shortage in appropriately qualified educators for important subjects like mathematics and science, as key reason for the province's poor results in the final Grade 12 examinations (Du Toit, 2005). An intervention aimed at mathematics higher grade was implemented as the first pilot project of the province wide Khanya Project. The University of Cape Town (UCT) was appointed as independent assessment partner of the pilot project and the results showed a marked improvement in results – participating schools increased their mathematics pass rates by 42% (Du Toit, 2005; WCED, 2004). On the basis of the successful pilot phase the Khanya Project was expanded to 60 primary schools in 2003 (Du Toit, 2005). Using a pre-test – post-test research design, a 9% improvement in literacy and 15% improvement in numeracy levels were recorded in these schools after 10 weeks. The UCT research team found a significant increase in pass rates in schools where the Khanya Project was active for more than a year, indicating a positive maturation of the project (Du Toit, 2005).

In 2006 the project won the Technology Top 100 Leader in Empowerment Award (WCED, 2006). In 2007 the Khanya Project was awarded with the Centre for Public Service Innovation's Public Sector Innovation Award for Innovative use of ICT for Effective Service Delivery (WCED, 2007b). By 2008 it was estimated that the Khanya Project reached 727 049 learners and 21 598 educators in 1 096 Western Cape schools (WCED, 2008).

Educator empowerment to teach with technology was a central aspect of the design and rollout of the Khanya Project and the project leaned heavily on the expertise of a team of ex-educators who acted as ICT facilitators in the project. The focus of the educator empowerment programme was on ICT skills for educators, the integration of ICT in the curriculum and teaching with ICT (Du Toit, 2005; WCED, 2006).

The GDE launched the GautengOnline project in collaboration with the Gauteng Provincial Government (GPG) in 2002 with the vision of equipping every public school in Gauteng with an internet connected computer laboratory with 25 networked computers (Draper, 2010; GPG, 2008). While most of the African ICT projects in education at the time were development-oriented, GautengOnline was unique in that it was an education-centred project. (Petjé et al., 2002). The GPG identified ICT as one of the methods that can be utilised to improve the lives of the citizens of Gauteng and it was envisaged that these laboratories could be used by community members after hours in order to gain access to a number of development initiatives aimed at adults (GPG, 2008).

Formal handover of the laboratories to schools was planned for 2005. As part of the project, it was envisaged that 2 200 educators will be trained in the use and integration of ICT in the curriculum (GPG, 2008; Petjé et al., 2002). The long-term goals of the GautengOnline project included improving school management, and making the laboratories available to the community after hours for adult learning, small, medium and micro enterprises (SMME's), as well as making eGovernance available to all community members (GPG, 2008, 2012). However, by 2015 the GautengOnline project had established computer laboratories in only 1 538 of Gauteng's 2 854 public schools (GDE, 2015). In a review of the project in 2015, a lack of educator training in the use and integration of ICT in the classroom was identified as one of the main contributing factors to the low impact of the programme (GDE, 2015).

Subsequent to the launch of GautengOnline in 2002, the GDE and GPG launched several other education-related ICT projects in Gauteng (GDE, 2015). In a research project commissioned by the GDE, several factors influencing the impact of ICT-related projects in education were identified. ICT-related projects in Gauteng and their identified success factors are depicted in Table 2.3.

Table 2.3: ICT projects in education implemented by the GDE and GPG

Project description	Project objectives	Lessons learned
GautengOnline project (2002 to date)	Provision of ICT infrastructure to Gauteng public schools.	Educators need training to use the technology in the classroom. Educators need access to devices to use for preparation and planning.
Digital Content project (2012 to date)	Distribution of digital mathematics and physical science content on CD-ROM and eBook format to identified schools in the province.	Positive learner outcomes when using interactive, multimedia content. Content aimed at educators (e.g. user guides, sample lesson plans, etc.) adds to professionalism of educators. A central hub of digital content is cost effective and efficient. Mentoring of educators is essential to the success of the implementation.
Satellite Broadcast project (2013 to date)	Live broadcast of mathematics lessons to identified schools.	Educator plays important role as mediator of learning in the classroom. Content needs to be followed closely by practical exercises in class.
SA-SAMS project	All schools in Gauteng are expected to have electronic school management systems in place. SA-SAMS (South African Schools Administration and Management System) is available to all schools without management systems.	Implementation needs to take place around existing routines and requirements. A clear change management programme is essential. Stakeholders must be able to identify the value proposition of implementing the programme.
eLearning Solution (2014 to date)	Provision of mobile ICT infrastructure (40 internet connected tablets per school) to 2 097 public schools.	Project still ongoing.
'Schools of the Future' project (2015 to date)	Phased approach to improve ICT infrastructure, digital content, educator training and development and school refurbishments of public schools.	Project still ongoing.

Adapted from GDE (2015).

The lessons learned by the GDE (GDE, 2015) correlates with the success factors for the implementation of ICT in education identified by Hansen et al. (2012) in the Ethiopian OLPC project. South Africa is not the only country in the world that has invested large sums of money to implement ICT in education in an effort to support corrective teaching and learning (Butcher, 2011). During their study, Bai et al. (2016) found that Turkey spent around 11.7% of its education budget on ICT, while China planned to increase their investment in ICT in education so that there is a computer laboratory in every rural school in China by 2021 (Bai et al., 2016).

Howie and Blignaut (2009) found that only 18% of South African mathematics educators that took part in the SITES 2006 study used ICT for teaching and learning. Mlitwa and Koranteng (2013) believe that the current model used for implementing ICT in South African schools is not working optimally to make sure that investment in ICT reach the learner in the classroom. Howie (2010) and Mlitwa and Koranteng (2013) suggest a review of both the process, and the funding model of ICT implementation in South African schools.

2.8.2. Mathematics education in South Africa

Increasingly learners today grow up in an era where higher-order thinking skills are becoming the essential basic skills for functioning in a fast developing world (ISTE, 2016; Stols, 2012; United Nations, 2015; WEF, 2015). During the industrial era basic calculation skills were sufficient to function, but as knowledge increases at a greater pace than is possible to learn, higher-order intellectual skills such as problem solving and logical thinking are becoming increasingly more important for effective functioning in society (Gudmundsdottir, 2010; Stols, 2012). In a study by Fuchs and Woessmann (2004) they found that basic mathematics and writing skills had a significant positive impact on the employability and the wages a person earns.

In 2013 the South African Government adopted the National Development Plan 2030 (NDP) as roadmap to eradicate poverty and decrease inequality in South Africa by 2030 (National Planning Commission, 2012b). According to the NDP, South Africa can

> *"…realise these goals by drawing on the energies of its people, growing an inclusive economy, building capabilities, enhancing the capacity of the state, and promoting leadership and partnerships throughout society"* (National Planning Commission, 2012a, p. 14).

The NDP identifies high quality mathematics education as a national priority that will enable the reach of the NDP goals (National Planning Commission, 2012a). The importance of higher-order thinking skills, such as those developed through mathematics education, already features prominently in the DBE's CAPS curriculum statement for mathematics:

> "*Identify and solve problems and make decisions using critical and creative thinking… collect, analyse, organise and critically evaluate information*" (DBE, 2011, p. 5).

The inclusion of the requirement for higher-order thinking skills in the CAPS curriculum statements, places the onus of the teaching of higher-order thinking skills squarely on the shoulders of educators (DBE, 2011). However, the legacy of inadequate mathematics education in South Africa is still widespread in most South African public schools after more than 20 years of democracy (Spaull, 2013) and this severely hampers the mathematics achievement of a large number of South African learners (Spaull & Kotze, 2015).

Annually the DBE releases a list of schools performing exceptionally well in the end-of-year NSC Grade 12 assessments (DBE, 2017b). When looking at the use of higher-order thinking skills by learners in these high performing schools, Stols (2012) found that even though these learners perform well in the NSC exams, their achievement in areas where the TIMSS assessments require higher-order thinking skills and problem solving, was on par with the rest of the South African participants. It is therefore evident that even high achievers in South Africa lack higher order mathematical thinking skills.

However, most South African learners lack basic mathematical skills (e.g. simple calculations, place and number value, etc.) and can barely function on the Knowing domain in the TIMSS cognitive domain as depicted in Appendix 3: Content domains, Topic areas and Topics in TIMSS (Mullis & Martin, 2013). Due to this lack of skills, these learners cannot function on the Applying or Reasoning domains of TIMSS which measure higher-order thinking.

The poor performance of South African learners in mathematics may be related to the mathematical knowledge and skills of their mathematics educators (Spaull, 2013; Stols et al., 2015). Rowland and Ruthven (2011) argue that there is a direct correlation between the content knowledge of the mathematics educator and the quality and quantity of teaching they bring to the classroom. Mathematics educators in many developing countries face a severe challenge in their own mathematics content knowledge as well as the teaching skills they bring to the classroom (Stols et al., 2015). There is evidence that poor mathematical subject knowledge translates negatively on the quality of teaching (Hodgen, 2011; Rowland & Ruthven, 2011). Additionally, Stols et al. (2015) suggest that mathematics educators often do not have the skills to select suitable learning resources for their learners. A need therefore exists in developing countries for pre-selected learning support materials packages (Stols et al., 2015).

If implemented properly, ICT in schools may assist with the teaching and learning of basic mathematical skills, as well as non-routine problem solving skills that require higher-order thinking skills. Barkatsas, Kasimatis and Gialamas (2009) found a strong correlation between learners' mathematics self-confidence and their achievement in mathematics. They found that the use of ICT in mathematics education increased the mathematics self-confidence of low achieving learners. In South Africa where large numbers of learners need assistance with basic mathematical skills, ICT may prove a good educational return on investment.

2.9. Conceptual framework

This study examined the relationship between the investment in ICT and the mathematics achievement of Grade 9 learners from a random sample of South African schools. These schools were situated throughout South Africa, in nine different provinces with nine different PEDs, in diverse communities with varying social and economic backgrounds (Joncas & Foy, 2012; LaRoche et al., 2016).

Due to the unique context of each school, a one-size-fits-all research approach would not have been appropriate when examining these schools. As the study relied on a secondary data analysis of the South African TIMSS 2011 and 2015 data, the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2007, 2010) was selected as basis for the conceptual framework of this study.

> *Creemers and Kyriakides are particularly interested in promoting longitudinal research and building on developments such as growth curve modelling of a range of students' outcomes because they see both school and teacher effects (and their relationships) as dynamic things that occur within multilevel, hierarchical, and dynamic structures. In other words, they recognise that not only do students' achievement and other outcome trajectories change over time, so too do the organisations (schools) and other contextual features that shape them.* (Sammons, 2009, p. 124)

The Dynamic Model views school effectiveness in the context of existing national and regional educational departments and policies. The Dynamic Model also takes individual school and classroom factors into account when evaluating school effectiveness. Additionally, the Dynamic Model relates closely with the areas of research on which the TIMSS context questionnaires are based (Creemers & Kyriakides, 2010; Mullis et al., 2009). Scheerens (2013, p. 10) sees the Dynamic model as "the most up-to-date multilevel model of educational effectiveness". Scheerens (2013) also sees great potential in linking national policies (as researched by large-scale international assessments, such as TIMSS and PISA) with school effectiveness. Additionally, data from TIMSS and PISA offers consistency when investigating relationships related to school effectiveness (Scheerens, 1990, 2013).

2.9.1. The Comprehensive Model of Educational Effectiveness

The Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2007) was developed after an extensive review of the Comprehensive Model of Educational Effectiveness (Creemers, 2002a) by Creemers and Kyriakides (2006). Creemers and Kyriakides (2006) identified the need for an expanded, integrated model for educational effectiveness studies. Since the Comprehensive Model served as foundation for the Dynamic Model, it is necessary to first explore the origins of the Comprehensive Model.

School effectiveness and school improvement studies have different roots (Creemers, 2002b). School effectiveness studies aim to find out "what works in education and why" (Creemers, 2002b, p. 1). On the other hand school improvement studies focus on educational practice and related policies and aims to "change education in the desired direction" (Creemers, 2002b, p. 1). Up to the early 2000's, studies on educational effectiveness tended to focus on factors related to learner achievement in schools and on what made these schools work (Creemers, 2002a). Creemers (2002a) identified that most educational effectiveness studies of the time were not based on any theory, but were simply focused on the confirmation of statistical relationships between aspects of educational effectiveness and school and learner achievement. Consequently, Creemers (2002a) identified the need for the testing of theories that could explain these differences in achievement.

Creemers (2002a) saw that most of the studies had several aspects in common, most notably a focus on individual learner achievement, the level at which the teaching and learning was pitched, the influence of educators, as well as the influence of the context in which learning took place. Creemers (2002a) found the studies mostly followed one of three approaches: the economic approach (the relationship between the supply of educational resources and educational outcomes), the learner background approach (the relationship between learning ability, motivation, personality, etc. and learning processes in the classroom), and the sociological approach (elements that describe the educational context of learners, such as gender, SES and their peer group). However, what was lacking from these educational effectiveness studies was an integrated educational effectiveness theory that could explain the differences in learner achievement (Creemers, 2002b).

The Comprehensive Model of Educational Effectiveness (Creemers, 2002a) provided for the examination of educational effectiveness on four different levels in education: the wider context (country) level, the school level, the classroom level, and the learner level. The

Comprehensive Model was based on the 1963 Carroll Model of School Learning (Carroll, 1989), incorporating the key ideas of the Carroll Model (time for learning, quality of instruction) with the four levels in education. The Comprehensive Model defined the key concepts of the Carroll Model on each of the educational levels, and showed how the different levels of education influenced teaching and learning (Creemers, 2002a). The Comprehensive Model of Educational Effectiveness is depicted in Figure 2.4.

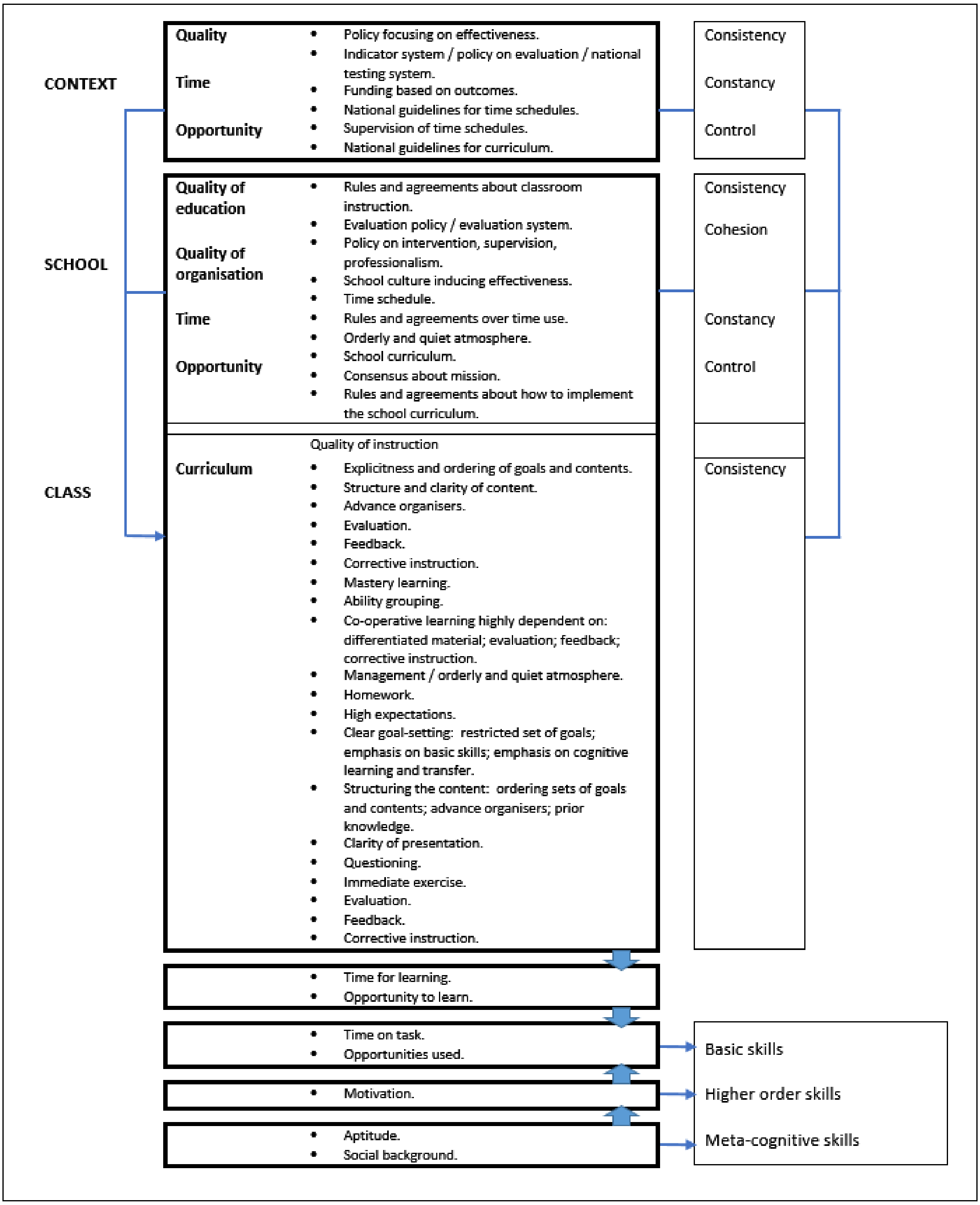

Figure 2.4: The Comprehensive Model of Educational Effectiveness (Creemers, 2002a, p. 20)

However, educational effectiveness studies performed in a number of countries indicated that there were multiple impacts on learner achievement, and that these impacts occurred on multiple levels (Creemers & Kyriakides, 2007, 2010; Kyriakides, 2008). As early as 1997, Creemers and Reezigt (1997) identified a dissonance between educational effectiveness research and educational improvement. The models of education effectiveness research and education improvement remained fairly diverse, especially in terms of their approach to theory and methodology (Sammons, 2009). Creemers and Reezigt (1997) argued for a stronger relationship between school effectiveness and school improvement by the strengthening of application processes and the improved reconstruction of knowledge during educational effectiveness research and school improvement research.

In an in-depth review of the Comprehensive Model of Educational Effectiveness, Creemers and Kyriakides (2006) identified the need for a new, more dynamic model of educational effectiveness research that could answer to new objectives in education. Any new model would have to incorporate a wider range of skills than the narrow range of skills in the Comprehensive Model. Creemers and Kyriakides (2006) identified four critical characteristics that a new model of educational effectiveness research would have to comply with. These critical characteristics are depicted in Figure 2.5. Creemers and Kyriakides (2006) found the Comprehensive Model (Creemers, 2002a) in line with at least two requirements of a new, more dynamic model.

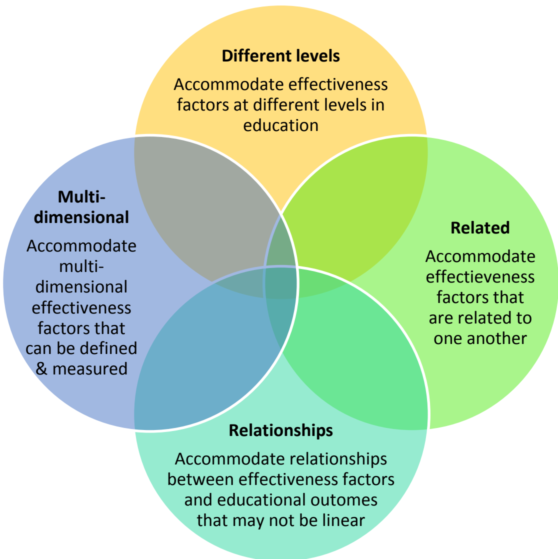

Figure 2.5: Characteristics required of a new model for educational effectiveness

Creemers and Kyriakides (2007) aimed to strengthen the relationships between educational effectiveness research and school improvement research with the development of the Dynamic Model of Educational Effectiveness. During the development of the Dynamic Model, Creemers and Kyriakides (2007) identified three shortcomings of the Comprehensive Model that had to be addressed. The new model would have to reflect the new objectives of education and their effects on teaching and learning. The new model would have to be developed in such a way that it enables rational decision-making by educational practitioners and policymakers in schools. Lastly, the new model will have to be more complex due to the multifaceted nature of education, the interrelatedness between different levels in education, and the related factors associated with educational effectiveness.

2.9.2. The Dynamic Model of Educational Effectiveness

The Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2007) attempts to define the dynamic factors associated with educational effectiveness. The model focuses on four distinct, but connected levels in the structure of education effectiveness – context-related factors (e.g. national and regional educational departments and policies), school-related factors (e.g. school policies for teaching and learning), classroom and educator-related factors, and learner-related factors.

The structure of the Dynamic Model of Educational Effectiveness is depicted in Figure 2.6. Figure 2.6 also illustrates the interrelated nature of the Dynamic Model where each of the four levels has either a direct or an indirect effect on the other levels in the model.

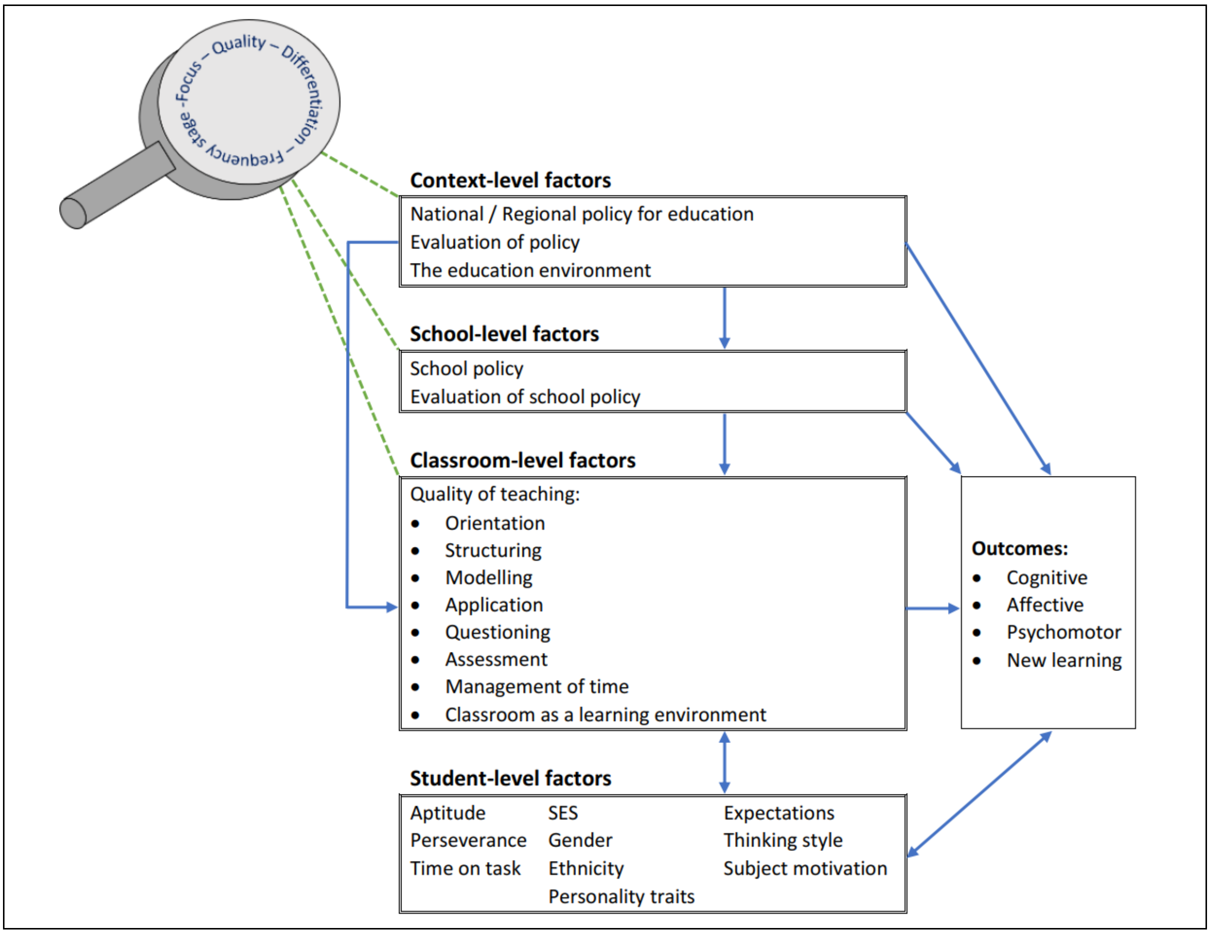

Figure 2.6: The Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2007, pp. 77, 150)

Creemers and Kyriakides (2007) used the teaching and learning situation as foundation for the development of the Dynamic Model. The student-level factors and classroom-level factors describe the education situation by exploring the factors influencing the two key players in education – the educator and the learner. Creemers and Kyriakides (2007, p. 78) state that

> *"…the model takes as its point of departure the fact that learning, especially differences in learning outcomes, has to be explained by the primary processes at the classroom level."*

This is the main reason why classroom-level factors are mainly described through the observable behaviour of the educator in the classroom (Creemers & Kyriakides, 2007). According to the Dynamic Model, the student-level factors and classroom-level factors may have an influence on educational effectiveness in the other level.

School-level factors are related with student-level factors and classroom-level factors and may have an influence on educational effectiveness in the other two levels. According to the Dynamic Model, school-level factors influence the teaching and learning environment in which educators and learners are expected to operate. The school-level factors include policies that have a direct bearing on teaching and learning, such as policies aimed at creating a conducive teaching and learning environment (Creemers & Kyriakides, 2007).

The fourth, and final level of the Dynamic Model looks at context-level factors. Context-level factors are closely related to the education system in which the school operates and may have an influence on educational effectiveness on both the school-level and classroom-level. Context-level factors refer to educational policies on national and regional level and how they influence the teaching and learning environment in schools (Antoniou et al., 2011).

One of the shortcomings identified in previous models of educational effectiveness studies was that they did not offer explicit measurement mechanisms for each of the effectiveness factors in a level (Creemers & Kyriakides, 2007). The Dynamic Model aimed to correct this and offers five distinct measurement mechanisms with which to measure each effectiveness factor in a level, namely differentiation, focus, frequency, quality and stage. (Antoniou et al., 2011). The five measurement mechanisms are described in Table 2.4.

Table 2.4: Definitions and the measuring of effectiveness factors

Measurement mechanism	**Definition**	**Means of measurement**
Differentiation	Degree to which the activities related to an effectiveness factor are applied uniformly for all its stakeholders.	Degree to which the activities related to an effectiveness factor are provided to all stakeholders involved in the effectiveness factor.
Focus	The function of an effectiveness factor on system, school and classroom level. Two aspects of *focus* are measured: • Specificity; and • The purpose why an activity takes place.	The two aspects of *focus* are measured as follows: • Specificity – the degree to which an activity is either too general, or too specific. • How many purposes of an activity are projected to be attained?

Measurement mechanism	Definition	Means of measurement
Frequency	The number of times an activity related to an effectiveness factor occurs at system, school or classroom level.	Frequency is measured by looking at two indicators: • How many activities are used? • How much time does each activity take?
Quality	The characteristics of each specific effectiveness factor as discussed in Creemers and Kyriakides (2007).	Quality is measured by looking at two indicators: • What are the characteristics of the activities related to an effectiveness factor? And how does it reveal the functioning of the effectiveness factor? • The degree each function of the activity aligns with the literature (Creemers & Kyriakides, 2007).
Stage	The time at which an activity takes place. Creemers and Kyriakides (2007) assumes that effectiveness factors need to occur over an extended period of time in order to have either a direct, or an indirect influence on teaching and learning.	Stage is measured by looking at one indicator: • When does an activity occur? Based on data from this indicator, data about the continuity of an effectiveness factor can be derived.

Adapted from Creemers and Kyriakides (2007, p. 84)

The Dynamic Model (Creemers & Kyriakides, 2007) therefore enables research on possible relationships between educational effectiveness and school improvement. Additionally, the Dynamic Model is sufficiently inclusive to cater for research on the multifaceted character of education and it should support educational practitioners and policymakers with decision-making in schools (Sammons, 2009).

After consideration of the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2007) and the IEA guidelines for researchers using TIMSS data (Foy, 2017a; Foy, Arora & Stanco, 2013a), it became clear that this study will also have to take the research areas identified by the IEA into account when examining the TIMSS 2011 and 2015 data. This study utilised a secondary data analysis of the TIMSS 2011 and 2015 data and the IEA stipulates that researchers should not report on school or educator responses to variables individually, but should rather interpret these responses in terms of the number of learners affected by the responses to an individual variable (Foy, 2017c). A decision was therefore taken to include the research areas on which the TIMSS context questionnaires focus in the conceptual framework of this study.

2.9.3. Research areas covered by TIMSS

The TIMSS studies were designed around a curriculum model that focuses on three aspects of teaching and learning, namely the intended curriculum, the implemented curriculum and the attained curriculum (Mullis & Martin, 2013). The TIMSS curriculum model is illustrated in Figure 2.7. As foundation of the TIMSS studies it aligns satisfactorily with the levels of educational effectiveness as described in the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2007).

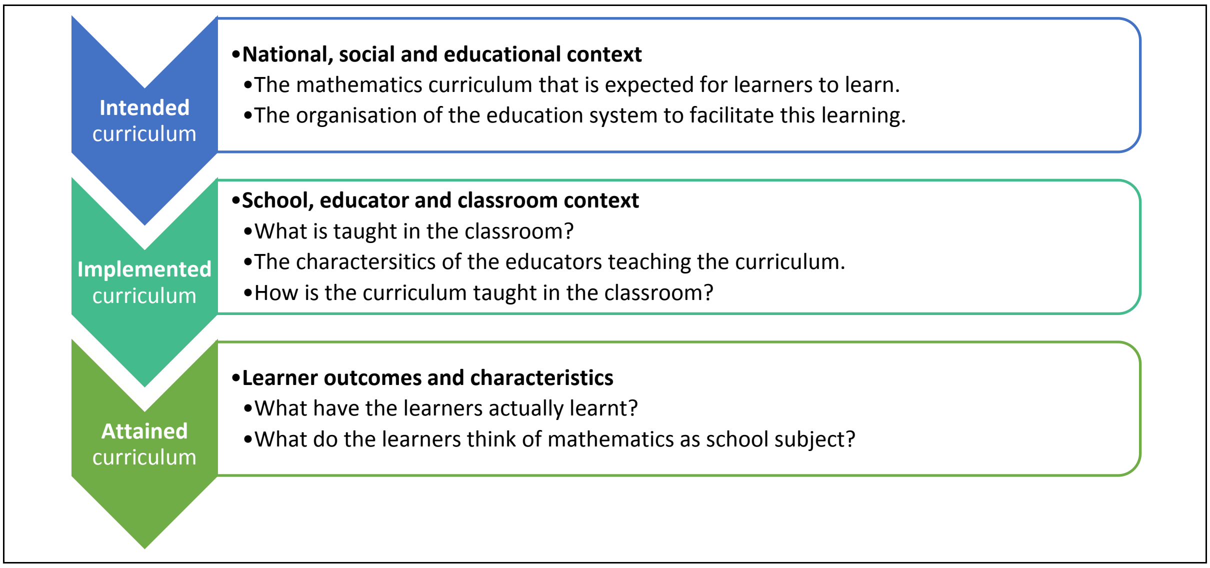

Figure 2.7: The TIMSS curriculum model (Mullis & Martin, 2013)

Learner achievement in schools can be influenced by a variety of elements and many of these elements are directly associated with the context in which the learner functions (Creemers et al., 2007). In order to improve understanding of the context in which the TIMSS Grade 8 mathematics studies were implemented, the IEA developed four context questionnaires to collect background data from sampled schools, educators and learners (Martin, Mullis & Hooper, 2016). The four context questionnaires are the Eighth Grade *Mathematics Curriculum* Questionnaire, the Eighth Grade *School* Questionnaire, the Eighth Grade *Mathematics*

Teacher Questionnaire, and the Eighth Grade *Student* Questionnaire (Foy, 2017b; Foy, Arora & Stanco, 2013b). The TIMSS context questionnaires were designed within the framework of the TIMSS curriculum model (Mullis & Martin, 2013).

Mullis et al. (2009) identified four distinct areas of research on which the TIMSS context questionnaires focus. The areas of research covered by the TIMSS context questionnaires are depicted in Table 2.5. This study focused on three of the TIMSS context questionnaires, namely the Eighth Grade *School* Questionnaire, the Eighth Grade *Mathematics Teacher* Questionnaire, and the Eighth Grade *Student* Questionnaire.

Table 2.5: TIMSS context questionnaires research areas

TIMSS context questionnaire	Areas of research
Eighth Grade *Mathematics Curriculum* Questionnaire • Country context	The mathematics curriculum as set out by the participating country's department of education.
Eighth Grade *School* Questionnaire • School context	The school context in which both the learner and educator functions – this includes aspects such as the availability of resources, perceived safety at school and perceived support from school management.
Eighth Grade *Mathematics Teacher* Questionnaire • Educator and classroom context	The background of the educator and the influence of the educator on teaching and learning effectiveness in the classroom context – this includes aspects such as the educational background of the educator, teaching techniques of the educator as well as application of learning in the classroom.
Eighth Grade *Student* Questionnaire • Learner context	The context in which the learner functions – this includes learner-related information such as the learner's home environment, the learner's academic motivation and application, as well as background on the learner's parents and the support available from their side.

Adapted from Mullis et al. (2009)

The four areas of research covered by the TIMSS context questionnaires relate closely to the four levels of education effectiveness factors identified in the Dynamic Model, namely context-related factors (the country and region), school-related factors, classroom- and educator-related factors, and learner-related factors (Creemers & Kyriakides, 2007). Schools do not function in a social vacuum and it is therefore essential to view the TIMSS results within the broader socioeconomic contexts of the communities in which these schools are situated.

2.9.4. Conceptual framework of this study

This study utilised a secondary data analysis of the South African TIMSS 2011 and 2015 results in an attempt to answer the research questions. In order to customise the study for the South African context, an adaptation of the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2007) was used as conceptual framework for the study. In order to guide the study, the conceptual framework consists of a combination of the Dynamic Model, the TIMSS Curriculum Framework, as well as the research areas covered by the TIMSS context questionnaires.

The conceptual framework allowed for the examination of ICT-related elements in schools and their relationship with mathematics achievement in a diverse set of schools in South Africa. The relationship between the Dynamic Model of Educational Effectiveness, the TIMSS curriculum model and the TIMSS context questionnaires is depicted in Table 2.6.

Table 2.6: Relationship between the Dynamic Model of Educational Effectiveness, the TIMSS curriculum model and the TIMSS context questionnaires

Dynamic Model of Educational Effectiveness	**TIMSS curriculum model**	**TIMSS context questionnaires**
Context-level factors (country and region)	Intended curriculum	• Mathematics curriculum – Eighth Grade *Mathematics Curriculum* Questionnaire
School-level factors	Implemented curriculum	• School context – Eighth Grade *School* Questionnaire
Classroom-level factors	Implemented curriculum	• Classroom and educator context – Eighth Grade *Mathematics Teacher* Questionnaire
Student-level factors	Attained curriculum	• Learner achievement in TIMSS – Eighth Grade Mathematics *assessment* • Learner context and background – Eighth Grade *Student* Questionnaire

Adapted from Creemers and Kyriakides (2007), Foy (2017b) and Mullis and Martin (2013)

While schools in the South African education system follow a uniform mathematics curriculum, namely CAPS (DBE, 2011), the implementation methodology and context of implementation vary vastly between different schools across the country.

Taking the diverse school and learner population in the country into account, a one-dimensional view on mathematics achievement will therefore be inappropriate. Additionally, schools and learners do not function in a social vacuum and it is essential to view the TIMSS results within the contexts of the communities in which these learners and schools are situated. The conceptual framework of the study attempts to take all these considerations into account and is depicted in Figure 2.8.

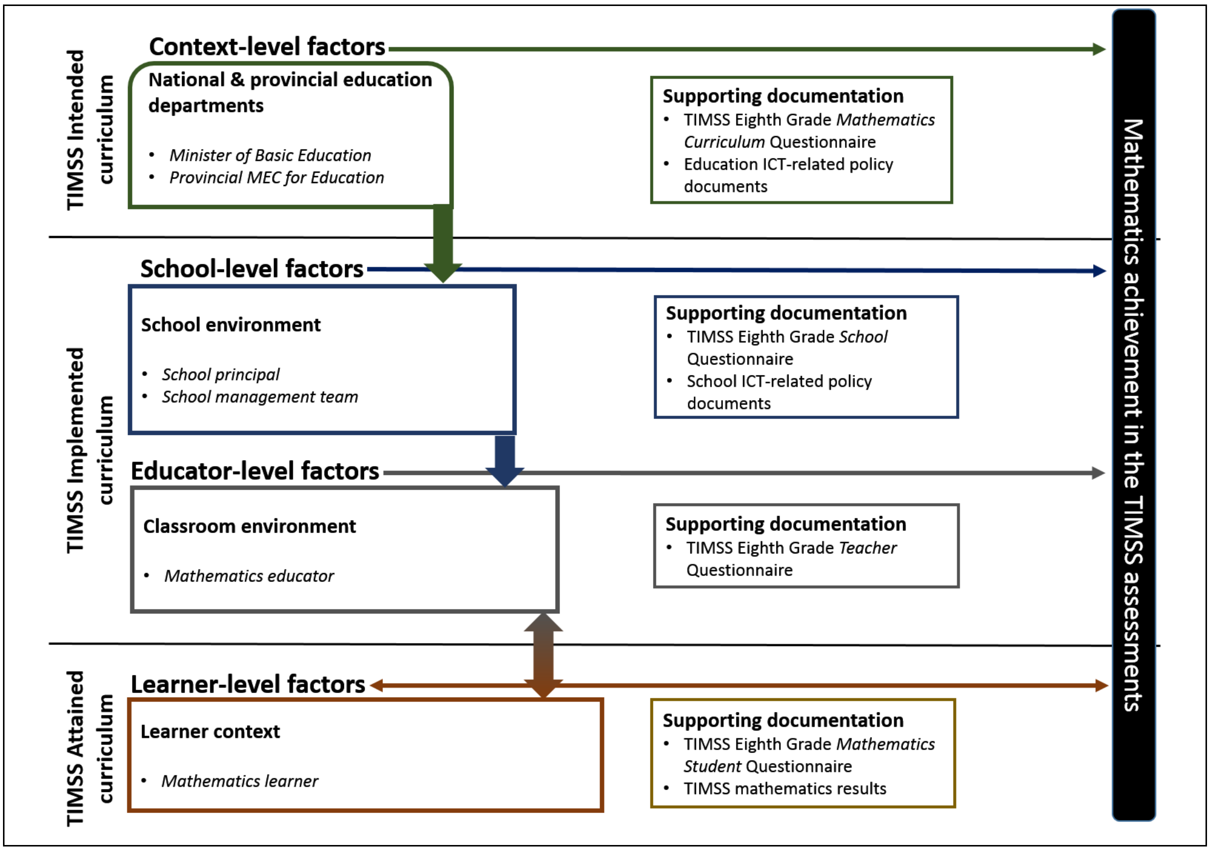

Figure 2.8: Conceptual framework of the study as adapted from Creemers and Kyriakides (2007), Foy (2017b) and Mullis and Martin (2013)

Participation in international comparative studies such as TIMSS, should not be seen as a competitive exercise to determine a country's standing in relation to other countries' performance on the TIMSS assessment scales (Van Staden, 2010). The focus should rather be on assessing what was intended with a country's curriculum over the last four years, what was implemented over the last four years, and what was attained over the last four years (Mullis & Martin, 2013; Mullis et al., 2009). The conceptual framework guided the research project in examining changes in ICT-related variables and mathematics achievement from 2011 to 2015.

2.10. Summary

Chapter 2 provided an overview of the literature that was consulted prior to the start of this study. An overview of ICT and its benefits and challenges in education was presented, the background to the South African education system and mathematics education in South Africa was examined, and the development of the conceptual framework was discussed. The literature review guided the design and implementation of the study.

Chapter 3 will provide background on the research methodology that was followed during this research project. The chapter will focus on the research methodology followed by the TIMSS studies, as well as the research methodology that guided this study.

3. CHAPTER 3 – RESEARCH METHODOLOGY

"We conduct high-quality, large-scale comparative studies of education across the globe in order to provide educators, policymakers, and parents with insights into how students perform."

(IEA, 2017f, para. 2)

In order to ensure the integrity of Trends in International Mathematics and Science Study (TIMSS) assessments across the world and to enable studies with TIMSS data from different years, the International Association for the Evaluation of Educational Achievement (IEA) and the TIMSS & PIRLS International Study Center at the Lynch School of Education, Boston College, maintains strict control over all aspects of the TIMSS studies (Mullis, Martin & Loveless, 2016). This chapter therefore relies heavily on the official TIMSS background documentation as released by the TIMSS & PIRLS International Study Center (IEA, 2017d).

3.1. Introduction

The IEA is an international network of national research organisations, researchers and analysts whose aim it is to understand and improve education across the globe (IEA, 2017a). More than 60 countries, representing more than 100 education systems, are actively involved in the IEA studies (IEA, 2017a). The IEA has conducted worldwide, comparative studies focusing on mathematics, science and reading since 1958. The aim of these large-scale comparative studies is to provide governments, policymakers, educators and other interested parties with insight on how effective policies and practices in education can support educational progress (IEA, 2017b). Since inception, the IEA managed more than 30 comparative studies of educational achievement globally (IEA, 2017c).

The first TIMSS study was conducted in 1995 and has been repeated every four years since, with studies taking place in 1999, 2003, 2007, 2011 and also in 2015 (IEA, 2017h). TIMSS utilises a quasi-longitudinal design in that learners are assessed in Grade 4 and again four years later in Grade 8 – the rationale behind this design is that Grade 4 results may act as an early warning system for necessary curriculum and policy reforms in an education system (IEA, 2017h). The Grade 8 results four years later may act as monitor of the effectiveness of the reforms of the past four years (IEA, 2017h). It should therefore be possible to identify specific trends in a country's education system when comparing current achievement with achievement in previous cycles.

These trends provide countries with extensive data and information to advance education in mathematics (Grønmo, Lindquist, Arora & Mullis, 2013; Mullis, Martin & Loveless, 2016). An interesting example that emanated from a comparison of TIMSS 2011 data with previous years, is that an early start in school seems to have a positive influence on learners' achievement in mathematics and science later in life (Mullis & Martin, 2013). The 2015 iteration of TIMSS was therefore the fifth time that South Africa took part in the IEA's series of worldwide assessments aimed at improving education in mathematics and science, since the South African government elected not to take part in the 2007 study (HSRC, 2017).

Data collected during the TIMSS assessments comprise of more than just data on learner achievement in mathematics. As part of their studies, the IEA also collects background information from learners, educators, school principals and policymakers on the aspects that influence teaching and learning in participating schools (Mullis & Martin, 2013; Mullis et al., 2009). Extensive data on the availability of resources in participating schools, the backgrounds of participating learners and educators, as well as data on the quality of teaching and the implementation of the curriculum in participating schools are also collected (Mullis & Martin, 2013; Mullis et al., 2009).

Additionally, variables in the TIMSS context questionnaires are aligned with similar variables in previous iterations of TIMSS. It is therefore possible to focus on specific related variables that occurred in both the TIMSS 2011 and 2015 context questionnaires in order to gain a quasi-longitudinal view of the variables. The index of variables in Supplement 1 of the TIMSS 2015 User Guide for the International Database (Foy, 2017b) contains a column named 'TIMSS 2011 Variable Name' where related variables from TIMSS 2011 are indicated. This enables researchers to identify related variables for studies over the two iterations of TIMSS.

In 2011 more than 600 000 learners from 63 countries participated in the TIMSS assessments (Mullis, Martin, Foy, et al., 2012). In 2015 more than 270 000 learners from 57 countries took part in the TIMSS 2015 assessments (TIMSS & PIRLS International Study Center, 2016). The countries that participated in TIMSS 2011 and TIMSS 2015 are depicted in Table 3.1.

Table 3.1: Countries participating in TIMSS 2011 and TIMSS 2015

Countries participating in TIMSS 2011 and TIMSS 2015			
Armenia	Finland	Kuwait	Saudi Arabia
Australia	France**	Lebanon	Serbia
Austria*	Georgia	Lithuania	Singapore
Azerbaijan*	Germany	Macedonia*	Slovak Republic
Bahrain	Ghana*	Malaysia	Slovenia
Belgium (Flemish)	Honduras*	Malta	South Africa
Botswana	Hong Kong SAR	Morocco	Spain
Bulgaria**	Hungary	Netherlands	Sweden
Canada	Indonesia	New Zealand	Syrian Arab Republic*
Chile	Iran, Islamic Rep. of	Northern Ireland	Thailand
Chinese Taipei	Ireland	Norway	Tunisia*
Croatia	Israel	Oman	Turkey
Cyprus**	Italy	Poland	Ukraine*
Czech Republic	Japan	Portugal	United Arab Emirates
Denmark	Jordan	Qatar	United States
Egypt**	Kazakhstan	Romania*	Yemen*
England	Korea, Rep. of	Russian Federation	
* TIMSS 2011 only			
** TIMSS 2015 only			

Adapted from Mullis, Martin, Minnich, et al. (2012) and TIMSS & PIRLS International Study Center (2016)

A TIMSS National Research Coordinator (NRC) in participating countries manages the TIMSS assessments locally. In the case of South Africa, the role of the TIMSS NRC was conducted by the Education and Skills Development Unit of the HSRC (HSRC, 2017).

Based on the poor achievement of South African Grade 4 and Grade 8 learners in the 1995 and 1999 studies, the South African TIMSS NRC took a decision in 2002 to expand the TIMSS assessments to Grade 5 and Grade 9 learners as well (Spaull, 2013). The TIMSS assessments were too demanding for the South African learners and it was found that too many learners were performing on "guessing level" on the multiple choice items (Spaull, 2013, p. 16). Subsequently the South African TIMSS NRC took the decision in 2010 to focus future iterations of TIMSS on South African Grade 5 and Grade 9 learners only (Reddy et al., 2013). This was done in order to better match the South African mathematics curriculum with the TIMSS assessments and to maintain trend measurement for the country (Reddy et al., 2013; TIMSS & PIRLS International Study Center, 2016). It is interesting to note that because the Norwegian Grade 5 and 9 mathematics curricula align with the Grade 4 and 8 Finnish and Swedish mathematics curricula, Norway chose to assess their Grade 5 and 9 as well as their Grade 4 and 8 learners in 2015 in order to obtain better comparisons with Finland and Sweden (TIMSS & PIRLS International Study Center, 2016).

The results of TIMSS 2011 and TIMSS 2015 confirmed the results of previous local and international mathematics assessments that concluded that mathematics education in South Africa is in serious trouble (Howie & Hughes, 1998; Mullis, Martin, Foy, et al., 2012; Mullis, Martin, Foy, et al., 2016; Reddy, 2006; Spaull, 2013). South African learners did improve by 20 points on the TIMSS assessment scale, moving from 352 in 2011 to 372 in 2015 (Mullis, Martin, Foy, et al., 2012; Mullis, Martin, Foy, et al., 2016), but the country is still ranked with the second lowest score of all participating countries.

3.2. Research design and methodology of TIMSS

The IEA studies focus on the processes and the outcomes of education in participating countries (IEA, 2017h). These studies aim to understand the relationships between the intended curriculum (what learners are expected to learn according to the educational policies and curriculum of a country), the implemented curriculum (what is taught in the classroom and the characteristics of those teaching it) and the achieved curriculum (what learners have learned as well as what they think of these subjects) (Mullis & Martin, 2013).

The TIMSS study is organised around several frameworks that guided the development and implementation of the TIMSS assessments and questionnaires (Grønmo et al., 2013; Hooper, Mullis & Martin, 2013; Mullis & Martin, 2013; Mullis et al., 2009). These frameworks are adapted for use in each of the participating countries, taking the local context into account and thereby ensuring that learners can identify with the questions asked in the TIMSS assessments as well as the TIMSS context questionnaires (HSRC, 2017).

3.2.1. The TIMSS assessment frameworks

The TIMSS study comprised of detailed assessment frameworks for both mathematics and science in Grade 4 and Grade 8. The items in the TIMSS academic assessments covered thinking skills contained in three cognitive domains, namely knowing, applying and reasoning.

The TIMSS assessment frameworks are depicted in Table 3.2. This study focused on the TIMSS Mathematics Framework for Grade 8 and the TIMSS Contextual Frameworks for Grade 8.

Table 3.2: TIMSS assessment frameworks

Grade	Mathematics framework	Science framework	Contextual framework
Grade 4	TIMSS Mathematics—Fourth Grade TIMSS Numeracy[6]	TIMSS Science—Fourth Grade	Fourth Grade *School* Questionnaires for mathematics and science Fourth Grade *Mathematics Teacher* Questionnaire Fourth Grade *Student* Questionnaire Fourth Grade *Home* Questionnaire
Grade 8	TIMSS Mathematics—Eighth Grade	TIMSS Science—Eighth Grade	Eighth Grade *Curriculum* Questionnaires for mathematics and science Eighth Grade *School* Questionnaire Eighth Grade *Teacher* Questionnaire Eighth Grade *Student* Questionnaires for mathematics and science

Adapted from Mullis et al. (2009) and Mullis and Martin (2013)

The TIMSS assessment frameworks are updated regularly in order to give participating countries the opportunity to add or remove information from the assessment for their respective countries (Mullis & Martin, 2013). One of the main responsibilities of the TIMSS NRC is to collaborate with the international TIMSS team to make sure that the study responds to the country's needs with regards to mathematics assessment (Mullis & Martin, 2013; Mullis et al., 2009). The TIMSS NRC is expected to liaise with local and international experts on possible changes to the content and cognitive domain questions in the TIMSS assessments. This results in educationally relevant assessments and allows the assessments to evolve gradually with the curriculum in participating counties (Mullis et al., 2009).

The TIMSS 2015 assessment frameworks were reviewed and adapted using an interactive process starting with the TIMSS NRC in each country. Using assessment information from the TIMSS 2011 Encyclopedia (Mullis, Martin, Minnich, et al., 2012) as well as inputs from

[6] TIMSS Numeracy is an easier version of TIMSS Mathematics Fourth Grade. It was newly developed for TIMSS 2015.

participating countries, the TIMSS 2011 assessment frameworks were reviewed and adapted for TIMSS 2015. The TIMSS NRC was expected to consult with local experts on the relevance and applicability of the content and cognitive domains of the TIMSS 2015 assessments for their country. Once the assessments were adapted by the TIMSS NRCs, the TIMSS 2015 Science and Mathematics Item Review Committee (SMIRC) conducted their own comprehensive review of the assessment questions and collaborated with the TIMSS NRCs to adopt a final version of the TIMSS 2015 assessments for their country (Mullis & Martin, 2013). Since the identification of trends in mathematics and science achievement is one of the main goals of TIMSS, the assessment frameworks of successive TIMSS assessments closely resemble one another (Mullis & Martin, 2013; Mullis et al., 2009).

3.2.2. The TIMSS mathematics frameworks

The TIMSS 2015 mathematics frameworks were reviewed, updated and approved by the South African TIMSS NRC for distribution in South Africa. Grønmo et al. (2013) note that only minor updates were made to the South African TIMSS 2015 mathematics frameworks in order to reflect changes in mathematics education and the country's mathematics curriculum.

The mathematics framework is structured around two areas of assessment: the content domain (the mathematics content to be assessed), and the cognitive domain (the thinking processes required of learners as they participate in the mathematics assessments) (Grønmo et al., 2013; Mullis et al., 2009). Table 3.3 illustrates the allocation of content and cognitive domain assessment items in the Grade 8 TIMSS assessments.

Table 3.3: TIMSS Grade 8 Content and Cognitive domains

Grade 8 Content domains		**Grade 8 Cognitive domains**	
Number	30%	Knowing	35%
Algebra	30%	Applying	40%
Geometry	20&	Reasoning	25%
Data and chance	20%		

Adapted from Mullis et al. (2009) and Grønmo et al. (2013)

The TIMSS mathematics assessment item pool contained items per grade. Most of these items assessed learners' reasoning and application skills (Mullis & Martin, 2013; Mullis et al., 2009). The item pool developed for the TIMSS 2015 Grade 8 mathematics assessment consisted of 219 assessment items – an item pool of this size was essential due to the broad analysis goals pursued by the TIMSS assessments (Grønmo et al., 2013).

3.2.3. The TIMSS mathematics content domains

One of the objectives of TIMSS was to assess whether learners can use mathematics in problem solving scenarios. Around two-thirds of the items in TIMSS relate to the learners' use of reasoning and application skills. Each of the content domains include topic areas and each topic area is further divided into smaller topics (Grønmo et al., 2013; Mullis et al., 2009). The Content domains, Topic areas and Topics in TIMSS 2015 are depicted in Appendix 3.

The alignment of the TIMSS 2011 and TIMSS 2015 Grade 8 mathematics content domains with the South African mathematics curriculum was one of the aspects taken into consideration by the South African TIMSS NRC when they determined the TIMSS 2011 and 2015 assessments to be on an appropriate level for South African Grade 9 learners (Reddy, Arends, et al., 2016; Reddy et al., 2013).

3.2.4. The TIMSS mathematics cognitive domains

The assessment items in TIMSS expect of learners to know the mathematics content and be able to use a range of cognitive skills to solve situation based problems (Grønmo et al., 2013; Mullis et al., 2009). These cognitive skills in TIMSS are closely related to the content domains of the assessment. The Cognitive domains, Topic areas and Topics in TIMSS are depicted in Appendix 4.

The *knowing domain* includes the mathematical concepts, facts and procedures that learners in Grade 8 are expected to know. Any application of mathematics in problems solving situations depends on knowledge of mathematical concepts, facts and procedures (Grønmo et al., 2013; Mullis et al., 2009; Stols, 2012). Without a sound mathematical knowledge base learners find focussed mathematical thinking in problem situations impossible (Grønmo et al., 2013). While mathematical concepts form the basis of mathematical thought, mathematical procedures on the other hand form a link between basic mathematical knowledge and using mathematics to solve problems (Grønmo et al., 2013).

The *applying domain* concentrates on the ability of learners to apply their mathematical knowledge and understanding in problem solving situations. In this domain it is also expected of learners to apply their mathematical knowledge to create representations of ideas, e.g. diagrams that represent problems, displaying data in tables and graphs and equivalent calculations. Grønmo et al. (2013) sees representation as the core of mathematical thinking, reasoning and communication. Learner success in mathematics relies heavily on the ability to create equivalent representations. Problem solving makes up a large portion of the applying domain with the focus on problems requiring more well-known and routine mathematical tasks.

The *reasoning domain* focuses on the solution of complex problems in unfamiliar situations. Mathematical reasoning requires systematic, logical thinking based on patterns to reach solutions for problems in unfamiliar circumstances. This requires transferring current knowledge and skills to a new situation in order to solve an unfamiliar problem (Grønmo et al., 2013; Mullis et al., 2009). Reasoning involves making valid conclusions based on specific assumptions and then defending the results.

A valuable outcome of mathematics education is the potential to expand the application of learners' higher order thinking skills beyond the mathematics classroom (Siyepu, 2013; Stols, 2013). South Africa still grapples with the legacy of inferior mathematics and science education to a large segment of learners (Spaull, 2013) and if the results from the TIMSS assessments are acted upon, it may assist with addressing this appalling legacy (Cho, Scherman & Gaigher, 2014).

3.2.5. The TIMSS Context Questionnaire Framework

A positive climate for teaching and learning is greatly influenced by supportive home, community, school and classroom experiences (Creemers & Kyriakides, 2010; Scheerens, 1990). Additionally, these contextual elements may also have an influence on learner achievement (Creemers et al., 2007). In order to comprehend the different contexts in which teaching and learning take place, the IEA assessments also collect a range of contextual data with each assessment cycle. The four broad areas of the TIMSS Contextual Framework are the national and community context, the school context, the educator and classroom context, as well as the learner's learner characteristics and their attitudes toward learning (Hooper et al., 2013; Mullis & Martin, 2013; Mullis et al., 2009). The background information collected during the TIMSS studies is determined by the TIMSS Context Questionnaire Framework (Hooper et al., 2013; Mullis et al., 2009). The focus areas of the TIMSS context questionnaires are summarised in Appendix 5.

The aim of the collection of contextual information is to attempt to reveal how different education systems promote and deliver mathematics and science education (Hooper et al., 2013). The TIMSS NRC in each participating country contributes a chapter to the TIMSS Encyclopedia (Mullis, Martin, Goh & Cotter, 2016; Mullis, Martin, Minnich, et al., 2012). This chapter gives the background to the national schooling system, policies and curricula that impact on mathematics and science education in that specific country (Reddy, Arends, et al., 2016).

Any country's education system, and by implication also the mathematics curriculum prescribed by that education system, is influenced by political, economic, cultural and social factors (Mullis et al., 2009). Chiu and Khoo (2005) found that access to economic resources and socioeconomic equity has a positive effect on the creation of an enabling environment that supports learner achievement. It can be problematic if high level decisions on aspects that influence teaching and learning, such as resource allocation, minimum standards for facilities, educator qualifications and the curriculum, are taken without keeping in mind what is needed to support teaching and learning in the classroom (Mullis et al., 2009; Van de Werfhorst & Mijs, 2010). Additionally, Van de Werfhorst and Mijs (2010) found greater educational equality in education systems with a high level of centralisation, because of variances in school operations and how learners are taught in decentralised systems.

An effective school operates as a well-managed, integrated system where the actions of the different role-players directly affect the other parts of the system (Creemers & Kyriakides, 2010; Scheerens, 1990). The environment in which a school is located and the internal organisation of the school has a direct bearing on reaching the educational goals set by the curriculum (Creemers & Kyriakides, 2007). The Eighth Grade *School* Questionnaires focus on seven school quality indicators, namely school location, the composition of the school according to learner socioeconomic background, mathematics teaching affected by shortages in educational resources, educator availability and retention, leadership by the school principal, the emphasis by the school on academic success, and whether the school is safe, orderly, and disciplined (Hooper et al., 2013).

Generally schools in rural areas struggle more to get access to educational resources (Agirdag, Van Houtte & Van Avermaet, 2011; Chiu & Khoo, 2005). However, Milam, Furr-Holden and Leaf (2010) found that many schools in urban areas are situated in low socioeconomic areas and that they also have difficulty in getting resources for teaching and learning. It is interesting to note that Agirdag et al. (2011) found many learners from lower socioeconomic backgrounds were overwhelmed by a sense of futility and that they could not comprehend the future value of education.

While qualified mathematics educators play an important role in the academic success of learners, it may be difficult for schools to employ and retain suitable candidates (Ingersoll & Perda, 2010). Results from TIMSS 2011 indicated better learner achievement for educators who indicated that they work under conducive working conditions (Hooper et al., 2013). Additionally, research has shown that school principals can have a positive influence on learner achievement by guiding the school, educators and learners by setting goals, assisting in the creation of an efficient learning environment and creating a positive school ethos (Witziers, Bosker & Krüger, 2003). Cohen, McCabe, Michelli and Pickeral (2009) found that a positive school climate could have a positive impact on learner achievement in the school. The focus areas of the Eighth Grade *School* Questionnaires are summarised in Appendix 6.

Most of the teaching and learning that learners are exposed to occur in the classroom, therefore any effective learning is dependent on the classroom environment and the teaching and learning activities presented there (Creemers & Kyriakides, 2010; Hooper et al., 2013). The Eighth Grade *Mathematics Teacher* Questionnaires focused on six practices that improve teaching and learning, namely educator preparation and experience, the mathematics themes taught in class, educational resources and technology in the classroom, time allocated for instruction, instructional engagement, and assessment in the classroom (Hooper et al., 2013).

Harris and Sass (2011) found that educator experience and professional development can positively influence learner achievement in mathematics. It seems as if ICT is starting to play an increasingly central role in the teaching of mathematics in schools (Hooper et al., 2013; OECD, 2010). However, despite ICT being available for teaching and learning, it seems as if many educators' decision to use ICT is still influenced by their own beliefs on the value of ICT, their attitudes towards ICT and their own comfort levels with ICT (Mueller, Wood, Willoughby, Ross & Specht, 2008; O'Bannon & Thomas, 2014).

Effective classroom management creates a conducive teaching and learning environment since it focuses the instructional time on the task at hand (Lipowsky et al., 2009). Yair (2000) conceptualised the idea that learners are torn between engagement with the content and unrelated distractions – a well-managed classroom therefore creates a supporting atmosphere and this supports engagement (Lipowsky et al., 2009). The focus areas of the Eighth Grade *Mathematics Teacher* Questionnaires are summarised in Appendix 7.

The relationship between learner attitude towards a school subject and their academic success in that subject, is an important topic in educational research and in policy circles it is debated whether developing a positive attitude towards mathematics should be one of the goals of the curriculum (Barkatsas et al., 2009; Bonaveri et al., 2015). The TIMSS learner characteristics and attitudes towards learning context questionnaire includes information on four areas, namely learner readiness to learn, learner motivation, learner self-concept, and learner characteristics (Hooper et al., 2013). Learners need to be physiologically ready to learn and have the requisite pre-knowledge in order to engage with content because "every new thing that a person learns must be attached to what the person already knows" (McLaughlin et al., 2005, p. 5).

Deci and Ryan (1985) stated that learners who were intrinsically motivated found mathematics more interesting and enjoyed doing mathematics more than learners who were extrinsically motivated. Research by Becker, McElvany and Kortenbruck (2010) and Vansteenkiste, Timmermans, Lens, Soenens and Van den Broeck (2008) confirmed this finding on intrinsic motivation and additionally, also found a closer relationship between intrinsic motivation and academic achievement, than extrinsic motivation and academic achievement. While concern has previously been raised about girls' achievement in mathematics, a large cluster of current research (TIMSS included) shows the achievement differences between boys and girls to be minimal (Hooper et al., 2013; Lindberg, Hyde, Petersen & Linn, 2010; Mullis, Martin, Foy, et al., 2012; Mullis, Martin, Foy, et al., 2016). The focus areas of the Eighth Grade *Student* Questionnaires are summarised in Appendix 8.

The way children are brought up at home and their home environment have a huge impact on their achievement at school (Hooper et al., 2013). The IEA used two questionnaires in TIMSS that focused on the home environment, one aimed at learners, and one aimed at their parents or guardians (Foy, 2017b). Data was gathered on resources for learning available at home, the language(s) spoken at home, the educational expectations that parents had for their children, parents' own academic status, as well as literacy and numeracy activities parents did with their children while they were still young (Hooper et al., 2013). Other researchers found SES to be a prominent background factor influencing learner achievement (Bradley & Corwyn, 2002; Davis-Kean, 2005; Martin, Foy, Mullis & O'Dwyer, 2013).

The OECD manages a set of worldwide assessments similar to TIMSS, namely the Programme for International Student Assessment (PISA). PISA is a set of literacy, mathematics and science assessments that are conducted every three years (OECD, 2018). It is interesting to note that the OECD acknowledged the influence of contextual factors on learner achievement and included questions on the social and emotional wellbeing of participants for the first time in the 2015 iteration of PISA (The Economist, 2017). The findings from PISA 2015 also suggest that participants' contextual factors influence achievement as much as teaching and learning (OECD, 2017).

Research has also shown that learners who do not use the language of learning and teaching at home are often disadvantaged because they experience a gap in their understanding because they first need to learn new mathematical content and concepts in a new language (Schnepf, 2007; Van Staden, 2010). When parents draw parallels between school work and its everyday application in the 'real world', they unconsciously focus their children's attention on the importance of education. Taylor, Clayton and Rowley (2004) call this process academic socialisation, and interestingly, results from TIMSS 2011 indicated a positive impact from academic socialisation on learner achievement in school (Hooper et al., 2013). Melhuish et al. (2008) found that if parents are involved in literacy and numeracy activities with their children when they are still small, it had a positive impact on the child's later development of literacy and numeracy. These findings are important because learners who attain numeracy skills early in life achieve better results in mathematics in primary school (Duncan et al., 2007). The focus areas of the TIMSS *Home* Questionnaires are summarised in Appendix 9.

3.2.6. Identification of the TIMSS target population

Every iteration of TIMSS focuses on two specific target populations in a country, namely all Grade 4 and all Grade 8 learners (Mullis, Martin & Loveless, 2016). Countries may decide whether to test only one, or both grades. Due to the existence of different education systems, policies and procedures in participating countries, the local TIMSS NRC has the responsibility to ensure that the TIMSS assessment instruments are appropriate for the sampled populations of that country (Joncas & Foy, 2012). The South African TIMSS NRC determined the TIMSS 2011 and TIMSS 2015 assessments to be on an appropriate level for South African Grade 5 and Grade 9 learners (Reddy et al., 2013; Reddy, Visser, et al., 2016).

The IEA uses the levels of schooling as described in the UNESCO International Standard Classification of Education (ISCED) (UNESCO Institute for Statistics, 2012) to define the international target populations for the TIMSS assessment (LaRoche et al., 2016). The ISCED education levels correspond directly with the years of formal schooling that a learner has received (UNESCO Institute for Statistics, 2012). The IEA uses this classification because not all countries use the same naming convention when referring to a specific year in school. TIMSS is aimed at learners in the 4^{th} and 8^{th} years of formal schooling (LaRoche & Foy, 2016). Grade 4 of TIMSS therefore corresponds with Level 4 of ISCED, and Grade 8 of TIMSS corresponds with Level 8 of ISCED (LaRoche et al., 2016). The TIMSS assessments are demanding for very young learners, so the IEA suggested an average age of 9.5 years for Grade 4 learners and 13.5 years for Grade 8 learners participating in TIMSS (LaRoche & Foy, 2016).

The national target population consists of all learners in the grades identified by the TIMSS NRC and these learners are therefore all eligible to take the TIMSS assessments. It is interesting to note that South African Grade 5 learners who participated in TIMSS 2015 had an average age of 11.5 years, while the Grade 9 participants had an average age of 15.7 years (LaRoche & Foy, 2016). South Africa achieved a 100% coverage rate in TIMSS 2015 (LaRoche & Foy, 2016). This means that every eligible school, class and learner was included in the target population.

3.2.7. The TIMSS sample design

The TIMSS NRC in participating countries is responsible for drawing up a national sampling plan (Joncas & Foy, 2012). This plan defines the national target population and identifies sampling methods needed to reach a representative sample of schools and learners. Due to the number of schools and learners involved, TIMSS employs a two-stage cluster sample design (Joncas & Foy, 2012).

During the first stage of sampling, a sample of schools is selected from the target population of all schools in the country. Random-start fixed-interval systematic sampling is used to draw the TIMSS school sample (Joncas & Foy, 2012; LaRoche & Foy, 2016), with schools drawn from the population with probability proportional to size. This list of schools represents the school sampling frame of the study and is stratified according to demographic variables identified by the national TIMSS NRC. In the case of South Africa, the sampling frame was stratified according to the province in which a specific school was situated. The sampled selection of schools represents the primary sampling unit (PSU) for the study (LaRoche et al., 2016).

During the second stage of sampling, a sample of one or more intact classes[7] is selected from identified schools. The TIMSS assessments focus on intact classes and the local TIMSS NRC has to be sure that learners appear on only one class list in the school. This is necessary to

[7] During sampling full classes are selected to represent the secondary sampling unit.

ensure that every eligible learner in a school has an equal chance of being sampled (Johansone, 2016).

The sampling of classes is conducted by the local TIMSS NRC in collaboration with Statistics Canada and the IEA DPC. The sampled selection of classes represent the secondary sampling unit (SSU) for the study (LaRoche et al., 2016). In South Africa, mathematics is still a compulsory subject in Grade 9 and as such the sampling of intact classes do not pose a challenge as in countries where mathematics can be selected as subject by the learners (Reddy, Arends, et al., 2016).

It is important that intact classes are sampled for the TIMSS assessments as there is a strong focus on learners' experiences regarding the curriculum and the teaching they receive, and these experiences are typically related to the specific class of the learner (LaRoche et al., 2016). Joncas and Foy (2012) also identify the operational advantage of less disruption to the school programme if intact classes are sampled.

3.2.8. The TIMSS national sampling plan

The national sampling plan is a strategy for defining a country's TIMSS target population. Additionally, the national sampling plan guides the application of the TIMSS sampling methods to the target population in order to realise a representative sample of schools and learners in participating countries (Joncas & Foy, 2012; LaRoche et al., 2016).

The IEA DPC works with Statistics Canada in advising the local TIMSS NRC on sampling related matters. Employees from the IEA DPC, Statistics Canada and the TIMSS NRC work closely together to select the national school sample (LaRoche et al., 2016). This entails the production of supporting documentation for sampled schools, confirming that the school sampling frame (the complete, national target population from which the sample will be drawn) is complete, assuring that classifications of excluded learners are well-defined and kept to a minimum, as well as assisting the TIMSS NRC in defining the sample size and a national stratification plan (Joncas & Foy, 2012; LaRoche & Foy, 2016; LaRoche et al., 2016).

An important aspect of the national sampling plan is an appropriate measure of size (MOS) for schools in the population (LaRoche et al., 2016). The MOS of a school is an accurate count of all learners in the specific target grade in that school (LaRoche et al., 2016). The MOS is an important measure because larger sized schools have an increased probability of selection due to a higher number of different classes and learners.

The TIMSS NRC is responsible for conducting the sampling in a country (LaRoche et al., 2016). This entails identifying the local school grades that correspond with the content of the Grade 4 and Grade 8 TIMSS assessments. In South Africa TIMSS 2003 was administered to both grades 8 and 9 learners, while TIMSS 2011 and TIMSS 2015 were administered to Grade 9 learners only (Reddy, Visser, et al., 2016).

Once sampling has been done and data collection completed, Statistics Canada assists with the documentation of population coverage and learner and school participation rates. This information is the used to develop applicable sampling weights for use when analysing and reporting on the TIMSS results (Joncas & Foy, 2012; LaRoche et al., 2016).

3.2.9. National sampling accuracy in TIMSS

The accuracy of national estimates of learner achievement in TIMSS is of primary concern to all parties involved in the TIMSS study (Joncas & Foy, 2012; LaRoche et al., 2016). The TIMSS standards for sampling accuracy stipulates a standard error of no more than 0.035 standard deviation units for the country’s mean achievement (LaRoche et al., 2016). With a standard deviation of 100 on the TIMSS achievement scale, this translates into a 95% confidence interval of ±7 points for the achievement average, and of ±10 points for the difference in achievement averages between consecutive TIMSS cycles, e.g. TIMSS 2011 and TIMSS 2015 (Joncas & Foy, 2012; LaRoche et al., 2016). The IEA requires a confidence interval of ±3.5% for any learner-level percentage estimate (LaRoche et al., 2016). In order to achieve the required accuracy, countries need to supply a school sample of at least 150 schools and a learner sample of at least 4 000 learners per grade (LaRoche et al., 2016).

The IEA aims for 100% participation in TIMSS to minimise the effect of non-response bias (Joncas & Foy, 2012; LaRoche et al., 2016). The national sample is deemed acceptable if it recorded a minimum of 85% learner participation rate from participating schools, a 95% classroom participation rate from sampled schools, and an 85% school participation rate from originally sampled schools. Classes where less than 50% of learners participated in the TIMSS assessments were deemed as non-participatory classes and were excluded from the study (LaRoche et al., 2016).

3.2.10. Stratification of schools in TIMSS

The stratification of schools in TIMSS entails arranging schools in the school sampling frame into strata that share mutual characteristics (Joncas & Foy, 2012; LaRoche et al., 2016). The stratification variables are identified by the local TIMSS NRC in consultation with Statistics Canada and the IEA DPS. Examples of stratification variables in TIMSS include province, school type and language of instruction (LaRoche et al., 2016).

Stratification is used to increase the reliability of the estimates by improving the effectiveness of the sample design, to allow for the implementation of different sample designs to specific groups of schools, and to ensure representivity of specific groups of schools in the sample (Joncas & Foy, 2012; LaRoche et al., 2016). In TIMSS the stratification of schools takes two forms: explicit stratification and implicit stratification.

Explicit stratification occurs when a separate list of schools is developed for each individual stratum before a sample of schools is drawn from that stratum. Explicit stratification is used to ensure the appropriate allocation of schools in a sample across strata. An example from the South African sample is where the school list is stratified according to province, to ensure the same number of schools from each province in the sample.

Implicit stratification occurs when schools are sorted by one or more stratification variables within a specific stratum, or within the whole school sampling frame if explicit stratification is not used. Implicit stratification is an effective way of ensuring that the learners in the study are allocated proportionally across all strata. An example from the South African sample is school size, which is always included as an implicit stratification variable. The stratification variables identified for the South African TIMSS assessments are depicted in Table 3.4.

Table 3.4: Grade 8 stratification variables for TIMSS

Explicit stratification variables		**Number of explicit strata**	**Implicit stratification variables**	
School type (2 strata):	Independent Public	17 variables	Performance level	Lower quintile First quintile Second quintile Higher quintiles Other quintiles
Province (9 strata):	Eastern Cape Free State Gauteng KwaZulu-Natal Limpopo Mpumalanga North West Northern Cape Western Cape		Region (2 variables)	GT/WC region Other region
Language (3 strata)	Afrikaans English Bilingual		School size	Measure of school size (MOS)
Socioeconomic status (2 strata)	Low Medium/high			

Adapted from LaRoche et al. (2016) and LaRoche and Foy (2016)

In order to sample schools with probability proportional to its size, schools from each of the explicit stratification variables were sorted according to the implicit stratification variables as well as by their measure of size (MOS) (LaRoche et al., 2016). The MOS is a measure assigned to individual schools and was based on the number of eligible learners in the school population.

3.2.11. TIMSS sampling weights

The learner sample in the TIMSS assessments aims to accurately represent the national population within a definite acceptable margin of error (LaRoche & Foy, 2016). The stratified, two-stage sampling procedure followed by the IEA to identify the TIMSS sample provides learners with an equal probability of selection (Joncas & Foy, 2012; LaRoche et al., 2016). However, over years the IEA found that inconsistent sampling, using explicit strata by varying the number of classes selected and combining it with varying patterns of non-response, require unique sampling weights for participating schools, classes and learners in the study (LaRoche et al., 2016).

Schools in TIMSS are sampled with probability of selection proportional to school size while classes are sampled with probability of selection inversely proportional to school size (Joncas & Foy, 2012). This sampling procedure affords learners with an equal probability for selection (LaRoche et al., 2016). The probability of a class being selected for TIMSS varies with the size of the school – because there are fewer classes in smaller schools, these classes have an increased probability of selection (Joncas & Foy, 2012; LaRoche et al., 2016). This relatively smaller probability for selection of classes in smaller schools is offset by the school's probability of selection being inversely proportional to school size.

In order to offset for a reduction in sample size should a sampled school or class not participate, the basic school and within-school weights are adjusted in these cases. School-level non-participation adjustments are calculated separately for individual strata (Joncas & Foy, 2012; LaRoche et al., 2016).

The learner sampling weight is calculated using a combination of weighting components that reflect the selection prospects and sampling outcomes on three levels – school, class within the school, and learner within the class (Joncas & Foy, 2012). Sampling weights are calculated individually for each grade and each TIMSS study. Countries usually have only one set of sampling weights per population (LaRoche et al., 2016).

3.2.12. TIMSS participation rates

Non-participation of sampled schools, classes, and learners may lead to sample bias and misrepresentative results (LaRoche et al., 2016). Special care is therefore taken to ensure that sampled learners, classes and schools actually take part in the TIMSS studies.

In order to compensate for possible non-participation of sampled schools, classes, and learners when calculating the results, TIMSS calculates both unweighted and weighted participation rates (Joncas & Foy, 2012; LaRoche et al., 2016). Unweighted participation rates refer to a simple count of participating learners, classes and schools. Weighted participation rates refer to participation rates based on the sampling weights as described in this chapter.

The unweighted participation rates are used to monitor the participation of sampled learners, classes and schools during the rollout of the TIMSS assessments. On the other hand the weighted participation rates are used as the final indicator of participation by sampled learners, classes and schools after the TIMSS assessments have been completed (Joncas & Foy, 2012; LaRoche et al., 2016).

3.2.13. TIMSS data collection methods

TIMSS aims to give countries an indicator of their learning context and their learner achievement profiles (Mullis, Martin & Loveless, 2016). These indicators are based on data collected during the TIMSS assessments every four years. TIMSS is data driven, therefore the quality of collection at all levels of the TIMSS assessments is of crucial importance to the trustworthiness of the TIMSS data (Johansone, 2016).

While the development of instruments and the selection of a sample population is a joint effort between the IEA partners and the TIMSS NRC, the management of the local TIMSS assessment process and the collection of the TIMSS data is the responsibility of the TIMSS NRC (Mullis & Martin, 2013). In order to ensure uniformity in the approach to the TIMSS assessments followed by NRCs across the globe, the TIMSS NRC is expected to follow a set of standard operating procedures that were developed over the past cycles of TIMSS (Johansone & Wry, 2016; Mullis & Martin, 2012).

These standard operating procedures were jointly developed by the TIMSS & PIRLS International Study Center, the IEA DPC, the IEA Secretariat, Statistics Canada, and the TIMSS NRCs (Johansone, 2016). With each iteration of TIMSS these procedures are refined to enhance accuracy and efficiency (Johansone, 2016). The TIMSS & PIRLS International Study Center provided the TIMSS NRCs with detailed documentation on all operational activities related to TIMSS. A set of documents, the *Survey Operations Procedures*, was made available to TIMSS NRCs to ensure they had all the information and tools required to implement the TIMSS assessments successfully (Johansone, 2016). The documents contained in the *Survey Operations Procedures* is depicted in Table 3.5.

Table 3.5: Survey Operations Procedures documentation

Document	Target audience	Objective of the document
Procedures units	School coordinators Assessment administrators	Detailed manuals on all tasks associated with the coordination and administering of the TIMSS 2015 assessment. These manuals were adapted for local use by the TIMSS NRCs.
Survey operations procedures	NRCs	A set of seven documents entailing all tasks TIMSS NRCs are responsible for. Detailed description of all tasks TIMSS NRCs are responsible for.

Adapted from Johansone (2016)

TIMSS tracks class sampling procedures, the assignment of assessment instruments as well as learner, educator and school information using a number of tracking forms that participants and coordinators need to complete (Johansone, 2016). These tracking forms are also used during the data collection and data verification phases of the TIMSS study.

In March and April 2014 all TIMSS NRCs conducted a field test of all the TIMSS 2015 instruments and operational procedures to prepare for the full TIMSS 2015 study that took place in October and November 2014. The field tests allowed TIMSS NRCs and their teams to become acquainted with the instruments and procedures of TIMSS 2015 before full-scale rollout. The field test resulted in some improvements in the operations of the TIMSS 2015 teams (LaRoche & Foy, 2016)

3.2.14. Development of the TIMSS assessment instruments

The TIMSS NRC is responsible for the preparation of all TIMSS related documentation – this includes the assessment instruments (the tests) and the different TIMSS context questionnaires. A total of 14 different TIMSS achievement assessment instruments and four TIMSS context questionnaires were developed (Johansone, 2016; Mullis & Martin, 2012). These achievement assessment instruments and the context questionnaires were developed in English by the TIMSS & PIRLS International Study Center and were then distributed to participating countries (Ebbs & Korsnakova, 2016).

Participating countries were expected to translate and adapt the international versions of the TIMSS assessment instruments and context questionnaires for local use (Ebbs & Korsnakova, 2016; Johansone, 2016). The IEA assessment translation guidelines allow for local translation and customisation as long as comparability to the international version is preserved (Mullis & Martin, 2012; Wry & Johansone, 2016). Assessment and language specialists performed multiple rounds of review on the adapted materials to ensure that the local TIMSS documentation was equivalent to the international versions. The IEA Secretariat employed independent international translation verifiers who appraised the quality of the local TIMSS documentation in comparison with the international versions (Ebbs & Korsnakova, 2016). The translation verifiers were trained by the IEA Secretariat and worked according to a detailed set of instructions to assist with their work. The independent feedback from the translation verifiers enabled the TIMSS NRCs to improve the quality of the local TIMSS documentation before the TIMSS assessments were rolled out (Ebbs & Korsnakova, 2016; Mullis & Martin, 2012).

All adaptations were documented in detail by the TIMSS NRC on a set of standardised forms, the National Adaptation Forms (Ebbs & Korsnakova, 2016; Mullis & Martin, 2012). These forms were submitted for approval to the IEA Secretariat, the TIMSS & PIRLS International Study Center, and the IEA DPC. These stakeholders verified that the adaptations did not compromise the ability of the TIMSS assessment instruments and context questionnaires to produce comparable data for items that were changed (Johansone, 2016; Mullis & Martin, 2012). The verification of the adapted TIMSS documentation confirmed that participating countries implemented the required processes and procedures for adapting and translating correctly (Ebbs & Korsnakova, 2016). Once the final versions of the TIMSS assessment instruments and context questionnaires were approved, the TIMSS NRC printed and distributed all TIMSS documentation to participating schools.

3.2.15. Management of the rollout of TIMSS

The implementation of the TIMSS assessments at schools was conducted by the School Coordinators according to a set of standardised procedures distributed by the TIMSS NRC (Johansone, 2016; Mullis & Martin, 2012). In order to assure that standardised TIMSS procedures were followed during the implementation of the assessments in schools, the TIMSS & PIRLS International Study Center, in collaboration with the IEA Secretariat, developed and then implemented the International Quality Assurance Program (Johansone & Wry, 2016).

A group of independent International Quality Control Monitors (IQCMs) was appointed in each country. IQCMs were expected to perform onsite visits during the implementation and data collection phase of the TIMSS assessments. The IQCMs visited 15 randomly selected schools in each country during the assessment phase. The IQCMs physically attended the assessment sessions and recorded any deviation from the standardised, prescribed TIMSS procedures and timing. Figure 3.1 depicts an extract with actual results from the observation instrument used by IQCMs for Grade 8 mathematics assessment sessions.

Exhibit 9.2: Observations of TIMSS 2015 Eighth Grade Assessment Administration Sessions —614 Sessions (Percent of IQCM Responses)

Question	Yes (%)	No (%)	Not Answered (%)
Did the Test Administrator distribute the test booklets according to the booklet assignment on the *Student Tracking Form* and booklet labels?	99	1	0
Did the total testing time for Part 1 equal the time allowed?	96	4	0
Did the Test Administrator announce "you have 10 minutes left" prior to the end of Part 1?	93	7	0
Were there any other time remaining announcements made during Part 1?	20	80	0

Figure 3.1: Extract of the TIMSS 2015 IQCM Grade 8 observation instrument (Johansone & Wry, 2016, p. 9.4)

It is important to note that the IQCMs acted independently from the TIMSS NRC in the country (Johansone & Wry, 2016) and observed a total of 614 Grade 8 and Grade 9 assessment sessions for TIMSS 2015 worldwide. An interesting observation made by the IQCMs was that in 65% of the TIMSS 2015 sessions globally, learners were given motivational talks or special incentives by an educator or official at the school (Johansone & Wry, 2016).

School principals of the sampled schools received an Eighth Grade *School* Questionnaire while educators of the sampled classes received an Eighth Grade *Mathematics Teacher* Questionnaire. Each sampled learner was assigned a TIMSS assessment instrument as well as an Eighth Grade *Student* Questionnaire (Johansone, 2016; Mullis & Martin, 2012). All these documents were labelled in such a way that the learner assessment instrument could be linked to the different context questionnaires for analysis.

The individual TIMSS assessment instruments for learners consisted of two sections and the time allocated to each section was standardised on 45 minutes and was strictly enforced for each group. There was a compulsory break of up to 30 minutes between the two sections. Learners completing the assessment instruments early were not allowed to leave the room and were encouraged to review their answers. Learners were given 30 minutes to complete the Eighth Grade *Student* Questionnaires and extra time was allowed if learners did not finish in the allocated time (Johansone, 2016; Mullis & Martin, 2012).

If the participation rate for any class was less than 90%, the School Coordinator was expected to conduct a catch-up session for learners who were absent on the day of the assessment (Johansone, 2016). Once all the assessment sessions in a school were conducted, the school coordinator returned all TIMSS related documentation and assessment instruments to the TIMSS NRC for scoring and data capturing.

3.2.16. Assessment of the TIMSS Constructed Response Items

The TIMSS assessments consist of a large proportion of constructed response items (Meyer, Cockle & Taneva, 2016). The valid and reliable assessment of these items is critical for the usability of the TIMSS assessment results (Mullis & Martin, 2012). To ensure the valid and reliable assessment of the constructed response items globally, the TIMSS & PIRLS International Study Center provided detailed assessment guides and comprehensive training in the use of constructed response items before the TIMSS assessments were implemented in a country (Martin, Mullis & Hooper, 2016; Mullis & Martin, 2012).

The TIMSS assessment design required learners to respond to only a subset of questions in the item pool – this design required limited responses from each sampled learner while preserving content representation when responses were combined across all learners (Martin, Mullis & Hooper, 2016). TIMSS used a psychometric scaling technique, based on item response theory (IRT), in order to calculate an estimate of a learner's overall score if they completed all the items in the item pool (Martin, Mullis & Hooper, 2016).

The TIMSS database displayed this score as a plausible value (PV) on the TIMSS assessment scale. Plausible values were standardised with a mean of 500 and a standard deviation of 100 and can be compared across TIMSS iterations (Mullis & Martin, 2012). TIMSS uses PV to estimate learners' proficiency in mathematics by using learner responses to the items in the Eighth Grade mathematics assessment and adjusting these responses according to the background data available for that specific learner (Laukaityte & Wiberg, 2017).

Wu (2005) identified three advantages of using plausible values in large-scale assessments. The first advantage is that using PVs addresses concerns regarding possible bias in the estimation of population parameters when point estimates of latent achievement are used to estimate these parameters. Secondly, using PVs allow secondary data analysists to use standard statistical methods and software (such as SPSS) to analyse achievement data that may include extensive measurement error components. Lastly, the use of PVs allows for the calculation of standard errors of estimates when the sample design is complex.

3.2.17. Primary analysis of TIMSS data

Once the assessment process was concluded, the TIMSS NRC had the responsibility to coordinate the capture of the country's TIMSS data. The data was then reviewed by the TIMSS NRC before submission to the IEA DPC for scrutiny (Meyer et al., 2016; Mullis & Martin, 2012). Data entry reliability was ensured by the submission of a sample of 5% of all TIMSS instruments to the IEA DPC for independent verification (Meyer et al., 2016). The IEA DPC checked that the margin of error in the captured data fell within the acceptable range. At the same time staff at the TIMSS NRC verified the completeness of the documentation by cross-referencing information from the educator and learner forms (Meyer et al., 2016; Mullis & Martin, 2012).

Once the IEA DPC received a country's data files, the data was checked for discrepancies and was formatted and cleaned to enable a standardised output (Meyer et al., 2016). This cleaning process involved checking that the database replicates the defined IEA DPC database structure, that all national adaptations to materials were documented and captured, that all variables were comparable across countries, and that all quality control processes and procedures were followed throughout the data capturing process (Meyer et al., 2016; Mullis & Martin, 2012). The two key aims of the cleaning process are to ensure that learner, educator and school information can be linked across different data files, and to ensure that the data represents the country's information consistently and accurately (Meyer et al., 2016).

During the data capture process of TIMSS two types of data entries were possible, namely valid data values and missing data values. Missing data can tell a story of its own, and the IEA DPC facilitated further analysis of the missing data by assigning additional codes to the missing data (Meyer et al., 2016; Mullis & Martin, 2012). The four types of missing data used for the completion of the TIMSS International Database are depicted in Table 3.6.

Table 3.6: Missing data values in TIMSS 2015

Data type	**Description**
Omitted or invalid	Respondent did not answer the question. Also used for uninterruptable responses.
Not administered	Item was not administered to the respondent. Also used to indicate outstanding home, educator or school questionnaires where linkage could not be done.
Logically not applicable	Response to a preceding filter question made this question not relevant.
Not reached	Applies to individual assessment items that the respondent did not attempt due to a lack of time.

Adapted from Mullis and Martin (2012) and Meyer et al. (2016)

Before the TIMSS International Database was finalised by the IEA DPC, two versions of the data files were sent back to individual countries for scrutiny by the TIMSS NRC (Meyer et al., 2016). The first version data files contained the cleaned data records and this allowed the TIMSS NRC to review and comment on the cleaning process. The second version data files contained only records that were used in the final analysis and this allowed the TIMSS NRC to replicate the IEA DPC results contained in the final TIMSS International Database (Meyer et al., 2016; Mullis & Martin, 2012). This version also allowed for further in-depth analysis of the data on country level.

The IEA DPC processes ensure that the TIMSS International Database contains high-quality, reliable data. The variables used in the TIMSS International Database are internationally comparable, the variables reflect national adaptations to the TIMSS instruments, information in the databases can be linked to other databases, and sampling weights and learner achievement scores are available for all countries to enable international comparison (Meyer et al., 2016; Mullis & Martin, 2012).

TIMSS data is not released by the TIMSS NRCs. The data is released by the IEA DPC after ensuring the integrity of the data. Once the IEA and the TIMSS NRC are confident that the data accurately represents a country's achievement in TIMSS, the results for that iteration of TIMSS are released in the public domain as part of the TIMSS International Database (IDB) (IEA, 2017d).

3.2.18. Validity of the TIMSS instruments

Validity refers to how effectively a research instrument actually measures what it sets out to measure, or in other words how successfully it reflects the reality it claims to represent (McMillan & Schumacher, 2014). In order to ensure content validity of the TIMSS assessment instruments, emphasis is placed on the validity of the instruments right from the start of the development of the instruments. Content validity in TIMSS is ensured through the process of item development (Martin, Mullis & Hooper, 2016; Mullis & Martin, 2012).

An international item pool was developed and aligned to the TIMSS assessment framework. TIMSS NRCs from participating countries conducted the development of the first draft of the assessment instruments (Mullis & Martin, 2012). During this process, every draft item was also classified according to whether or not it was meant to measure knowledge, or a specific skill associated with mathematics (see Appendix 3: Content domains, Topic areas and Topics in TIMSS, and Appendix 4: Cognitive domains, Topic areas and Topics in TIMSS).

The draft item pool was scrutinised, screened and complemented in a review session by mathematics experts. The item pool was then approved for field-testing by the TIMSS Item Review Committee. The TIMSS NRC in each participating country was involved in the field-testing of items with a representative sample of learners in the country (Martin, Mullis & Hooper, 2016). The TIMSS NRC had the opportunity to change test items in order to align them better to local conditions and customs.

The TIMSS NRC recommended the final version of the assessment instruments for approval. Once recommended for approval, the assessment instruments were also assessed by a test-and-curriculum matching analysis to investigate the appropriateness of the TIMSS assessment instrument for learners in the particular country (Martin, Mullis & Hooper, 2016; Mullis & Martin, 2012). Only once the test-and-curriculum matching analysis was concluded, were the assessment instruments tabled for approval by the IEA DPC.

3.2.19. Reliability of the TIMSS instruments

Cohen, Manion and Morrison (2013) states that reliability in instruments translates into dependability, consistency, and replicability over time, over instruments, and over groups of respondents. In other words, how accurately would the research be replicated in a second identical piece of research?

In studies such as TIMSS where trends in mathematics are researched over many years, over different groups of learners and over different assessment instruments, reliability is of critical importance to ensure that data from different iterations can be compared and studied (Mullis, Martin, Goh, et al., 2016; Mullis, Martin, Minnich, et al., 2012). In TIMSS, items that were used in previous iterations of TIMSS, were included in the assessment instruments in order to guarantee reliable measurement of trends over different iterations of TIMSS (Martin, Mullis & Hooper, 2016; Mullis & Martin, 2012).

Assessment reliability was further improved through the development of a large pool of assessment items. Each item was assigned to one of a set of subject-matter blocks and sampled learners received a random sample of questions from each block. This ensured broad subject matter coverage without sampled learners having to take all the items. Since sampled learners did not take the same assessment items, TIMSS estimated learner achievement using Item Response Theory (IRT) as scaling method. In IRT learner achievement does not depend on using the same set of assessment items (Martin, Mullis & Hooper, 2016; Mullis & Martin, 2012).

The reliable assessment of the constructed response items is critical in the achievement of high quality TIMSS data (Johansone, 2016). The reliability of the assessment of the TIMSS assessments was established within each participating country. A random sample of 200 learner responses from each constructed response item was assessed by two independent assessors. The measure of agreement between the two sets of assessors was viewed as a measure of the reliability of the assessment process (Johansone, 2016). A large measure of assessor agreement could be seen as evidence that assessors applied the assessment guidelines consistently and that items were scored reliably (Foy et al., 2016).

The assessment reliability validation was an ongoing activity that was integrated in the main assessment process. South Africa scored an average of 100% for correctness score agreement (where both assessors were in agreement on the correctness of a response) and 99% for diagnostic score agreement (where both assessors were in agreement on the mathematics performance level of the learner) for assessment reliability (Foy et al., 2016; Mullis & Martin, 2012). Table 3.7 depicts the details of the assessment reliability scores that South Africa achieved in TIMSS 2015.

Table 3.7: Assessment reliability for TIMSS Grade 8 mathematics

Country	**Correctness score agreement**			**Diagnostic score agreement**		
	Average of exact % agreement	Range of exact % agreement		Average of exact % agreement	Range of exact % agreement	
		Minimum	Maximum		Minimum	Maximum
South Africa	100%	94%	100%	99%	89%	100%
International average	98%	89%	100%	97%	84%	100%

Adapted from Foy et al. (2016)

One of the aims of TIMSS is the identification of specific trends in education in a country over time (Grønmo et al., 2013; Mullis, Martin & Loveless, 2016). The TIMSS assessment process incorporated trend reliability assessment to measure the reliability of the assessments from one iteration of TIMSS to the next. TIMSS 2015 utilised assessment results from TIMSS 2011 in order to establish a measure for trend reliability assessment (Foy et al., 2016; Mullis & Martin, 2012). Assessors assessed 150 to 200 learner responses from specific items from the previous iteration of TIMSS. Assessment results awarded in the current iteration were then compared with the assessment results awarded four years ago to establish the trend reliability.

The trend reliability validation process was an ongoing activity, also integrated in the main assessment process. South Africa scored an average of 96% for correctness score agreement (where both assessors were in agreement on the correctness of a response) and 91% for diagnostic score agreement (where both assessors were in agreement on the mathematics performance level of the learner) in trend scoring reliability (Foy et al., 2016; Mullis & Martin, 2012). Table 3.8 depicts the details of the trend scoring reliability scores that South Africa achieved in TIMSS 2015.

Table 3.8: Trend scoring reliability for TIMSS Grade 8 mathematics

Country	**Correctness score agreement**			**Diagnostic score agreement**		
	Average of exact % agreement	Range of exact % agreement		Average of exact % agreement	Range of exact % agreement	
		Minimum	Maximum		Minimum	Maximum
South Africa	96%	87%	99%	91%	71%	99%
International average	97%	81%	100%	94%	73%	100%

Adapted from Foy et al. (2016)

The TIMSS studies also give countries the ability to benchmark the effectiveness of their education system against the education systems of other countries taking part in TIMSS (IEA, 2017h; Mullis, Martin & Loveless, 2016). The TIMSS assessment process, therefore also incorporated cross-country reliability scoring in order to ensure the comparability of results across global TIMSS partners (Johansone, 2016).

The cross-country reliability validation entailed the independent assessment by two independent assessors of 200 randomly selected learner responses from 11 Grade 4 and 13 Grade 8 assessment items from each country (Foy et al., 2016). Reliability scoring across countries is defined by the percentage of these comparative assessments that was in similar agreement. The cross-country reliability assessment process was started as soon as the main assessment process had been concluded. Internationally, the average Grade 8 mathematics cross-country reliability score for correctness score agreement (where both assessors were in agreement on the correctness of a response) was 93 % and the diagnostic score agreement (where both assessors were in agreement on the mathematics performance level of the learner) was 91% (Foy et al., 2016).

In order to confirm that the TIMSS 2015 context questionnaires provide comparable data across different countries, the Cronbach's Alpha coefficients of reliability were calculated for all context questionnaire items. Internationally the context questionnaires items scored at an acceptable level in the Cronbach's Alpha coefficients of reliability with most above 0.70 and many above 0.80 (Martin, Mullis, Hooper, et al., 2016).

Once the local assessment processes were completed, the TIMSS & PIRLS International Study Center reviewed all the assessment items across all participating countries. This review was critical for IRT scaling in order to obtain learner achievement scores for analysis and reporting purposes (Foy et al., 2016). Part of the review process was the calculation of the reliability of the TIMSS assessments and the Cronbach's Alpha coefficient of reliability was calculated for all the TIMSS assessment responses. Overall the reliability coefficients for TIMSS 2015 were reasonably high, with the international median for Grade 8 mathematics at 0.88. The median for South African Grade 8 mathematics was 0.80 (Foy et al., 2016).

The IEA takes great care to ensure that results from the TIMSS assessments can be used to explore the processes and the outcomes of education in participating countries. Trends in education can be monitored by comparing current learner achievement with achievement in previous cycles. These trends could provide countries with extensive data and information in order to improve education.

3.3. Research design and methodology of this study

This study followed a quantitative research approach, designed around a secondary data analysis (SDA) of the 2011 and 2015 South African TIMSS datasets. ICT-related variables were identified from the TIMSS context questionnaires in order to examine the relationship between the ICT-related variables and the mathematics achievement of learners that took part in TIMSS 2011 and 2015.

3.3.1. Data sources used in this study

The TIMSS studies are conducted and the data maintained by the IEA and the TIMSS & PIRLS International Study Center at the Lynch School of Education, Boston College. The TIMSS databases comprise of learner achievement data for mathematics and science as well as contextual background data for schools, educators and learners (IEA, 2017d). The TIMSS 2011 database contained data from 45 countries (Mullis, Martin, Minnich, et al., 2012) and the TIMSS 2015 database contained data from 63 countries (Mullis, Martin, Goh, et al., 2016).

Data related to South Africa was extracted from the TIMSS 2011 and TIMSS 2015 databases for use in this study. The study focussed on the mathematics achievement of South African Grade 9 learners, accordingly all data applicable to South African Grade 5 learners was disregarded. The TIMSS databases for South Africa included rich information about learners, educators, classrooms and schools that could be used to examine the relationship between ICT-related variables and learner achievement in mathematics within the country.

3.3.2. Participants in this study

The target populations of TIMSS were defined as all learners in their 4th and 8th years of formal schooling (LaRoche & Foy, 2016). South Africa elected to administer the TIMSS 2011 and 2015 assessments to Grade 5 and Grade 9 learners (Reddy, Isdale, et al., 2016; Reddy et al., 2013). This study therefore focused on South African Grade 9 mathematics learners who participated in TIMSS 2011 and 2015.

3.3.3. South African Grade 9 participants in TIMSS 2011

The TIMSS NRC, in collaboration with the TIMSS & PIRLS International Study Center, used language of teaching and learning (Afrikaans, English, dual medium), school type (public school, independent school) and province as explicit stratification variables in the sampling of schools for TIMSS 2011 (Mullis & Martin, 2012). Originally 298 schools were sampled for participation in TIMSS 2011 (Mullis & Martin, 2012), of which 283 schools agreed to participate in the study. A total number of 11 969 Grade 9 learners and 327 Grade 9 mathematics educators participated in TIMSS 2011 (Reddy et al., 2013). Small schools with 10 and fewer learners and special needs schools were excluded from the TIMSS 2011 sample (Mullis & Martin, 2012).

A summary of the South African Grade 9 TIMSS 2011 school sample is depicted in Appendix 10. The TIMSS 2011 learner sample was composed of 11 969 participants (6 078 male, 5 888 female[8]; M[9] = 15.0 years; μ[10] = 16.0 years; SD[11] = 1.177; age range = 10-20 years).

[8] Three TIMSS 2011 participants did not indicate their gender.
[9] M – median
[10] μ – mean
[11] SD – standard deviation

3.3.4. South African Grade 9 participants in TIMSS 2015

Statistics Canada, in collaboration with the South African TIMSS NRC, used the DBE list of all schools in the country in 2013 to draw the TIMSS 2015 sample (Reddy, Visser, et al., 2016). At the time this list comprised of 9 099 public schools and 910 independent schools.

Statistics Canada used language of teaching and learning (Afrikaans, English, dual medium), school type (public school, independent school) and province as stratification variables. A total of 292 out of 300 schools sampled agreed to participate in the TIMSS 2015 study (Reddy, Visser, et al., 2016). This meant that a total number of 12 514 Grade 9 learners and 334 Grade 9 mathematics educators participated in TIMSS 2015 (Martin, Mullis & Hooper, 2016). Small schools with 15 and fewer learners and special needs schools were excluded from the TIMSS 2015 sample (LaRoche & Foy, 2016).

A summary of the South African TIMSS 2015 Grade 9 school sample is depicted in Appendix 11. The TIMSS 2015 learner sample was composed of 12 514 participants (6 084 male, 6 422 female[12]; M = 15.50 years; μ = 15.74 years; SD = 1.223; age range = 10-20 years).

3.3.5. Sample design of this study

TIMSS used a two-stage sampling design in order to select a representative sample of South African learners for the 2011 and 2015 studies (Joncas & Foy, 2012). This led to the selection of 285 schools for TIMSS 2011 and 282 schools for TIMSS 2015 (Reddy et al., 2013; Reddy, Visser, et al., 2016).

[12] Eight TIMSS 2015 participants did not indicate their gender.

As discussed in this chapter, the IEA DPC took great care to ensure that a representative sample of schools, educators and learners were selected for TIMSS 2011 and 2015. The original TIMSS sampling design ensured a representative sample of South African schools, educators and learners, therefore this study made use of purposive sampling and consequently all TIMSS 2011 and 2015 South African Grade 9 participants were included in the study.

3.3.6. Data instruments used in this study

The study followed a quantitative research approach utilising data collected by the IEA during the TIMSS 2011 and 2015 assessments in South Africa. Muijs (2010, p. 1) prefers the definition of quantitative research methods as developed by Aliaga and Gunderson (2002) and sees quantitative research methods as "explaining phenomena by collecting numerical data that are analysed using mathematically based methods (in particular statistics)."

Copies of the TIMSS 2011 and 2015 context questionnaires are packaged with the TIMSS databases (IEA, 2017d). All 2011 questionnaires are available in the TIMSS 2011 User Guide for the International Database (Foy et al., 2013a). Questionnaires used in 2015 are available in the TIMSS 2015 User Guide for the International Database (Foy, 2017a). The following questionnaires and accompanying data from TIMSS 2011 and TIMSS 2015 were used during this study:

a. Learner achievement in TIMSS – Eighth Grade mathematics *assessment results*
b. School context – Eighth Grade *School* Questionnaire
c. Classroom and educator context – Eighth Grade *Mathematics Teacher* Questionnaire
d. Learner context and background – Eighth Grade *Student* Questionnaire

The quasi-longitudinal design of TIMSS ensures that related variables can be compared across years (IEA, 2017h). This study explored data and variables from both TIMSS 2011 and TIMSS 2015 in order to report on the research questions.

3.3.7. Variables selected for this study

Variables for this study were selected based on the conceptual framework of the study, a review of existing literature on the integration of ICT in education (see Chapter 2), and the relevance of the specific variables on the integration of ICT in teaching and learning. The dependent variable in the study was the mathematics score of the learner, expressed as a plausible value (PV) on the TIMSS achievement scale. The PV was calculated as the mean of the PV sub-topic area scores, namely algebra, number, geometry, measurement, and data (Mullis & Martin, 2012).

The independent variables were grouped in three areas of study, namely school background, educator and classroom background, and learner background. Each group of variables consisted of a number of existing ICT-related variables in the TIMSS databases. The conceptual framework of the study guided the selection of ICT-related variables from the TIMSS context questionnaires and a mapping of these variables between the conceptual framework and the TIMSS context questionnaires is depicted in Table 3.9.

Table 3.9: Mapping levels in the conceptual framework with ICT-related variables in the study

Levels in the conceptual framework	**Variables in this study**	**Documentation**
School level	• Shortage of computers for instruction? • Shortage of computer software? • Shortage of audio-visual materials?	School context (Eighth Grade *School* Questionnaire)
Educator and classroom level	• Adequate support for integrating technology in teaching? • Availability of computers during mathematics lessons? • Use the computer to explore new concepts? • Use the computer to do procedures? • Use the computer to look up new ideas? • Use the computer to process data? • Attended professional development in the use of technology in class in the last two years?	Classroom and educator context (Eighth Grade *Mathematics Teacher* Questionnaire)

Levels in the conceptual framework	Variables in this study	Documentation
Learner level	Learner background: • Availability of a computer or tablet at home? • Use of a computer at home for school work? • Use of a computer at school for school work? • Use of a computer at another place for school work?	Learner context and background (Eighth Grade *Student* Questionnaire)

Adapted from Creemers and Kyriakides (2007), Foy (2017b) and Mullis and Martin (2013)

The statistical analysis and results of the school level ICT-related variables will be discussed in Chapter 5 of this thesis. Chapter 6 will focus on the statistical analysis and results of educator and classroom level ICT-related variables, while Chapter 7 will focus on the statistical analysis and results of learner level ICT-related variables.

3.3.8. Secondary analysis of the TIMSS data

The use of secondary data for research has become an increasingly popular method among researchers in the social and behavioural sciences (Cheng & Phillips, 2014; Goodwin, 2012). Primary datasets are data collected for a specific purpose by the researcher, or by a team the researcher was part of (Goodwin, 2012; McMillan & Schumacher, 2014). Secondary datasets are identified as data collected by "someone else for some other purpose" (Boslaugh, 2007, p. 1). Secondary datasets may be used for a different purpose than what the original researcher planned to do with the data (Goodwin, 2012; McMillan & Schumacher, 2014). There are no right or wrong reasons for using either primary or secondary data - the choice of using primary or secondary data should be influenced on obtaining data appropriate for answering the research questions (Boslaugh, 2007; Coyer & Gallo, 2005).

Boslaugh (2007) and Rosenberg, Greenfield and Dimick (2006) identify economy as one of the major advantages of using secondary data – because the data has already been collected, the researcher does not have to allocate resources to this phase of the research. This holds especially true for large-scale international research projects where the databases contain large quantities of high quality data and are accessible in the public domain (IEA, 2017h). The second advantage Boslaugh (2007) identifies is the scope of data available as secondary data. When looking at the TIMSS project, very few individual researchers would have the time or resources to conduct a study of this scale in one country, let alone across the world. The third advantage that Boslaugh (2007) identifies is that the original data collection process is very often informed by expertise not available to individual researchers. In the case of the TIMSS project, the research project is managed and coordinated by the IEA DPC, who has been specialising in large-scale, international research studies since 1958 (IEA, 2017b).

One of the disadvantages of using secondary data, is that because the data is often collected with another research question in mind, not all information that might be needed for the current study may be collected (Boslaugh, 2007). A disadvantage related to this, is when variables have been defined or categorised differently to what is required for the current study. Additionally, because the researcher was not part of the original planning and execution of the data collection process they may not have all the information required to interpret the data.

In the case of the TIMSS studies a comprehensive set of documents, called the TIMSS 2011 Encyclopedia: Education Policy and Curriculum in Mathematics and Science (Volumes 1 and 2) (Mullis, Martin, Minnich, et al., 2012) and the TIMSS 2015 Encyclopedia: Education Policy and Curriculum in Mathematics and Science (Mullis, Martin, Goh, et al., 2016) were published to provide all relevant research related background information per participating country.

3.4. Summary

Chapter 3 provided background to the research methodology that was followed during this research project. The chapter focused specifically on the research methodology followed by the TIMSS studies, as well as the research methodology followed by this study.

Chapter 4 will provide an introduction to the data analysis of the ICT-related variables selected for inclusion in this study. Chapter 5 will focus on the data analysis and results of ICT-related variables from the Eighth Grade *School* Questionnaires, Chapter 6 will focus on the data analysis and results of ICT-related variables from the Eighth Grade *Mathematics Teacher* Questionnaires, and Chapter 7 will focus on the data analysis and results of ICT-related variables from the Eighth Grade *Student* Questionnaires.

4. CHAPTER 4 – BACKGROUND TO THE DATA ANALYSIS OF THE TIMSS CONTEXT QUESTIONNAIRES

4.1. Introduction

This study aims to report on the findings of the secondary data analysis of ICT-related variables from the TIMSS 2011 and 2015 context questionnaires. In order to explore the background and context in which the TIMSS mathematics assessments were conducted, the IEA used context questionnaires to get as complete a view of the context of implementation as possible. The three context questionnaires from TIMSS 2011 and TIMSS 2015 used in this study, are the Eighth Grade *School* Questionnaires (Foy, 2017b, p. 290; Foy et al., 2013b, p. 292), the Eighth Grade *Mathematics Teacher* Questionnaires (Foy, 2017b, p. 237; Foy et al., 2013b, p. 234), and the Eighth Grade *Student* Questionnaires (Foy, 2017b, p. 162; Foy et al., 2013b, p. 166).

Bos (2002) argues that research items should be logically grouped in order to keep both conceptual and empirical homogeneity. Conceptual homogeneity refers to variables that match the literature on that subject (Bos, 2002). In this study conceptual homogeneity was strengthened by consulting the theoretical framework of the study and the existing literature relating to the topic. Empirical homogeneity on the other hand refers to variables that exhibit an appropriate relationship with the dependent variable (Bos, 2002). In this study the mathematics achievement of South African Grade 9 learners, expressed as a plausible value (PV) on the TIMSS achievement scale, was selected as dependent variable. Empirical homogeneity was strengthened by selecting only ICT-related variables from the different TIMSS context questionnaires.

4.2. Variable selection

The conceptual framework of this study was used as guideline in the identification of the appropriate TIMSS context questionnaires for inclusion in the study. In order to address the school-level factors, educator- and classroom-level factors, and student-level factors identified in the Dynamic Model, three TIMSS context questionnaires were selected for inclusion in the study, namely the Eighth Grade *School* Questionnaire, the Eighth Grade *Mathematics Teacher* Questionnaire and the Eighth Grade *Student* Questionnaire.

This study therefore focused on ICT-related variables that occurred in both the TIMSS 2011 and 2015 context questionnaires in order to gain a quasi-longitudinal view of the variables. The index of variables in Supplement 1 of the TIMSS 2015 User Guide for the International Database (Foy, 2017b) contains a column named 'TIMSS 2011 Variable Name' where related variables from TIMSS 2011 are indicated. This enables researchers to identify related TIMSS variables for quasi-longitudinal studies over the two iterations of TIMSS. Using the information supplied in the TIMSS 2015 User Guide for the International Database on the relationships between variables in 2015 and 2011, related variables were identified in the TIMSS 2011 context questionnaires. As example, Figure 4.1 depicts an extract from the index of variables from the TIMSS 2015 User Guide for the International Database illustrating the way in which related variables in the 2011 and 2015 Eighth Grade *School* Questionnaires are identified.

Exhibit S1.9: Index of International Background Variables for the TIMSS 2015 School Questionnaire - Eighth Grade

TIMSS 2015 Question Number	TIMSS 2015 Variable Name	TIMSS 2015 Variable Description (See questionnaire for full item text)	TIMSS 2011 Variable Name	Notes
ScQ-01	BCBG01	What is the total enrollment of students in your school as of <first day of month TIMSS testing begins, 2015>?	BCBG01	
ScQ-02	BCBG02	What is the total enrollment of <eighth grade> students in your school as of <first day of month TIMSS testing begins, 2015>?	BCBG02	
ScQ-03a	BCBG03A	Approximately what percentage of students in your school have the following backgrounds? Come from economically disadvantaged homes	BCBG03A	
ScQ-03b	BCBG03B	Approximately what percentage of students in your school have the following backgrounds? Come from economically affluent homes	BCBG03B	

Figure 4.1: Example of relationships between similar variables in TIMSS 2011 and TIMSS 2015 (Foy, 2017b, p. 290)

A number of ICT-related variables were identified for inclusion in this study from the three identified TIMSS 2015 context questionnaires. Four variables were identified from the 2015 Eighth Grade *School* Questionnaire, seven variables from the 2015 Eighth Grade *Mathematics Teacher* Questionnaire, and five variables from the 2015 Eighth Grade *Student* Questionnaire.

4.3. Data selection

Data from the TIMSS studies are maintained by the IEA and the TIMSS & PIRLS International Study Center at the Lynch School of Education, Boston College. The TIMSS databases comprise of learner achievement data for mathematics and science as well as the contextual background data for the schools, the educators, the classrooms, as well as the learners (IEA, 2017d). The TIMSS 2011 database contained data from 45 countries (Mullis, Martin, Minnich, et al., 2012) and the TIMSS 2015 database contained data from 63 countries (Mullis, Martin, Goh, et al., 2016).

This study focused on South African Grade 9 learners that participated in the TIMSS studies. Therefore, only data related to Grade 9 South African participants was extracted from the TIMSS 2011 and TIMSS 2015 databases for use in this study. The TIMSS databases for South Africa included rich information about learners, educators, classrooms and schools that were used to examine the relationship between ICT-related variables and learner achievement in mathematics within the country.

The TIMSS 2011 database contained data on 283 schools, comprising of 11 969 learners, and 327 Grade 9 mathematics educators (Reddy et al., 2013). The TIMSS 2015 database contained data on 292 schools, 12 514 Grade 9 learners, and 334 Grade 9 mathematics educators (Reddy, Visser, et al., 2016).

4.4. Data analysis

The IEA used a Likert-type response scale in the design of both the TIMSS 2011 and 2015 context questionnaires. The Statistical Package for the Social Science (SPSS) was used to recode the Likert-type response scales to dichotomous scales for the purpose of the statistical analysis in this study (Field, 2014). The original variable responses were recoded into two categories: those representing a low level of agreement with the variable statement, and those representing a high level of agreement with the variable statement. The original coding values

'1 = Not at all' and '2 = A little'

were recoded and collapsed into the recoded value '101 = Minimal effect'. Similarly the original coding values

'3 = Some' and '4 = A lot'

were recoded and collapsed into the recoded value '102 = Considerable effect'. As example, Table 4.1 depicts the way the original TIMSS coding values of variable BCBG09BB were recoded to a dichotomous scale.

Table 4.1: Example of dichotomous recoding of variable coding values

Variable	**Year**	**Question text**	**Original coding values**	**Recoded values**
BCBG09BB	2011	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of computers for mathematics instruction?	1 = Not at all 2 = A little	101 = Minimal effect
			3 = Some 4 = A lot	102 = Considerable effect
			9 = Omitted or invalid	9 = Omitted or invalid

The key to statistical analysis of the IEA data is to take the unique sampling weights, the assessment design, the sampling variance and the plausible values into consideration when doing the analysis (Rutkowski, Gonzalez, Joncas & Von Daver, 2010). The IEA developed specialised statistical software, the IEA International Database (IDB) Analyzer (IEA, 2017g), which is available to all researchers that analyse data from the IEA large-scale assessments.

The IEA IDB Analyzer works in conjunction with the SPSS software. The IEA IDB Analyzer generates SPSS syntax files that takes cognisance of the unique sampling design, sampling variance and plausible values of the IEA large-scale assessments. The SPSS syntax generated by the IEA IDB Analyzer enables researchers to generate "descriptive statistics and conduct statistical hypothesis testing on groups in the population without having to develop specialised programming code" (IEA, 2017e, 4:05).

In this study the IEA IDB Analyzer was used to generate SPSS syntax in order to conduct a secondary analysis of the data and to generate descriptive and inferential statistics on variables identified from the TIMSS context questionnaires. The SPSS output was generated according to the recoded dichotomous Likert-type scale values. Each variable was analysed per province and per Likert response, taking the weighting of the mathematics achievement (expressed at a plausible value – PV) of learners in that province into account.

The South African TIMSS 2011 data sets contained missing data entries. The IDB Analyzer employs three techniques in dealing with missing data: Mean Value Replacement (referred to as MeanSubstitution in the IDB Analyzer), Pairwise deletion, or Listwise deletion. The reference documentation of the IDB Analyzer clarifies the different options as follows:

> *Note that there are three options under the **Missing Data Option** dropdown menu – **Pairwise**, **Listwise** and **MeanSubstitution**. When choosing **Pairwise**, all available data are used in the analysis, when choosing **Listwise** only cases with complete data are used in the analysis, when choosing **MeanSubstitution** missing data will be replaced with the mean for the variable. We do not recommend the use of MeanSubstitution when entering categorical variables in your analysis. This option is only used to select cases based on the continuous variables* (IEA, 2018).

In this study, missing data was addressed by using the Listwise deletion function of the IDB Analyzer. This means that only cases with complete data was used in the analysis of the TIMSS data for this study.

It is important to note that the SPSS syntax generated by the IEA IDB Analyzer does not report on school or educator responses individually, but rather interprets these responses in terms of the number of learners affected by responses to a variable (Foy, 2017c). In the statistical analysis of variables from the TIMSS context questionnaires, the research findings are therefore linked to the number of learners affected by the responses to a variable. The reasoning behind this is that because only one person completes the Eighth Grade *School* Questionnaire (usually the school principal), but a school might have more than one mathematics educator completing the Eighth Grade *Mathematics Teacher* Questionnaire, statistics may be skewed towards the Eighth Grade *Mathematics Teacher* Questionnaire because the number of these questionnaires completed is higher than that of the Eighth Grade *School* Questionnaire.

Variables identified were examined in terms of the relationship between the different scale responses and the mathematics achievement of South African learners using SPSS syntax generated by the IEA IDB Analyzer. Each identified variable was explored in terms of its relationship with the mathematical achievement of learners from each of the nine South African provinces.

The descriptive statistical analysis of the variables consisted of the calculation of the percentage of responses, as well as the calculation of the average mathematics achievement of Grade 9 learners related to that specific response. The descriptive statistical analysis is presented in graphical format per province.

The appropriate inferential statistical analysis techniques relevant to this set of ICT-related variables were discussed with Dr Eugenio J. Gonzalez, the Director of the Research and Analysis Unit at the IEA DPC and he suggested the following:

> *"When comparing dichotomous variables, you are better off comparing mean differences instead of correlations. For example, compute the mean difference*

between boys and girls in each year, and compare these two differences" (E.J. Gonzalez, personal communication, 21 June 2017).

The inferential statistical analysis of the variables therefore consisted of the calculation of the statistical significance of the mean difference in mathematical achievement in the two groups between 2011 and 2015 by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis is presented in table format per province. It is important to note that the absolute difference in relationships was analysed in this study, and not the direction of the difference. In this thesis whenever the term 'difference' is used, it refers to an absolute difference. The word 'absolute' is therefore dropped throughout the thesis in order to be concise.

This study used a 5% level of significance and therefore all p-values were compared to 0.05. Accordingly, if a p-value was less than 0.05 it was assumed that there was a statistically significant difference, and if a p-value was greater than 0.05 there was no statistical difference.

The Bonferroni adjustment (Bonferroni, 1936) is a statistical method used to adjust the probability values in studies where multiple, repetitive statistical tests are required. The Bonferroni adjustment aims to minimise the risk of identifying a significant difference, if it is in fact not present. However, several researchers question the use of the Bonferroni adjustment in studies where a small number of comparisons are made (Armstrong, 2014; Perneger, 1998). The decision was therefore taken not to include the Bonferroni adjustment in the statistical analysis of variables in this study, due to the fact that only three relationships were examined for each variable.

The decision not to include the Bonferroni adjustment in this statistical analysis of the TIMSS data was also discussed with Dr Eugenio J. Gonzalez, the Director of the Research and Analysis

Unit at the IEA DPC, and he concurred that the inclusion of the Bonferroni adjustment in the statistical analysis of the data for this study was unnecessary.

> *The trouble with Bonferroni corrections is that the significance changes with the number of comparisons. So 2 researchers testing the same hypothesis, one could find a result to be significant, and the other not, depending on how many comparisons they do. To me, and many others, this makes little sense. So corrections for multiple comparisons are generally not used.* (E.J. Gonzalez, personal communication, 16 August 2017)

The structure of the data analysis chapters is as follows:

- Chapter 5 – Eighth Grade *School* Questionnaires data analysis and results
- Chapter 6 – Eighth Grade *Mathematics Teacher* Questionnaires data analysis and results
- Chapter 7 – Eighth Grade *Student* Questionnaires data analysis and results
- Chapter 8 – Findings and Recommendations

4.5. Objectives of the study

The results of TIMSS 2011 and TIMSS 2015 confirmed the results of previous local and international mathematics assessments that concluded that education in South Africa, and more specifically mathematics education, is facing severe challenges (Howie & Hughes, 1998; Mullis, Martin, Foy, et al., 2012; Mullis, Martin, Foy, et al., 2016; Reddy, 2006; Spaull, 2013).

The purpose of the data analysis chapters is to provide the results and findings of a secondary analysis of both the TIMSS 2011 and TIMSS 2015 studies in order to establish the relationship between the identified ICT-related factors and the mathematics achievement of South African

Grade 9 learners. Figure 4.2 depicts a comparison between the mathematics achievement of South African learners in TIMSS 2011 and TIMSS 2015.

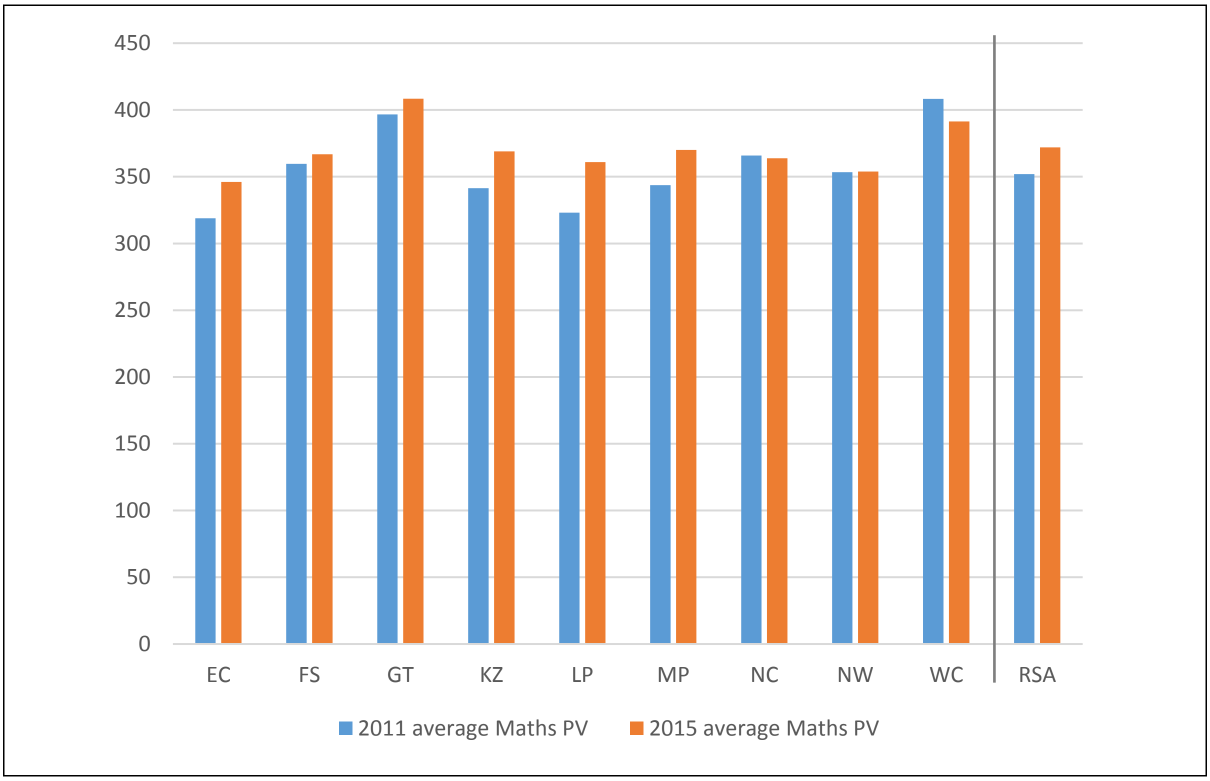

Figure 4.2: Comparison of the mathematics achievement of South African learners in TIMSS 2011 and TIMSS 2015

4.6. Summary

Chapter 4 provided background to the secondary data analysis of the Eighth Grade *School* Questionnaires, the Eighth Grade *Mathematics Teacher* Questionnaires and the Eighth Grade *Student* Questionnaires. Chapter 5 will be dedicated to the data analysis of ICT-related variables from the Eighth Grade *School* Questionnaires.

5. CHAPTER 5 – TIMSS EIGHTH GRADE *SCHOOL* QUESTIONNAIRES DATA ANALYSIS AND RESULTS

5.1. Introduction

This chapter reports on the results of the secondary data analysis of ICT-related variables from the Eighth Grade *School* Questionnaires. The variables discussed in this chapter emanates from ICT-related questions identified in the 2015 Eighth Grade *School* Questionnaire (Mullis & Martin, 2013) and the 2011 Eighth Grade *School* Questionnaire (Mullis et al., 2009). School principals, or identified representatives, were requested to complete the questionnaires and indicate whether teaching and learning in their schools were affected by the topics identified by the IEA.

Three ICT-related variables were identified from the 2015 Eighth Grade *School* Questionnaire for inclusion in this study. Using the information supplied in Supplement 1 of the TIMSS 2015 User Guide for the International Database (Foy, 2017b) on the relationships between variables in TIMSS 2015 and TIMSS 2011, three related variables were identified in the 2011 Eighth Grade *School* Questionnaire. Figure 5.1 depicts an extract from Supplement 1 of the TIMSS 2015 User Guide for the International Database (Foy, 2017b) illustrating the way in which related variables in the Eighth Grade *School* Questionnaires were identified.

Exhibit S1.9: Index of International Background Variables for the TIMSS 2015 School Questionnaire - Eighth Grade

TIMSS 2015 Question Number	TIMSS 2015 Variable Name	TIMSS 2015 Variable Description (See questionnaire for full item text)	TIMSS 2011 Variable Name	Notes
ScQ-01	BCBG01	What is the total enrollment of students in your school as of <first day of month TIMSS testing begins, 2015>?	BCBG01	
ScQ-02	BCBG02	What is the total enrollment of <eighth grade> students in your school as of <first day of month TIMSS testing begins, 2015>?	BCBG02	
ScQ-03a	BCBG03A	Approximately what percentage of students in your school have the following backgrounds? Come from economically disadvantaged homes	BCBG03A	
ScQ-03b	BCBG03B	Approximately what percentage of students in your school have the following backgrounds? Come from economically affluent homes	BCBG03B	

Figure 5.1: Example of relationships between similar variables in TIMSS 2011 and TIMSS 2015 (Foy, 2017b, p. 290)

The ICT-related variables from the Eighth Grade *School* Questionnaires used in the study as well as their original IEA Likert-type response values are depicted in Table 5.1. Variables that are related to the same question in the 2011 and 2015 Eighth Grade *School* Questionnaires respectively, are discussed in the same sub-section in this chapter.

Table 5.1: ICT-related variables from the Eighth Grade *School* Questionnaires

<table>
<tr><th>TIMSS 2011 variables</th><th>TIMSS 2015 variables</th><th>Variable description</th><th>Original IEA Likert response coding values</th></tr>
<tr><td>BCBG09BB</td><td>BCBG13AH</td><td>GEN\SHORTAGE\MATH\COMPUTERS FOR INSTR.</td><td rowspan="3">1 = Not at all
2 = A little
3 = Some
4 = A lot
9 = Omitted or invalid</td></tr>
<tr><td>BCBG09BC</td><td>BCBG13BB</td><td>GEN\SHORTAGE\MATH\COMPUTER SOFTWARE</td></tr>
<tr><td>BCBG09BE</td><td>BCBG13AG</td><td>GEN\SHORTAGE\MATH\AUDIO-VISUAL RESOURCE</td></tr>
</table>

Variables identified from Foy (2017b), Mullis et al. (2009) and Mullis and Martin (2013)

The six variables, three from 2011 and three from 2015, were statistically analysed using SPSS syntax generated by the IEA IDB Analyzer. The generated SPSS output was organised according to the recoded dichotomous scales. Each variable group was analysed per province and per response, taking the weighting of the mathematics achievement of learners (expressed as the plausible value – PV) in that province into account.

TIMSS results are reported on the TIMSS achievement scale with a range of 0 to 1 000 points (Mullis, Martin, Foy, et al., 2012; Mullis, Martin, Foy, et al., 2016). The IEA uses 500 points as centrepoint of the achievement scale across all TIMSS projects, however Mullis, Martin, Foy, et al. (2012) note that learner achievement usually ranges from 300 to 700 points. South African Grade 9 learners achieved an average of 352 points on the TIMSS achievement scale in the 2011 assessments (Mullis, Martin, Foy, et al., 2012). In the 2015 assessments South African Grade 9 learners achieved a slightly higher average score of 372 points on the TIMSS achievement scale (Mullis, Martin, Foy, et al., 2016).

5.2. Shortage of computers for mathematics instruction (BCBG09BB and BCBG13AH)

Internationally a lack of access to ICT in schools has been identified as one of the serious constraints on the successful integration of ICT into teaching and learning (BECTA, 2004; Law, 2009; Law et al., 2008). South African educators face similar challenges in the integration of ICT in South African classes (Stols et al., 2015; Vandeyar, 2013). In recent studies South African educators specifically mentioned the lack of access to ICT in their classrooms as one of their main challenges (Mdlongwa, 2012; Mofokeng & Mji, 2010; Stols et al., 2015).

The IEA included a question related to the availability of computers for mathematics teaching and learning in both the 2011 and 2015 Eighth Grade School Questionnaires. School principals were asked whether effective teaching and learning in their school were affected by a shortage of computers for mathematics instruction. It is important to note that this question refers to the availability of computers in the school, and not necessarily to computers in mathematics classrooms. The details of variables BCBG09BB and BCBG13AH are depicted in Table 5.2.

Table 5.2: Shortage of computers for mathematics instruction (BCBG09BB and BCBG13AH)

Variable	Year	Question text	Original coding values	Recoded values
BCBG09BB	2011	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of computers for mathematics instruction?	1 = Not at all 2 = A little	101 = Minimal effect
			3 = Some 4 = A lot	102 = Considerable effect
			9 = Omitted or invalid	9 = Omitted or invalid
BCBG13AH	2015	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following? General School Resources: • Computer technology for teaching and learning	1 = Not at all 2 = A little	101 = Minimal effect
			3 = Some 4 = A lot	102 = Considerable effect
			9 = Omitted or invalid	9 = Omitted or invalid

5.2.1. Descriptive statistics – Shortage of computers for mathematics instruction (BCBG09BB and BCBG13AH)

Variable BCBG09BB (TIMSS 2011) and variable BCBG13AH (TIMSS 2015) dealt with the question of a shortage of computers for mathematics teaching and learning in the school. The statistical analysis of BCBG09BB and BCBG13AH is depicted in Figure 5.2

In order to present the relationship between learner achievement (represented by the average PV) and school principal responses (represented as a percentage of agreement or disagreement with the variable question) in each province, the two results are depicted in the same figure. The average PVs attained by South African Grade 9 participants are presented at the top of the figure. Blue dots indicate the average PVs attained in TIMSS 2011, while orange dots indicate the average PVs attained in TIMSS 2015. School principal responses to the variable question, are presented at the bottom of the figure with the use of bar graphs. The blue bars indicate the principal responses recorded in TIMSS 2011, while the orange bars indicate the principal responses recorded in TIMSS 2015.

A solid grid line structure is used to distinguish between the different provinces. Additionally, a dotted grid line structure is used to distinguish between the dichotomous variable scales, e.g. between a minimal effect on teaching and learning, and a considerable effect on teaching and learning in each individual province. Other upcoming figures are also presented in this manner.

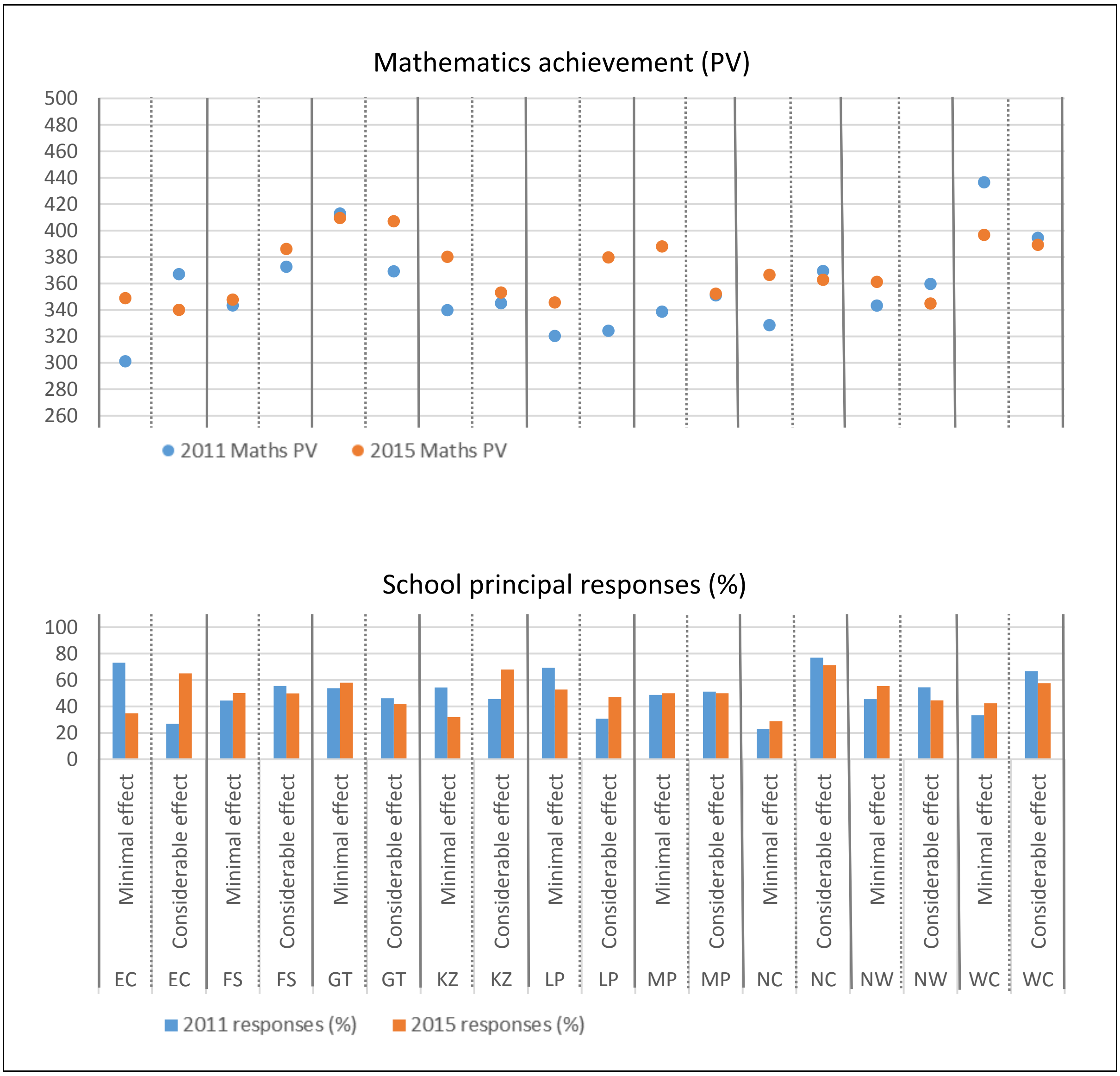

Figure 5.2: Shortage of computers for mathematics instruction (BCBG09BB and BCBG13AH) – mathematics achievement and school principal responses per province

Mathematics achievement in relation to a shortage of computers for mathematics instruction

An interesting trend in 2011 seems to be that for every province, except for Gauteng and the Western Cape, learners from schools where the majority of school principals indicated a considerable effect on mathematics teaching and learning due to a shortage of computers, achieved higher scores on the TIMSS achievement scale than those whose school principals indicated that they experienced a minimal effect on mathematics teaching and learning. In three provinces learners from schools where school principals indicated a considerable effect on mathematics teaching and learning, achieved scores of more than 25 points higher than those whose school principals indicated a minimal effect (EC PV difference = 66; FS PV difference = 29; NC PV difference = 41).

In previous studies it was found that effective leadership in schools led to improved teaching and learning in those schools (Creemers et al., 2007; Martin et al., 2013; Scheerens, 1990). A possible explanation may therefore be that South African school principals who were able to identify a *considerable effect* on teaching and learning due to a shortage of computers, were more hands-on in their schools, were able to identify challenges in the school, and were able to provide more effective leadership in the school. Additionally it may also indicate that where computers were not available, educators reverted back to traditional mathematics teaching methods and that this teaching on a level and in a language that the learner understands (Van Staden, 2010), led to improved mathematics achievement.

In 2015 learners in only two provinces (FS, LP) from schools where the school principals indicated a *considerable effect* on mathematics teaching and learning due to a shortage of computers, achieved higher marks on the TIMSS achievement scale when compared to those whose school principals indicated a *minimal effect* on mathematics teaching and learning. However, in these two provinces the difference in achievement between learners in schools experiencing a *considerable effect* on mathematics teaching and learning due to a shortage of computers, and those who do not, increased to above 30 points (FS PV difference = 38; LP PV difference = 34). This result seems to corroborate the explanation that the school principals in these two provinces who were able to identify a *considerable effect* on teaching and learning, were displaying more effective leadership in their schools and this may have led to more effective teaching and learning.

Learners from schools in Gauteng (PV = 413) and the Western Cape (PV = 437) where school principals indicated a *minimal effect* on mathematics teaching and learning in their schools due to a shortage of computers, were the top achievers in 2011. Learners from Gauteng schools (PV = 409) where school principals indicated a *minimal effect* on mathematics teaching and learning in their schools due to a shortage of computers, were the top achievers in 2015, followed by learners in Gauteng (PV = 407) where school principals indicated a *considerable effect* on teaching and learning, and Western Cape learners (PV = 397) from schools where school principals indicated a *minimal effect* on teaching and learning.

Generally, schools in Gauteng and the Western Cape are perceived to provide better quality education to learners (Govender, 2017) and learners from these provinces are among the top achievers in the annual National Senior Certificate examinations (DBE, 2016a), the final exit examination of the school system in South Africa. This may explain why even learners from schools where school principals indicated a *considerable effect* on teaching and learning due to a shortage of computers, still achieved higher scores on the TIMSS achievement scale than learners from other provinces.

School principal responses in relation to the effect of a shortage of computers for mathematics instruction

In 2011 the majority of school principals in five of the nine provinces (FS = 55.53%; MP = 51.19%; NC = 76.92%; NW = 54.47%; WC = 66.69%) indicated that a shortage of computers for mathematics teaching and learning had a *considerable effect* on teaching and learning. In 2015 the majority of school principals in five of the nine provinces (EC = 65.08%; KZ = 67.99%; MP = 50.03%; NC = 71.23%; WC = 57.66%) again indicated that a shortage of computers for mathematics teaching and learning had a *considerable effect* on teaching and learning. Therefore, between 2011 and 2015, the number of provinces in which the majority of school principals indicated a *considerable effect* on mathematics teaching and learning due to a shortage of computers, remained the same. It is interesting to note that while the number of provinces in which the majority of school principals indicated a *considerable effect* on mathematics teaching and learning due to a shortage of computers remained the same, only school principals in Mpumalanga, Northern Cape and the Western Cape reported a *considerable effect* on mathematics teaching and learning in both 2011 and 2015.

It is, however interesting to note that of the 10 provinces (five from 2011; five from 2015) the majority of school principals from only the Northern Cape and Western Cape indicated a *considerable effect* on mathematics teaching and learning in both 2011 and 2015. It is unclear from the ICT-related variables identified in the Eighth Grade *School* Questionnaire why this change occurred, and this may be a topic for further research.

In 2011, the two provinces where the lowest percentage of school principals indicated a *considerable effect* on mathematics teaching and learning due to a shortage of computers, were the Eastern Cape (26.90%) and Limpopo (30.69%). Again, while the minority of school principals in these two provinces indicated a *considerable effect* on mathematics teaching and learning due to a shortage of computers, learners from schools in the Eastern Cape (PV = 301) and Limpopo (PV = 320) achieved the lowest scores on the TIMSS achievement scale of all nine provinces. It seems as if many school principals from these two provinces did not have a clear understanding of the constructive contribution that computers may have on teaching and learning in their schools, and therefore did not identify a shortage of computers as a challenge.

In 2015, the two provinces where the lowest percentage of school principals indicated a *considerable effect* on mathematics teaching and learning due to a shortage of computers, were Gauteng (42.03%) and the North West (44.58%). While Gauteng learners achieved the highest score on the TIMSS achievement scale (PV = 407), it is a concern that learners from North West achieved the second lowest achievement on the TIMSS achievement scale (PV = 345), while their school principals did not identify a shortage of computers as having an effect on mathematics teaching and learning.

5.2.2. Inferential statistics – Shortage of computers for mathematics instruction (BCBG09BB and BCBG13AH)

SPSS syntax generated by the IEA IDB Analyzer was used to explore the relationship between the availability of computers for mathematics instruction at schools in the nine South African provinces and the mathematics achievement of learners in both categories (*minimal effect* on teaching and learning, and *considerable effect* on teaching and learning) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015, was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BCBG09BB and BCBG13AH is depicted in Table 5.3.

Table 5.3: Shortage of computers for mathematics instruction (BCBG09BB and BCBG13AH) – means, differences, t-tests and p-values

		TIMSS 2011 BCBG09BB		TIMSS 2015 BCBG13AH		Inferential statistics results			
Prov	**Effect**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Minimal	301.1394	10.5268	348.9009	29.1640	-47.7616	31.0056	-1.5404	0.1235
EC	Considerable	367.0696	23.7762	340.0596	15.6605	27.0100	28.4703	0.9487	0.3428
EC	Difference	-65.9302	22.8150	8.8414	31.3823	-74.7716	38.7991	-1.9271	0.0540
FS	Minimal	343.3247	11.4725	347.7113	14.9409	-4.3866	18.8374	-0.2329	0.8159
FS	Considerable	372.5903	11.7990	386.0643	18.1906	-13.4740	21.6821	-0.6214	0.5343
FS	Difference	-29.2656	16.8371	-38.3530	23.7894	9.0874	29.1448	0.3118	0.7552
GT	Minimal	412.9023	14.3925	409.4785	15.7772	3.4238	21.3557	0.1603	0.8726
GT	Considerable	369.1739	8.6534	407.0677	17.8739	-37.8938	19.8585	-1.9082	0.0564
GT	Difference	43.7284	18.7160	2.4107	24.6680	41.3176	30.9645	1.3344	0.1821
KZ	Minimal	339.7823	6.5986	380.1188	21.8804	-40.3365	22.8537	-1.7650	0.0776
KZ	Considerable	345.0435	8.8774	353.1427	15.7195	-8.0993	18.0530	-0.4486	0.6537
KZ	Difference	-5.2611	11.4183	26.9761	29.6005	-32.2372	31.7265	-1.0161	0.3096
LP	**Minimal**	**320.2659**	**6.9041**	**345.5963**	**6.4419**	**-25.3304**	**9.4427**	**-2.6825**	**0.0073**
LP	Considerable	324.1645	11.5093	379.7486	27.6519	-55.5841	29.9514	-1.8558	0.0635
LP	Difference	-3.8986	13.4129	-34.1523	30.5881	30.2537	33.3997	0.9058	0.3650
MP	**Minimal**	**338.6487**	**7.4508**	**387.9442**	**14.4365**	**-49.2955**	**16.2459**	**-3.0343**	**0.0024**
MP	Considerable	350.9764	6.0828	352.2558	6.0632	-1.2794	8.5885	-0.1490	0.8816
MP	**Difference**	**-12.3278**	**10.0007**	**35.6884**	**17.0598**	**-48.0161**	**19.7750**	**-2.4281**	**0.0152**
NC	**Minimal**	**328.5144**	**5.1390**	**366.4540**	**14.2917**	**-37.9396**	**15.1875**	**-2.4981**	**0.0125**
NC	Considerable	369.4357	20.8923	362.7742	8.5095	6.6615	22.5588	0.2953	0.7678
NC	Difference	-40.9213	21.7404	3.6798	16.8688	-44.6011	27.5173	-1.6208	0.1051
NW	Minimal	343.3025	13.8925	361.2407	13.5788	-17.9381	19.4264	-0.9234	0.3558
NW	Considerable	359.6392	16.3306	344.7916	5.7573	14.8476	17.3157	0.8575	0.3912
NW	Difference	-16.3367	21.3344	16.4491	13.6554	-32.7858	25.3303	-1.2943	0.1956

		TIMSS 2011 BCBG09BB		TIMSS 2015 BCBG13AH		Inferential statistics results			
Prov	**Effect**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
WC	Minimal	436.5402	20.0948	396.7737	17.5890	39.7665	26.7053	1.4891	0.1365
WC	Considerable	394.5380	8.2399	389.1945	10.5082	5.3434	13.3536	0.4001	0.6890
WC	Difference	42.0023	22.7709	7.5792	16.3396	34.4231	28.0267	1.2282	0.2194

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from 352 points in TIMSS 2011 to 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). However, when looking at the statistical significance of the changes in mathematics achievement related to a shortage of computers for mathematics teaching and learning, only three provinces (LP, MP, NC) returned statistically significant t-tests and p-values. Accordingly only these three provinces will be discussed in this section.

The mathematics achievement of **Limpopo** learners from schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning, increased from an average of 320 points in 2011 to 346 points in 2015. Since the p-value was less than 0.05, the difference of 25 points was statistically significant (t = -2.68; p = 0.0073). During the same time the percentage of learners who experienced a *minimal effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning, decreased by 16.51% from 69.31% (2011) to 52.81% (2015). The means (2011 = 320; 2015 = 346) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 56 points for schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning was not statistically significant. The increase in mathematics achievement from 2011 to 2015 was higher in Limpopo schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning.

The achievement of **Mpumalanga** learners from schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning, increased from an average of 339 points in 2011 to 388 points in 2015. Since the p-value was less than 0.05, the difference of 49 points was statistically significant (t = -3.03; p = 0.0024). During the same time the percentage of learners who experienced a *minimal effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning, increased by 1.17% from 48.81% (2011) to 49.97% (2015). The means (2011 = 339; 2015 = 388) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 1 point for learners from schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning, was not statistically significant. In 2011, Mpumalanga learners from schools that reported a *minimal effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning, scored an average of 12 points lower than learners from schools that reported a *considerable effect*. In 2015, learners from schools that reported a *minimal effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning, scored an average of 36 points higher than learners from schools that reported a *considerable effect*. The difference of 48 points was statistically significant (t = -2.43; p = 0.0152). The increase in mathematics achievement from 2011 to 2015 was higher in Mpumalanga schools that reported a *minimal effect* on mathematics teaching and learning due to a shortage of computers.

In the **Northern Cape** the mathematics achievement of learners from schools where school principals reported a *minimal effect* on mathematics teaching and learning due to a shortage of computers, increased from an average of 329 points in 2011 to 366 points in 2015. The p-value was less than 0.05, so the difference of 38 points was statistically significant (t = -2.50; p = 0.0125). During the same time the percentage of learners who experienced a *minimal effect* on teaching and learning due to a shortage of computers for mathematics teaching and learning, increased by 5.69% from 23.08% (2011) to 28.77% (2015). The means (2011 = 329; 2015 = 366) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. A decrease in achievement of 7 points for Northern Cape learners from schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of computers, was not statistically significant. In the Northern Cape the increase in mathematics achievement between the years was higher in schools that reported a *minimal effect* of the shortage on teaching and learning.

In two of the three provinces discussed in this section (MP; NC) the increase in mathematics achievement of learners between 2011 and 2015 was higher in schools that reported a *minimal effect* of the shortage on teaching and learning. A possible explanation for this may be that these schools were better resourced (they have computers) and that more effective teaching and learning was taking place in these schools. As such, the principals did not feel that there was a shortage and therefore they did not indicate that the shortage had a considerable effect.

The average mathematics achievement of South African learners in relation to a shortage of computers for mathematics teaching and learning, increased by 13 points from 357 (2011) to 370 (2015). Again, taking into account the relatively large jump in the average mathematics achievement of South African learners between 2011 and 2015, it was surprising how few of the increases in achievement were actually statistically significant. Out of 27 statistical calculations in Table 5.3, only four were statistically significant. This may indicate that a shortage of computers for mathematics teaching and learning statistically had a small influence on the overall 20 point increase between 2011 and 2015.

Limpopo and Mpumalanga recorded the largest statistically significant increase in mathematics achievement between 2011 and 2015 – the increase of 25 points in Limpopo and the increase of 49 points in Mpumalanga were statistically significant. Mpumalanga also recorded the largest statistically significant increase in the difference in achievement between the two categories of schools between 2011 and 2015. This increase of 48 points in Mpumalanga was also statistically significant. This may indicate that even though Limpopo and Mpumalanga were not the top achievers in 2011 or 2015, there seemed to be an increase in the effectiveness of mathematics teaching and learning and this may be worth investigating further.

5.3. Shortage of computer software for mathematics instruction (BCBG09BC and BCBG13BB)

The implementation of ICT for teaching and learning at schools is not limited to the availability of hardware alone – the maintenance of hardware and network infrastructure, instructional software for learners, and educator empowerment all need to be in place (Hassan & Geys, 2016). South Africa is by no means unique when it comes to the lack of access to ICT in schools. In developing countries the lack of ICT hardware and instructional software can be seen as some of the top challenges to the integration of ICT in teaching and learning (Goktas et al., 2013). Kozma (2008) identified the availability of instructional software and support for pedagogical and curriculum-related change management as well as digital content development as crucial components of effective integration of ICT in teaching and learning. These operational components need to be in balance to enable the effective pedagogical use of ICT in teaching and learning (Kennisnet Foundation, 2015).

The IEA included a specific question on the availability of computer software for mathematics instruction in both the 2011 and 2015 Eighth Grade *School* Questionnaires. School principals were asked whether teaching and learning in their school were affected by a **shortage of computer software for mathematics instruction**. It is important to note that this question does not refer to the use of software for administrative purpose in the school, but to educational software specifically. The particulars of variables BCBG09BC and BCBG13BB are depicted in Table 5.4.

Table 5.4: Shortage of computer software for mathematics instruction (BCBG09BC and BCBG13BB)

Variable	Year	Question text	Original coding values	Recoded values
BCBG09BC	2011	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of computer software for mathematics instruction?	1 = Not at all 2 = A little	101 = Minimal effect
			3 = Some 4 = A lot	102 = Considerable effect
			9 = Omitted or invalid	9 = Omitted or invalid
BCBG13BB	2015	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following? Resources for Mathematics Instruction: • Computer software / applications	1 = Not at all 2 = A little	101 = Minimal effect
			3 = Some 4 = A lot	102 = Considerable effect
			9 = Omitted or invalid	9 = Omitted or invalid

5.3.1. Descriptive statistics – Shortage of computer software for mathematics instruction (BCBG09BC and BCBG13BB)

Variables BCBG09BC (TIMSS 2011) and BCBG13BB (TIMSS 2015) dealt with the question of the availability of computer software for mathematics instruction in the school. The statistical analysis of BCBG09BC and BCBG13BB is depicted in Figure 5.3.

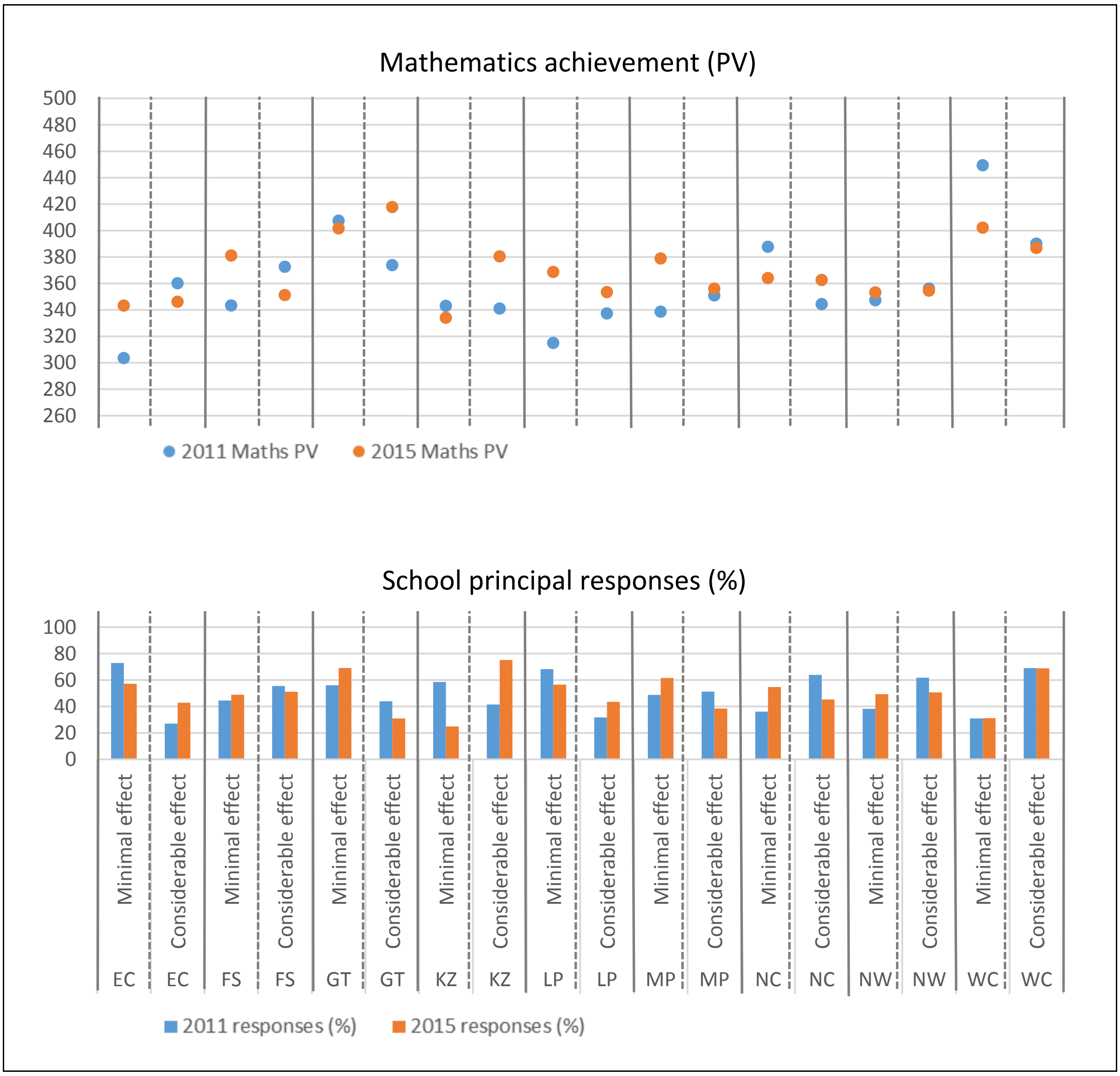

Figure 5.3: Shortage of computer software for mathematics instruction (BCBG09BC and BCBG13BB) – mathematics achievement and school principal responses per province

There seems to be a relationship between school principal responses to questions regarding the availability of computers for mathematics teaching and learning (variables BCBG09BB and BCBG13AH) and the availability of computer software for mathematics teaching and learning (variables BCBG09BC and BCBG13BB). Computer software need computers to run on, so there seems to be some consistency in the responses from school principals.

Mathematics achievement in relation to a shortage of computer software for mathematics instruction

An interesting observation from 2011 that seems to correspond with the availability of computers in schools (see Figure 5.2), is that in six of the nine provinces (EC, FS, KZ, LP, MP, NW), learners from schools where the school principals identified a shortage of computer software as having a *considerable effect* on teaching and learning, achieved higher marks on the TIMSS achievement scale than those whose school principals indicated they experienced a *minimal effect* on teaching and learning. This result seems to corroborate the explanation that school principals in these provinces who were able to identify a *considerable effect* on teaching and learning, were displaying more effective leadership in their schools and that this may have led to improved teaching and learning.

Learners from Gauteng (PV = 449) and Western Cape (PV = 407) schools where school principals indicated a *minimal effect* on teaching and learning in their schools due to a shortage of computer software, were the top achievers in 2011. In an interesting turn of events learners from schools in Gauteng (PV = 418) where school principals indicated a *considerable effect* on teaching and learning in their schools due to a shortage of computer software, were the top achievers in 2015. They were followed by learners from schools in Gauteng (PV = 402) and the Western Cape (PV = 402) where school principals indicated a *minimal effect* on teaching and learning.

It is therefore unclear from the ICT-related variables identified in the Eighth Grade *School* Questionnaires if a relationship exists between the perceptions of school principals of the effect on teaching and learning in their schools due to a shortage of computer software and mathematics achievement. This may be an additional topic for further research if the availability and use of computers for mathematics teaching and learning is explored.

School principal responses in relation to the effect of a shortage of computer software for mathematics instruction

In TIMSS 2011 the majority of school principals in five of the nine provinces (FS = 55.53%; MP = 51.19%; NC = 63.95%; NW = 61.77%; WC = 69.03%) indicated that a shortage of computer software for mathematics instruction had a *considerable effect* on effective teaching and learning in their schools. It is interesting to note that these five provinces were identical to the provinces that indicated a *considerable effect* on effective teaching due to a shortage of computers for mathematics teaching and learning (see Table 5.5). In TIMSS 2015 the majority of school principals in four of the nine provinces (FS = 51.09%; KZ = 75.13%; NW = 50.66%; WC = 68.82%) indicated that a shortage of computer software for mathematics instruction had a *considerable effect* on effective teaching and learning in their schools. In 2015 only two of these provinces (KZ, WC) were identical to the provinces that indicated a *considerable effect* on effective teaching due to a shortage of computers for mathematics teaching and learning (see Figure 5.2).

Again it is interesting to note that school principals in the Eastern Cape (+15.71%) recorded the second largest increase in reporting a *considerable effect* on teaching and learning due to a shortage of computer software in all the provinces, while learner achievement decreased by 14 points (2011 PV = 360; 2015 PV = 346) over the same period. School principals from KwaZulu-Natal (+33.65%) recorded the largest increase in reporting a *considerable effect* on teaching and learning due to a shortage of computer software. During the same time learner achievement in KwaZulu-Natal increased by 39 points (2011 PV = 341; 2015 PV = 380).

In 2011, school principals in the Eastern Cape (27.07%) and Limpopo (31.74%) again reported the lowest percentage of schools experiencing a *considerable effect* on effective teaching and learning due to a shortage of computer software for mathematics instruction. Again learners from the Eastern Cape (PV = 304) and Limpopo (PV = 315) achieved the lowest scores on the TIMSS achievement scale. In 2015, the two provinces where the lowest percentage of school principals that indicated a *considerable effect* on teaching and learning due to a shortage of computer software, were Gauteng (30.95%) and Mpumalanga (38.46%). It is a concern that learners from Mpumalanga achieved only 356 points on the TIMSS achievement scale, while the minority of their school principals identified a shortage of computer software as having a *considerable effect* on teaching and learning. There seems to be no clear link between the availability of computer software and mathematics achievement, and as such any relationship between the availability of computer software and learner performance could not be established conclusively.

5.3.2. Inferential statistics – Shortage of computer software for mathematics instruction (BCBG09BC and BCBG13BB)

The IEA IDB Analyzer was used to explore the relationship between the shortage of technologically competent staff at schools in the nine South African provinces and the mathematics achievement of learners in both categories (*minimal effect* on teaching and learning, and *considerable effect* on teaching and learning) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015, was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BCBG09BC and BCBG1BB is depicted in Table 5.5.

Table 5.5: Shortage of computer software for mathematics instruction (BCBG09BC and BCBG13BB) – means, differences, t-tests and p-values

		TIMSS 2011 BCBG09BC		**TIMSS 2015 BCBG13BB**		**Inferential statistics results**			
Prov	**Effect**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Minimal	303.5343	10.6594	343.2777	19.3077	-39.7435	22.0547	-1.8020	0.0715
EC	Considerable	360.2011	23.3798	346.1463	22.6955	14.0548	32.5837	0.4313	0.6662
EC	Difference	-56.6668	22.7150	-2.8685	29.6152	-53.7983	37.3233	-1.4414	0.1495
FS	Minimal	343.3247	11.4725	381.1022	22.0263	-37.7774	24.8350	-1.5211	0.1282
FS	Considerable	372.5903	11.7990	351.2373	14.4578	21.3530	18.6613	1.1442	0.2525
FS	Difference	-29.2656	16.8371	29.8648	26.5167	-59.1304	31.4106	-1.8825	0.0598
GT	Minimal	407.4968	12.6055	401.6221	14.2944	5.8747	19.0585	0.3082	0.7579
GT	Considerable	373.8525	8.8676	417.8283	25.3267	-43.9758	26.8342	-1.6388	0.1013
GT	Difference	33.6443	16.6840	-16.2062	30.7624	49.8504	34.9954	1.4245	0.1543
KZ	Minimal	342.9919	6.6229	334.0979	13.6081	8.8941	15.1342	0.5877	0.5567

		TIMSS 2011 BCBG09BC		TIMSS 2015 BCBG13BB		Inferential statistics results			
Prov	Effect	Maths PV (mean)	Maths PV s.e.	Maths PV (mean)	Maths PV s.e.	Difference of diff	Error of Diff	t-test	p-value
KZ	**Considerable**	**341.0369**	**8.3253**	**380.4873**	**15.3904**	**-39.4504**	**17.4978**	**-2.2546**	**0.0242**
KZ	**Difference**	**1.9550**	**9.9574**	**-46.3894**	**20.9266**	**48.3445**	**23.1748**	**2.0861**	**0.0370**
LP	**Minimal**	**315.0583**	**6.5366**	**368.7344**	**21.6679**	**-53.6761**	**22.6324**	**-2.3717**	**0.0177**
LP	Considerable	337.3264	18.8693	353.5130	18.5674	-16.1866	26.4726	-0.6114	0.5409
LP	Difference	-22.2681	21.7268	15.2214	29.9408	-37.4895	36.9933	-1.0134	0.3109
MP	**Minimal**	**338.6487**	**7.4508**	**378.8552**	**11.7406**	**-40.2066**	**13.9053**	**-2.8915**	**0.0038**
MP	Considerable	350.9764	6.0828	356.0663	10.4593	-5.0899	12.0995	-0.4207	0.6740
MP	Difference	-12.3278	10.0007	22.7889	15.9087	-35.1167	18.7910	-1.8688	0.0616
NC	Minimal	387.7287	40.3666	364.1335	9.9269	23.5952	41.5693	0.5676	0.5703
NC	Considerable	344.3520	6.6434	362.6768	11.3812	-18.3248	13.1782	-1.3905	0.1644
NC	Difference	43.3767	40.8172	1.4567	14.9992	41.9200	43.4859	0.9640	0.3351
NW	Minimal	347.3211	17.0966	353.2483	12.2442	-5.9272	21.0289	-0.2819	0.7781
NW	Considerable	356.1864	14.0909	354.5515	9.7099	1.6349	17.1124	0.0955	0.9239
NW	Difference	-8.8652	23.1105	-1.3032	15.3894	-7.5620	27.7656	-0.2724	0.7854
WC	Minimal	449.4733	25.3189	402.2347	18.3547	47.2386	31.2720	1.5106	0.1309
WC	Considerable	390.1622	7.6735	386.8781	12.4397	3.2841	14.6161	0.2247	0.8222
WC	Difference	59.3111	28.5123	15.3566	19.5762	43.9545	34.5858	1.2709	0.2038

Note: **Red** formatting indicates a statistically significant t-test and p-value

South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from 352 points in TIMSS 2011 to 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). However, when looking at the statistical significance of the changes in mathematics achievement in relation to the availability of computer software for mathematics instruction, only three provinces (KZ, LP, MP) returned statistically significant t-tests and p-values. Accordingly only these three provinces will be discussed in this section.

The mathematics achievement of **KwaZulu-Natal** learners from schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of computer software for mathematics instruction, increased from an average of 341 points in 2011 to 380 points in 2015. Since the p-value was less than 0.05, the difference of 39 points was statistically significant ($t = -2.25$; $p = 0.0242$). During this time the percentage of learners who experienced a *considerable effect* on teaching and learning due to a shortage of computer software for mathematics instruction, increased by 33.65% from 41.48% (2011) to 75.13% (2015). The means (2011 = 341; 2015 = 380) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. A decrease in achievement of 9 points for learners from schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of computer software for mathematics instruction, was not statistically significant. In 2011, KwaZulu-Natal learners from schools that reported a *minimal effect* on teaching and learning due to a shortage of computer software for mathematics instruction, scored an average of 2 points higher than learners from schools that reported a *considerable effect*. In 2015, learners from schools that reported a *minimal effect* on teaching and learning due to a shortage of computer software for mathematics instruction, scored an average of 46 points lower than learners from schools that reported a *considerable effect*. This difference of 48 points was statistically significant ($t = 2.09$; $p = 0.0370$). It is interesting to note that the increase in mathematics achievement in KwaZulu-Natal schools was higher in schools that reported a *considerable effect* on teaching and learning due to a shortage of computer software for mathematics instruction.

In **Limpopo** the mathematics achievement of learners from schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of computer software for mathematics instruction, increased from an average of 315 points in 2011 to 369 points in 2015. Since the p-value was less than 0.05, the difference of 54 points was statistically significant ($t = -2.37$; $p = 0.0177$). During the same time the percentage of learners who experienced a *minimal effect* on teaching and learning due to a shortage of computer software for mathematics instruction, decreased by 11.81% from 68.26% (2011) to 56.46% (2015). The means (2011 = 315; 2015 = 369) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 16 points for schools where school principals reported a *considerable effect* on teaching and learning was not statistically significant. In Limpopo the increase in mathematics achievement between 2011 and 2015 was higher in schools that reported a *minimal effect* of the shortage of computer software on mathematics instruction.

In **Mpumalanga** the mathematics achievement of learners from schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of computer software for mathematics instruction, increased from an average of 339 points in 2011 to 379 points in 2015. Since the p-value was less than 0.05, the difference of 40 points was statistically significant (t = -2.89; p = 0.0038). During the same time the percentage of learners who experienced a *minimal effect* on teaching and learning due to a shortage of computer software for mathematics instruction, increased by 12.73% from 48.81% (2011) to 61.54% (2015). The means (2011 = 339; 2015 = 379) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 5 points for schools where school principals reported a *considerable effect* on teaching and learning was not statistically significant. In Mpumalanga the increase in mathematics achievement between 2011 and 2015 was higher in schools that reported a *minimal effect* of the shortage of computer software on mathematics instruction.

The average mathematics achievement of South African learners in relation to a shortage of computer software for mathematics instruction, increased by 10 points from 359 (2011) to 369 (2015). Again, it was surprising how few of the increases in achievement were actually statistically significant. Out of 27 statistical calculations in Table 5.5, only four calculations were statistically significant. Again, this may indicate that a shortage of computer software for mathematics teaching and learning statistically had a relatively small influence on the 20 point increase between 2011 and 2015.

Limpopo recorded the largest increase in achievement between 2011 and 2015 for this variable – the increase of 54 points in Limpopo achievement was statistically significant. KwaZulu-Natal recorded the largest increase in the difference in achievement between the two groups of schools between 2011 and 2015. This increase of 48 points in KwaZulu-Natal was statistically significant. This may indicate that there could be an increase in the effectiveness of mathematics teaching and learning in relation to computer software for mathematics instruction in Limpopo and KwaZulu-Natal and that this relationship may be worth investigating further.

5.4. Shortage of audio-visual materials relevant to mathematics (BCBG09BE and BCBG13AG)

Webb (2002) defines learning with the use of ICT as using ICT as a tool to support teaching and learning in a traditional classroom. The Eighth Grade *School* Questionnaires primarily focus on traditional classroom teaching and learning and the use of ICT as a tool for learning in these classrooms (Mullis, Martin, Goh, et al., 2016; Mullis, Martin, Minnich, et al., 2012). Additional audio-visual materials provide educators with opportunities for expanding teaching beyond the classroom (Bonaveri et al., 2015; Mdlongwa, 2012), but the integration of these additional audio-visual resources in teaching and learning rely on the availability of ICT in the classroom or school (Condie & Munro, 2007).

The IEA included a question on the availability of audio-visual resources for mathematics instruction in both the 2011 and 2015 Eighth Grade *School* Questionnaires. School principals were asked whether teaching and learning in their school were affected by a **shortage of audio-visual for mathematics instruction**. It is important to note that even though this question does not directly refer to the use of ICT in the classroom or school, the integration of relevant audio-visual resources in teaching and learning relies heavily on the availability of ICT in the school. The details of variables BCBG09BE and BCBG13AG are depicted in Table 5.6.

Table 5.6: Shortage of audio-visual materials relevant to mathematics (BCBG09BE and BCBG13AG)

Variable	Year	Question text	Original coding values	Recoded values
BCBG09BE	2011	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of audio-visual resources for mathematics instruction?	1 = Not at all 2 = A little	101 = Minimal effect
			3 = Some 4 = A lot	102 = Considerable effect
			9 = Omitted or invalid	9 = Omitted or invalid
BCBG13AG	2015	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following? General School Resources: • Audio-visual resources for delivery of instruction	1 = Not at all 2 = A little	101 = Minimal effect
			3 = Some 4 = A lot	102 = Considerable effect
			9 = Omitted or invalid	9 = Omitted or invalid

5.4.1. Descriptive statistics – Shortage of audio-visual materials relevant to mathematics (BCBG09BE and BCBG13AG)

Variable BCBG09BE (TIMSS 2011) and variable BCBG13AHG (TIMSS 2015) dealt with the question of the availability of relevant audio-visual resources for mathematics instruction in the schools. The statistical analysis of BCBG09BE and BCBG13AG is depicted in Figure 5.4.

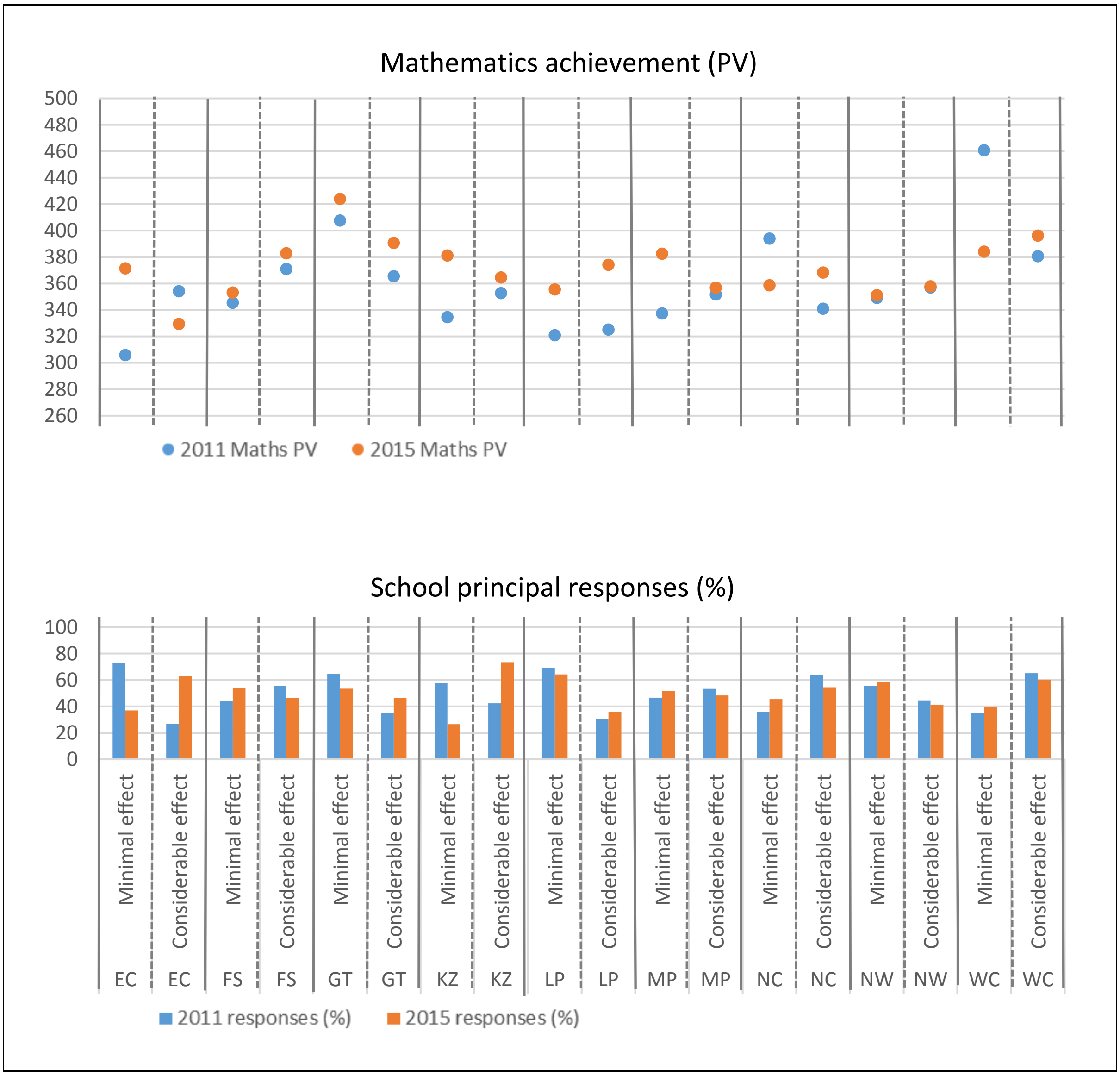

Figure 5.4: Shortage of audio-visual materials relevant to mathematics (BCBG09BE and BCBG13AG) – mathematics achievement and school principal responses per province

Mathematics achievement in relation to a shortage of audio-visual materials relevant to mathematics instruction

An interesting trend from 2011 is that in six of the nine provinces (EC; FS; KZ; LP; MP; NW) learners from schools where the majority of school principals indicated a *considerable effect* on teaching and learning due to a shortage of audio-visual materials relevant to mathematics, achieved higher marks on the TIMSS achievement scale than those whose school principals indicated that they experienced a *minimal effect* on teaching and learning. In 2015 the number of provinces where learners achieved higher marks if the majority of school principals indicated a *considerable effect* on teaching and learning due to a shortage of audio-visual materials relevant to mathematics, changed to five (FS; LP; NC; NW; WC). This trend also seems to correspond with the trend where learners achieved better results if their school principals indicated a *considerable effect* on teaching and learning due to a shortage of computers and computer software.

Learners from schools in Gauteng (PV = 408) and the Western Cape schools (PV = 461) where school principals indicated a *minimal effect* on teaching and learning in their schools due to a shortage of relevant audio-visual materials, were the top achievers in 2011. Learners from Gauteng schools (PV = 424) where school principals indicated a *minimal effect* on teaching and learning in their schools due to a shortage of relevant audio-visual materials were the top achievers in 2015, surprisingly followed by learners in the Western Cape (PV = 396) where school principals indicated a *considerable effect* on teaching and learning.

A big surprise was that in 2015, learners from Western Cape schools where school principals indicated a *considerable effect* on teaching and learning due to a shortage of audio-visual materials relevant to mathematics, scored an average of 12 points higher than those whose school principals indicated a *minimal effect* on teaching and learning. This may again reflect on the school management by hands-on school principals that create a school environment that is conducive to teaching and learning.

The biggest difference in achievement between schools where school principals indicated a *considerable effect* on teaching and learning due to a shortage of audio-visual materials relevant to mathematics, and those where school principals indicated a *minimal effect,* was in the Eastern Cape where learners from schools where school principals indicated a *considerable effect* on teaching and learning achieved an average of 42 points lower on the TIMSS achievement scale. As can be seen from the results of this and other variables in this chapter, there seems to have been a marked increase in awareness of ICT-related challenges in schools by Eastern Cape school principals, even though the Eastern Cape is one of South Africa's poorest provinces (Statistics South Africa, 2013, 2017) and the limited provincial finances is often spent on basic educational needs and not on ‘nice-to-have’s’ like ICT in classrooms (Eastern Cape Department of Education, 2016).

School principal responses in relation to the effect of a shortage of audio-visual materials relevant to mathematics instruction

In TIMSS 2011 the majority of school principals in four of the nine provinces (FS = 55.46%; MP = 53.36%; NC = 63.97%; WC = 65.16%) indicated that a shortage of audio-visual materials relevant to mathematics had a *considerable effect* on effective teaching and learning in their schools. In TIMSS 2015 the majority of school principals in four of the nine provinces (EC = 63.04%; KZ = 73.43%; NC = 54.50%; WC = 60.30%) indicated that a shortage of audio-visual materials relevant to mathematics had a *considerable effect* on effective teaching and learning in their schools.

Between 2011 and 2015, the number of provinces in which the majority of school principals indicated a *considerable effect* on mathematics teaching and learning due to a shortage of audio-visual materials, remained the same. However, it is interesting to note that again, of the eight provinces discussed in this section (four from 2011; four from 2015), the majority of school principals from only the Northern Cape and Western Cape indicated a *considerable effect* on mathematics teaching and learning in both 2011 and 2015. It seems as if there was an increased awareness among school principals in general regarding the importance of audio-visual materials relevant to mathematics teaching and learning in their schools, because different school principals could identify a *considerable effect* on teaching and learning in 2015.

In 2011, the two provinces where the lowest percentage of school principals indicated a *considerable effect* on teaching and learning due to a shortage of audio-visual materials relevant to mathematics, were again the Eastern Cape (26.87%) and Limpopo (30.69%). Again the learners from the top two provinces where school principals did not identify a negative influence on teaching and learning due to a shortage of audio-visual materials relevant to mathematics, also achieved the lowest scores on the TIMSS achievement scale – Eastern Cape (PV = 306) and Limpopo (PV = 321). It seems as if school principals from schools in the Eastern Cape and Limpopo again failed to recognise a shortage of relevant audio-visual materials as a challenge to mathematics teaching and learning in their schools.

In 2015 school principals in Limpopo reported the lowest percentage of schools experiencing a *considerable effect* on teaching and learning due to a shortage of audio-visual materials relevant to mathematics (35.79%). Again it is a concern that learners from North West again achieved the lowest achievement on the TIMSS achievement scale (PV = 351), while their school principals did not identify a shortage of audio-visual materials relevant to mathematics as having a negative effect on teaching and learning. It remains concerning that many school principals failed to recognise a shortage of audio-visual materials relevant to mathematics as a challenge to mathematics teaching and learning in their schools.

It seems as if many school principals did not have a clear understanding of the contribution that audio-visual materials relevant to mathematics can have on effective teaching and learning in schools, and therefore did not identify a shortage of audio-visual materials as a challenge. Alternatively, many school principals may have had the perception that their educators were successful and that a shortage of audio-visual materials relevant to mathematics therefore had a small effect on teaching and learning in their schools.

The availability of audio-visual materials relevant to mathematics seems to correspond with the availability of computers and computer software in schools in 2011 and 2015. Schools that experienced a *considerable effect* on teaching and learning due to a shortage of computers and computer software, also experienced a *considerable effect* on teaching and learning due to a shortage of audio-visual materials relevant to mathematics. This seems to support the notion that most modern audio-visual materials require some form of ICT to be delivered (Hansen et al., 2012; Mofokeng & Mji, 2010; Vandeyar, 2013).

5.4.2. Inferential statistics – Shortage of audio-visual materials relevant to mathematics (BCBG09BE and BCBG13AG)

The IEA IDB Analyzer was used to explore the relationship between the shortage of relevant audio-visual resources at schools in the nine South African provinces and the mathematics achievement of learners in both categories (*minimal effect* on teaching and learning, and *considerable effect* on teaching and learning) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015, was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BCBG09BE and BCBG13AG is depicted in Table 5.7.

Table 5.7: Shortage of audio-visual materials relevant to mathematics (BCBG09BE and BCBG13AG) – means, differences, t-tests and p-values

		TIMSS 2011 BCBG09BE		TIMSS 2015 BCBG13AG		Inferential statistics results			
Prov	**Effect**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	**Minimal**	**305.8756**	**9.2486**	**371.4293**	**30.8605**	**-65.5536**	**32.2165**	**-2.0348**	**0.0419**
EC	Considerable	354.1809	22.9806	329.3241	9.1939	24.8568	24.7515	1.0043	0.3153
EC	**Difference**	**-48.3053**	**24.9955**	**42.1051**	**30.2798**	**-90.4104**	**39.2638**	**-2.3026**	**0.0213**
FS	Minimal	345.4340	10.1137	353.1389	14.4516	-7.7050	17.6390	-0.4368	0.6622
FS	Considerable	370.9329	11.0497	382.7919	18.9942	-11.8590	21.9745	-0.5397	0.5894
FR	Difference	-25.4989	14.0724	-29.6530	23.8001	4.1540	27.6492	0.1502	0.8806
GT	Minimal	407.6050	11.8655	423.9959	18.0199	-16.3909	21.5756	-0.7597	0.4474
GT	Considerable	365.4164	10.0771	390.6488	11.1638	-25.2325	15.0393	-1.6778	0.0934
GT	Difference	42.1886	16.8851	33.3471	21.6585	8.8415	27.4626	0.3219	0.7475
KZ	Minimal	334.4849	6.3287	381.1843	25.1740	-46.6995	25.9574	-1.7991	0.0720
KZ	Considerable	352.6553	7.2805	364.5232	14.8537	-11.8678	16.5420	-0.7174	0.4731
KZ	Difference	-18.1704	9.1517	16.6612	31.0452	-34.8316	32.3660	-1.0762	0.2818
LP	**Minimal**	**320.8151**	**6.6672**	**355.4589**	**9.6221**	**-34.6438**	**11.7063**	**-2.9594**	**0.0031**
LP	Considerable	325.0854	11.4492	374.0357	33.9752	-48.9503	35.8525	-1.3653	0.1722
LP	Difference	-4.2703	13.2871	-18.5768	35.1420	14.3065	37.5700	0.3808	0.7034
MP	**Minimal**	**337.3168**	**7.6616**	**382.5105**	**13.4669**	**-45.1938**	**15.4938**	**-2.9169**	**0.0035**
MP	Considerable	351.6388	5.9096	356.8017	10.0275	-5.1629	11.6394	-0.4436	0.6574
MP	Difference	-14.3220	10.0260	25.7089	18.2398	-40.0309	20.8137	-1.9233	0.0544
NC	Minimal	393.9299	38.3130	358.5909	9.3709	35.3391	39.4423	0.8960	0.3703
NC	**Considerable**	**340.8719**	**4.4658**	**368.2099**	**10.7544**	**-27.3380**	**11.6447**	**-2.3477**	**0.0189**
NC	Difference	53.0581	38.4734	-9.6190	14.3760	62.6771	41.0715	1.5260	0.1270
NW	Minimal	349.0660	15.2233	351.1305	9.9712	-2.0645	18.1982	-0.1134	0.9097
NW	Considerable	356.9599	16.7747	357.8391	12.0363	-0.8792	20.6461	-0.0426	0.9660
NW	Difference	-7.8939	22.7609	-6.7086	15.7484	-1.1853	27.6780	-0.0428	0.9658

		TIMSS 2011 BCBG09BE		TIMSS 2015 BCBG13AG		Inferential statistics results			
Prov	Effect	Maths PV (mean)	Maths PV s.e.	Maths PV (mean)	Maths PV s.e.	Difference of diff	Error of Diff	t-test	p-value
WC	**Minimal**	**460.7790**	**25.1735**	**384.0150**	**15.7464**	**76.7640**	**29.6927**	**2.5853**	**0.0097**
WC	Considerable	380.5940	6.8010	396.2249	13.7802	-15.6308	15.3671	-1.0172	0.3091
WC	**Difference**	**80.1850**	**28.2722**	**-12.2098**	**19.7587**	**92.3948**	**34.4924**	**2.6787**	**0.0074**

Note: **Red** formatting indicates a statistically significant t-test and p-value

South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from 352 points in TIMSS 2011 to 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). When looking at the statistical significance of the changes in mathematics achievement in relation to the availability of audio-visual resources relevant to mathematics, five provinces (EC, LP, MP, NC, WC) returned statistically significant t-tests and p-values. Accordingly only these five provinces will be discussed in this section.

Northern Cape learners from schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of relevant audio-visual resources, increased their mathematics achievement from an average of 341 points in 2011 to 368 points in 2015. Since the p-value was less than 0.05, the difference of 27 points was therefore statistically significant (t = -2.35, p = 0.0189). During the same time the percentage of learners who experienced a *considerable effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, decreased by 9.46% from 63.97% (2011) to 54.50% (2015). The means (2011 = 341; 2015 = 368) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. A decrease in achievement of 35 points for learners in schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, was not statistically significant. The increase in the mathematics achievement from 2011 to 2015 of Northern Cape learners was higher in schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics.

The mathematics achievement of **Eastern Cape** learners from schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, increased from an average of 306 points in 2011 to 371 points in 2015. Since the p-value was less than 0.05, the difference of 66 points was statistically significant (t = -2.03, p = 0.0419). During the same time the percentage of learners who experienced a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, decreased by 36.17% from 73.13% (2011) to 36.96% (2015). The means (2011 = 306; 2015 = 371) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. On the other hand, the decrease in achievement of 25 points for learners from schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, was not statistically significant. In 2011, learners from Eastern Cape schools that reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, scored an average of 48 points lower than learners from schools that reported a *considerable effect*. In 2015, learners from schools that reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, scored an average of 42 points higher than learners from schools that reported a *considerable effect*. This difference of 90 points was statistically significant (t = -2.30; p = 0.0013). The increase in mathematics achievement from 2011 to 2015 was higher in Eastern Cape schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics.

Learners from **Limpopo** schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of relevant audio-visual resources, increased their mathematics achievement from an average of 321 points in 2011 to 355 points in 2015. Since the p-value was less than 0.05, the difference of 35 points was statistically significant (t = -2.96, p = 0.0031). During the same time the percentage of learners who experienced a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, decreased by 5.10% from 69.31% (2011) to 64.21% (2015). The means (2011 = 321; 2015 = 355) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 49 points for learners from schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, was not statistically significant. The increase in mathematics achievement from 2011 to 2015 was higher in Limpopo schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics.

The mathematics achievement of **Mpumalanga** learners from schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, increased from an average of 337 points in 2011 to 383 points in 2015. Since the p-value was less than 0.05, the difference of 45 points was statistically significant (t = -2.92, p = 0.0035). During the same time the percentage of learners who experienced a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, increased by 5.05% from 46.64% (2011) to 51.69% (2015). The means (2011 = 337; 2015 = 383) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 5 points for learners from schools from schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, was not statistically significant. The increase in mathematics achievement from 2011 to 2015 of Mpumalanga learners was higher in schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics.

The mathematics achievement of **Western Cape** learners from schools where school principals reported a *minimal effect* on teaching and learning due to a shortage of relevant audio-visual resources, decreased from an average of 461 points in 2011 to 384 points in 2015. Since the p-value was less than 0.05, the difference of 77 points was statistically significant (t = 2.59, p = 0.0097). During the same time the percentage of learners who experienced a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, increased by 4.86% from 34.84% (2011) to 39.70% (2015). The means (2011 = 461; 2015 = 384) indicate a negative difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant decrease in achievement. An increase in achievement of 16 points for schools where school principals reported a *considerable effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, was not statistically significant. In 2011, learners from Western Cape schools that reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, scored an average of 80 points higher than learners from schools that reported a *considerable effect*. In 2015, learners from schools that reported a *minimal effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics, scored an average of 12 points lower than learners from schools that reported a *considerable effect*. This difference of 92 points was statistically significant ($t = 2.68$, $p = 0.0074$). The increase in Western Cape mathematics achievement between 2011 and 2015 was higher in schools that reported a *considerable effect* on teaching and learning due to a shortage of audio-visual resources relevant to mathematics.

The average mathematics achievement of South African learners in relation to a shortage of audio-visual resources relevant to mathematics, increased by 12 points from 359 (2011) to 371 (2015). Again, it was surprising how few of the increases in achievement were actually statistically significant. Out of 27 statistical calculations in Table 5.7, only seven calculations were statistically significant. It seems as if a shortage of relevant audio-visual materials could have had a slightly larger influence on the 20 point increase between 2011 and 2015 when compared with the statistical significance of the increases in achievement related to other variables in this chapter. It therefore seems as if the perceptions of school principals regarding the effect of a shortage of audio-visual resources relevant to mathematics on teaching and learning was also not a good indication of learner achievement in mathematics.

Mpumalanga recorded the largest increase in achievement between 2011 and 2015 for this variable – the increase of 45 points in Mpumalanga achievement was statistically significant. This may indicate that there could be an increase in the effectiveness of mathematics teaching and learning in relation to audio-visual resources relevant to mathematics and that this relationship may be worth investigating further.

The Western Cape recorded the largest increase in difference in mathematics achievement between the two groups of schools between 2011 and 2015. This difference of 92 points was statistically significant. The decrease in achievement of 77 points between 2011 and 2015 was also statistically significant. While this decrease in mathematics achievement may be related to an influx of disadvantaged learners from other provinces, the achievement in Gauteng schools that experienced the same phenomenon, improved over the same period of time. It may be worth investigating the relationship between the availability of audio-visual resources relevant to mathematics and mathematics achievement in Gauteng and the Western Cape.

5.5. Findings from the statistical analysis of the Eighth Grade *School* Questionnaires

This chapter focused on the secondary data analysis of six ICT-related variables from the 2011 and 2015 Eighth Grade *School* Questionnaires. Three variables were identified from TIMSS 2015 and three from TIMSS 2011.

It seems as if most school principals' awareness of the importance of technology in schools increased in the period between 2011 and 2015. There was an increased reporting by school principals of a *considerable effect* on teaching and learning due to a shortage of audio-visual materials relevant to mathematics in their schools. It seems if, as technology became more prevalent in everyday life in South Africa over the last decade, school principals started recognising the added value when educators in their schools used technology, whether it be for planning, teaching or learning.

On the other hand, fewer school principals reported a *considerable effect* on teaching and learning due to a shortage of computers and computer software in 2015 than in 2011. This seems to suggest that there may have been progress in the rollout of computers to schools and that computers were more readily available in schools. The school principals' perceptions seem to indicate that a shortage of computers and computers software decreased between 2011 and 2015 and did not have as much of an effect on teaching and learning. Alternatively it may also suggest that school principals did not perceive a shortage of computers and computer software as an impediment to effective teaching and learning in their schools. It is interesting to note that variables related to questions regarding the availability of computers in schools in the SACMEQ III and SACMEQ IV studies yielded similar results in that there was an increase in the availability of computers reported by the sampled schools between 2007 and 2013 (DBE, 2017c). Further research is needed to establish the reason for the decrease in reporting a *considerable effect* on teaching and learning due to a shortage of computers and computer software.

In 2011 learners in all provinces, except for those in Gauteng, the Northern Cape and the Western Cape, achieved higher scores if their school principals indicated that a shortage of computers, computer software and relevant audio-visual materials had a *considerable effect* on teaching and learning in the school. This may indicate that educators in Gauteng, the Northern Cape and the Western Cape were able to utilise computers to optimally support teaching and learning, perhaps due to skills development that usually forms part of ICT integration projects in schools. Additionally, a possible explanation may be that school principals who were able to identify a *considerable effect* on teaching and learning due to a shortage of computers, were more hands-on in their schools, were able to identify challenges in the school, and were able to provide more effective leadership in the school. This finding may support the idea that effective leadership in schools usually leads to improved teaching and learning, but further investigation is required to conclude emphatically that a relationship exists.

In 2015 the picture changed completely, whereby learners in most provinces (excluding the Free State and Limpopo), achieved lower scores if their school principals indicated that a shortage of computers, computer software and relevant audio-visual materials had a *considerable effect* on teaching and learning in the school. This finding seems to support the idea that there could be a relationship between the availability of computers in schools and more effective teaching and learning in schools. A possible explanation may be that the availability of computers in schools is a good indication of the availability of resources in the school, which is closely linked to the SES of the majority of learners in that school. Learners from lower socioeconomic backgrounds generally find it harder to achieve academically. Also, schools that are better resourced (they have computers) seem to have more effective teaching and learning taking place in these schools. However, the study has not yielded finite conclusions as no strong trend could be identified in either direction.

The Western Cape recorded the largest decrease in mathematics achievement between the two groups of schools between 2011 and 2015. While this decrease in mathematics achievement may be related to an influx of disadvantaged learners from other provinces, the achievement in Gauteng schools that experienced the same phenomenon improved over the same period of time. It may be worth investigating which factors played a role in the decrease in mathematics achievement in the Western Cape.

The mathematics achievement of South African Grade 9 learners increased by 20 points on the TIMSS achievement scale from 2011 to 2015 (Reddy, Visser, et al., 2016). The study also explored the relationship between ICT-related variables and the difference in mathematics achievement between 2011 and 2015. It was surprising how few differences in mathematics achievement between 2011 and 2015 were actually statistically significant. Table 5.8 depicts the number of statistically significant findings for the ICT-related variables identified from the Eighth Grade *School* Questionnaires.

Table 5.8: Statistically significant findings for ICT-related variables from the Eighth Grade *School* Questionnaires

TIMSS 2011 variables	TIMSS 2015 variables	Variable description	Number of statistically significant findings	Reference to statistics
BCBG09BB	BCBG13AH	GEN\SHORTAGE\MATH\ **COMPUTERS FOR INSTR.**	4 out of 27	See Table 5.3
BCBG09BC	BCBG13BB	GEN\SHORTAGE\MATH\ **COMPUTER SOFTWARE**	4 out of 27	See Table 5.5
BCBG09BE	BCBG13AG	GEN\SHORTAGE\MATH\ **AUDIO-VISUAL RESOURCE**	7 out of 27	See Table 5.7

It seems as if a shortage of audio-visual materials relevant to mathematics (BCBG09BE and BCBG13AG) had the greatest effect on the difference in mathematics achievement between 2011 and 2015. Seven out of 27 statistical calculations in Table 5.7 were statistically significant. As expected, the number of statistically significant calculations for variables BCBG09BB and BCBG13AH (a shortage of computers for mathematics instruction) were similar to the number of statistically significant calculations for BCBG09BC and BCBG13BB (a shortage of computer software for mathematics instruction). In both these cases four out of 27 statistical calculations (see Table 5.3 and Table 5.5) were statistically significant.

5.6. Summary

This chapter focused on the secondary data analysis of ICT-related variables from the 2011 and 2015 Eighth Grade *School* Questionnaires. Eight ICT-related variables were identified from the Eighth Grade *School* Questionnaires. These variables were recoded in SPSS into a dichotomous scale – those representing a low level of agreement with the variable statement and those representing a high level of agreement with the variable statement.

The data analysis of the 2011 and the 2015 Eighth Grade *Mathematics Teacher* Questionnaires will be discussed in details in Chapter 6. Furthermore, the data analysis of the 2011 and the 2015 Eighth Grade *Student* Questionnaires will be discussed in details in

Chapter 7. Chapter 8 will present the consolidated findings from the secondary data analysis of variables from the three TIMSS context questionnaires.

6. CHAPTER 6 – TIMSS EIGHTH GRADE *MATHEMATICS TEACHER* QUESTIONNAIRES DATA ANALYSIS AND RESULTS

6.1. Introduction

This chapter reports on the results of the secondary data analysis of ICT-related variables from the Eighth Grade *Mathematics Teacher* Questionnaires. The variables discussed in this chapter emanates from ICT-related questions identified in the 2011 Eighth Grade *Mathematics Teacher* Questionnaire (Mullis et al., 2009) and the 2015 Eighth Grade *Mathematics Teacher* Questionnaire (Mullis & Martin, 2013). Mathematics educators teaching the mathematics classes sampled for the TIMSS assessments were requested to complete the Eighth Grade *Mathematics Teacher* Questionnaires. The questions in these questionnaires focused on the educators' personal experiences in their school, as well as the way in which they were teaching mathematics to the classes sampled for participation in TIMSS.

Seven ICT-related variables were identified for inclusion in this study from the 2015 Eighth Grade *Mathematics Teacher* Questionnaire. Using the information supplied in Supplement 1 of the TIMSS 2015 User Guide for the International Database (Foy, 2017b) on the relationships between variables in 2015 and 2011, seven related variables were identified from the 2011 Eighth Grade *Mathematics Teacher* Questionnaire. Figure 6.1 depicts an extract from Supplement 1 of the TIMSS 2015 User Guide for the International Database, indicating the way related variables in the Eighth Grade *Mathematics Teacher* Questionnaires were identified.

Exhibit S1.7: Index of International Background Variables for the TIMSS 2015 Mathematics Teacher Questionnaire - Eighth Grade

TIMSS 2015 Question Number	TIMSS 2015 Variable Name	TIMSS 2015 Variable Description (See questionnaire for full item text)	TIMSS 2011 Variable Name	Notes
TQG-01	BTBG01	By the end of this school year, how many years will you have been teaching altogether?	BTBG01	
TQG-02	BTBG02	Are you female or male?	BTBG02	
TQG-03	BTBG03	How old are you?	BTBG03	
TQG-04	BTBG04	What is the highest level of formal education you have completed?	BTBG04	Modified response options in 2015

Figure 6.1: Example of the relationships between similar variables in TIMSS 2011 and TIMSS 2015 (Foy, 2017b, p. 237)

The ICT-related variables from the Eighth Grade *Mathematics Teacher* Questionnaires used in this study and the original IEA Likert-type response coding values are depicted in Table 6.1. Variables that are related to the same question in the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires respectively, are discussed in the same sub-section in this chapter.

Table 6.1: ICT-related variables from the Eighth Grade *Mathematics Teacher* Questionnaires

TIMSS 2011 variables	TIMSS 2015 variables	Variable description	Original IEA Likert response coding values
BTBG09BC	BTBG08G	GEN\PC USE**ADEQUATE SUPPORT**	1 = Agree a lot 2 = Agree a little 3 = Disagree a little 4 = Disagree a lot 9 = Omitted or invalid
BTBM22A	BTBM20A	MATH**COMPUTER AVAILABILITY DURING MATH**	1 = Yes 2 = No 9 = Omitted or invalid
BTBM22CA BTBM22CB BTBM22CC BTBM22CD	BTBM20CA BTBM20CB BTBM20CC BTBM20CD	MATH\COMPUTER ACTIVITIES**EXPLORE CONCEPT** MATH\COMPUTER ACTIVITIES**DO PROCEDURES** MATH\COMPUTER ACTIVITIES**LOOK UP IDEAS** MATH\COMPUTER ACTIVITIES**PROCESS DATA**	1 = Every day or almost every day 2 = Once or twice a week 3 = Once or twice a month 4 = Never or almost never 6 = Logically not applicable 9 = Omitted or invalid
BTBM29D	BTBM24D	MATH**PROF DEVELOPMENT\IT**	1 = Yes 2 = No 9 = Omitted or invalid

Variables identified from Foy (2017b), Mullis et al. (2009) and Mullis and Martin (2013)

The 14 variables, seven from TIMSS 2011 and seven from TIMSS 2015, were statistically analysed using SPSS syntax generated by the IEA IDB Analyzer. The SPSS output was organised according to the recoded dichotomous scales. Each variable group was analysed per province and per response, taking the weighting of the mathematics achievement (expressed as the plausible value – PV) of learners in that province into account.

In the statistical analysis of a number of the ICT-related variables from the Eighth Grade *Mathematics Teacher* Questionnaires, the SPSS output generated by the IEA IDB Analyzer indicated a #Null value for some of the South African provinces. On further examination of the raw datasets it was found that in these cases, either a very low number of responses was recorded for the variables, or there was no variability within the chosen variables and a standard deviation could not be calculated (e.g. all responses were either *Agree* or *Disagree*).

In a discussion regarding the #Null errors with Dr Eugenio J. Gonzalez, Director of the Research and Analysis Unit at the IEA Data Processing and Research Center, it was revealed that the IEA IDB Analyzer requires a minimum number of 2.5% of the sample population responses in order to report on achievement:

> *From what I can see, after selecting out those to whom the variable does not apply, you are left with very few cases, if any at all in some of the categories. If you then divide these few remaining cases across the different regions, your reporting sample size goes further down. In many cases I suspect you will have one teacher "representing" a region, if any at all. As such, there is not much use for these data to make comparison at the national level, and much less at the regional level. A general rule used by TIMSS is that you want at least > 2.5% of the sample in a cell to report the achievement for that cell. On a typical sample of 4 500 students, this works out to be roughly 100 cases. If you look at the main table produced by the IDB Analyzer you will see that in most cases you do not reach this 100 limit. To complicate matters, since you are working with teacher data, even if you had 100 students in a cell, the teacher data for these students could be form 3 – 4 teachers only… Very few to work with*. (E.J. Gonzalez, personal communication, 6 November 2017)

The implication for this study was that at least 2.5% of the total sample population responses had to be recorded for a province in order for statistical analysis to be performed. The South African sample size of TIMSS 2011 was 11 969 learners and that of TIMSS 2015 was 12 514 learners (Reddy et al., 2013; Reddy, Visser, et al., 2016). Therefore, for any statistical analysis a minimum of 299 responses per province for TIMSS 2011, and 312 responses per province for TIMSS 2015, was required.

The conclusion was that the majority of the #Null errors were generated because of the small number of educators who indicated that they used computers in their teaching and learning. Additionally, four sets of variables in this chapter were logically dependent on the availability of computers during mathematics lessons – if computers were not available during mathematics lessons, educators were not expected to report on how they used computers in their class. Figure 6.2 depicts the variables from the Eighth Grade *Mathematics Teacher* Questionnaires that were logically dependent on the availability of computers during mathematics lessons.

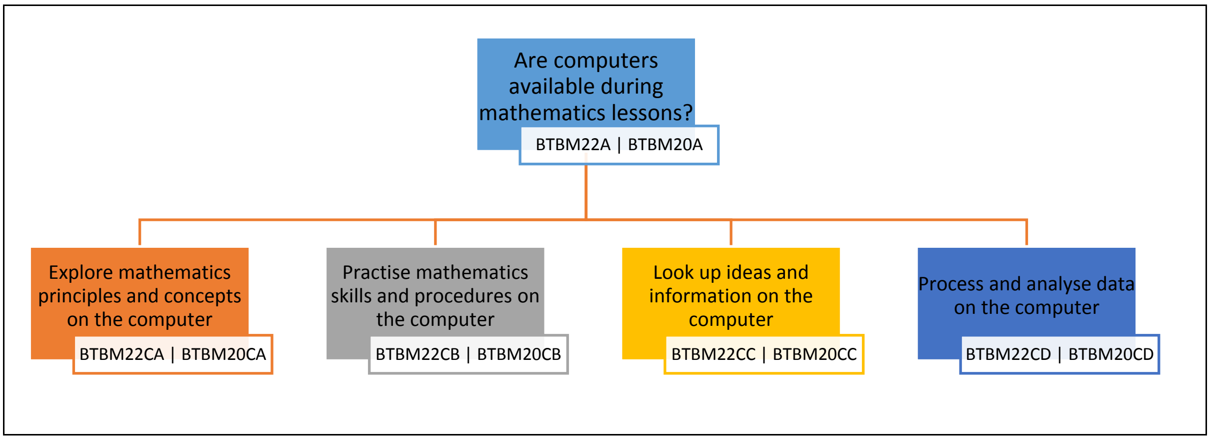

Figure 6.2: Variables logically dependent on the availability of computers

Six sets of variables returned #Null values for provinces for either 2011 or 2015. Variables that returned #Null values for provinces for either 2011 or 2015 are indicated as such and are not included in the discussion of the statistical analysis for that variable.

6.2. Support for integrating technology in teaching and learning (BTBG09BC and BTBG08G)

The integration of ICT in teaching and learning in South Africa is fairly new (Butcher, 2011; Chiles, 2012; Czerniewicz & Hodgkinson-Williams, 2005) and has been identified as a driver of eradicating inequality in South Africa (DOE, 2004). ICT in education is seen as an encouraging approach to assist disadvantaged learners and schools to improve access to quality education across the world (Bai et al., 2016; Mlitwa & Koranteng, 2013). When educators start integrating ICT into their teaching and learning their teaching approach tend to move from being educator-centred to a more learner-centred approach (Law, 2009). In a number of previous studies educators identified a lack of adequate support from their schools and peers when integrating ICT in their classrooms as one of the main reasons they are hesitant to use ICT in teaching and learning (Goktas et al., 2013; Stols et al., 2015; Vandeyar, 2013).

The importance of adequate support for educators when integrating ICT in teaching and learning necessitated the inclusion of a question on the availability of **support for integrating technology in teaching and learning** in both the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires. Educators were asked if they receive adequate support for integrating technology in their teaching activities. The details of variables BTBG09BC and BTBG08G are depicted in Table 6.2.

Table 6.2: Support for integrating technology in teaching and learning (BTBG09BC and BTBG08G)

Variable	Year	Question text	Original coding values	Recoded values
BTBG09BC	2011	How much do you agree that you receive adequate support for integrating computers in your teaching activities?	1 = Agree a lot 2 = Agree a little	101 = Agree - support
			3 = Disagree a little 4 = Disagree a lot	102 = Disagree - little support
			9 = Omitted or invalid	9 = Omitted or invalid
BTBG08G	2015	In your current school, how severe is each problem? • Teachers do not have adequate support for using technology	1 = Not at all 2 = A little	101 = Agree - support
			3 = Some 4 = A lot	102 = Disagree - little support
			9 = Omitted or invalid	9 = Omitted or invalid

6.2.1. Descriptive statistics – Support for integrating technology in teaching and learning (BTBG09BC and BTBG08G)

The availability of adequate support for educators when integrating technology in the classroom was addressed by variables BTBG09BC (TIMSS 2011) and BTBG08G (TIMSS 2015). The descriptive statistical analysis of BTBG09BC and BTBG08G is depicted in Figure 6.3.

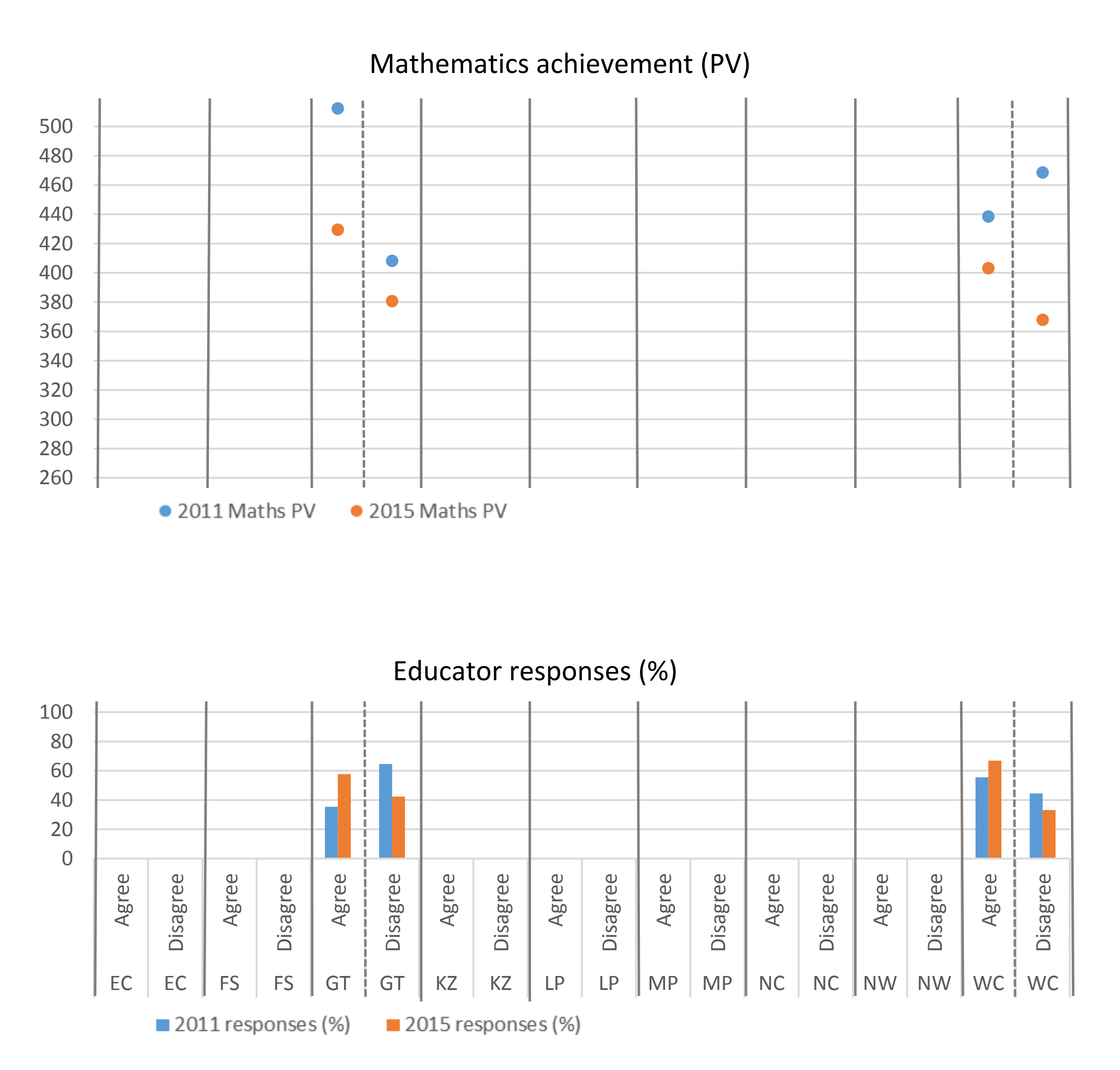

Figure 6.3: Support for integrating technology in teaching and learning (BTBG09BC and BTBG08G) – mathematics achievement and educator responses per province

A standard deviation was not calculable for seven of the nine provinces in 2011 and 2015 (see Table 6.3). The available data for Gauteng and the Western Cape allowed for the calculation of a standard deviation and the results are therefore captured in Figure 6.3 and included for discussion in Sections 6.2.1 and 6.2.2.

Mathematics achievement in relation to the availability of adequate support for educators when integrating ICT in the classroom

As part of the study, the relationship between the support that educators received for the integration of technology and the average mathematics achievement of their learners on the TIMSS achievement scale was examined. The learner achievement is expressed as a mathematics plausible value (PV) out of a possible 1 000 points on the TIMSS achievement scale. In general it seems as if learner achievement in mathematics is higher if their educators indicated that they received support in the integration of technology.

In 2011, the mathematics achievement of learners in Gauteng whose educators *agreed* that they received support in the integration of technology (PV = 512) was 104 points higher than learners whose educators *disagreed* that they received support (PV = 408). In 2015 the difference between the two Gauteng categories changed to 48 points (Agree PV = 429; Disagree PV = 381), which is still a huge difference on the TIMSS achievement scale. A possible explanation for the big difference in achievement may be related to the management style of the principal. This may indicate that principals who support the development of their educators are able to provide better leadership in the school and this may have led to improved teaching and learning in these schools (Creemers & Kyriakides, 2010; Witziers et al., 2003). Additionally, the perceived support that educators received with the integration of technology may have led to the improved use of technology in classrooms and this may have supported teaching and learning. However, it is not clear exactly which factors led to improved teaching and learning in these schools and further research will be required.

In 2011, the mathematics achievement of Western Cape learners whose educators *agreed* that they received support in the integration of technology (PV = 438) was 30 points lower than those whose educators *disagreed* that they received support (PV = 468). It is interesting to note that in 2011 learners from schools where educators *disagreed* that they received support for the integration of technology, achieved higher scores on the TIMSS achievement scale. It is not clear from the ICT-related variables in the 2011 Eighth Grade *Mathematics Teacher* Questionnaire what may have caused this anomaly. In 2015 the mathematics achievement in the Western Cape was higher if educators indicated that they received support in the integration of technology. The mathematics achievement of Western Cape learners whose educators *agreed* that they received support in the integration of technology (PV = 403) was 35 points higher than those whose educators *disagreed* that they received support (PV = 368), which is in line with the difference in achievement of Gauteng learners.

Support for the integration of technology in teaching and learning relies on the identification of this type of support as important by school management. It seems as if learners achieve higher mathematics achievement if they come from schools where the school management identified support for the integration of technology as important, and acted upon this information to arrange such support. This seems to support findings from the Eighth Grade *School* Questionnaires where a principal's ability to accurately identify strengths and weaknesses in their school seemed to have an impact on teaching and learning in the school.

Mathematics educator responses in relation to the availability of adequate support for educators when integrating ICT in the classroom

In 2011 only 35.41% of Gauteng educators *agreed* that they received adequate support for the integration of technology in their teaching and learning. At the same time 55.47% of Western Cape educators *agreed* that they received adequate support for the integration of technology. In both these provinces huge province-wide ICT in schools projects have been running for a few years and one would expect a larger portion of educators from these two provinces to indicate that they received adequate support for the integration of technology.

A possible reason for the relatively low percentage of educators that *agreed* that they received adequate support for the integration of technology in 2011, may be that educators from these provinces have been sensitised to the benefits of technology integration in teaching and learning and were therefore keen to receive assistance to implement technology in their classes. Additionally, this finding may also support findings in other studies (Lautenbach, 2011; Mlitwa & Koranteng, 2013; Smith & Hardman, 2014) that indicated a shortcoming in many ICT in schools projects whereby the main focus seemed to be on the deployment of hardware in schools, with educator empowerment in the use of the technology only a small part of the projects.

In 2015 an increased number of educators from Gauteng (57.64%) and the Western Cape (66.84%) indicated that they *agreed* that they received adequate support for the integration of technology. End-user assistance forms part of most ICT projects, and it seems as if many educators received the support they required from the projects. A further explanation for the increase in educators that *agreed* they received adequate support for the integration of technology, may be that the educators in schools may have reached a measure of "e-maturity" (Lautenbach, 2011, p. 44) over the five years between 2011 and 2015, and as such educators could support one another with the integration of technology in classrooms without having to wait for training sessions.

6.2.2. Inferential statistics – Support for integrating technology in teaching and learning (BTBG09BC and BTBG08G)

SPSS syntax generated by the IEA IDB Analyzer was used to explore the relationship between the support educators received for integrating technology in teaching and learning, and the mathematics achievement of learners in both categories (*agree* that they received support in integrating technology; *disagree* that they received support for interacting technology) in both 2011 and 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015 was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BTBG09BC and BTBG08G is depicted in Table 6.3.

Table 6.3: Support for integrating technology in teaching and learning (BTBG09BC and BTBG08G) – means, differences, t-tests and p-values

		TIMSS 2011 BTBG09BC		TIMSS 2015 BTBG08G		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Agree	#Null	#Null	384.7514	12.9498				
EC	Disagree	#Null	#Null	342.5551	15.0432				
EC	Difference			42.1963	16.1219				
FS	Agree	#Null	#Null	387.9925	17.5920				
FS	Disagree	#Null	#Null	337.3418	9.3323				
FS	Difference			50.6507	18.8003				
GT	**Agree**	**512.2314**	**10.6718**	**429.3723**	**16.9180**	**82.8591**	**20.0026**	**4.1424**	**0.0000**
GT	Disagree	408.1334	28.0194	380.5932	10.7337	27.5402	30.0050	0.9179	0.3587
GT	Difference	104.0980	29.3099	48.7791	21.0553	55.3189	36.0887	1.5329	0.1253
KZ	Agree	#Null	#Null	416.7962	20.2265				
KZ	Disagree	#Null	#Null	348.5219	13.8171				
KZ	Difference			68.2743	24.5966				
LP	Agree	#Null	#Null	384.2611	37.6245				
LP	Disagree	#Null	#Null	350.2994	9.7283				
LP	Difference			33.9617	39.9218				
MP	Agree	#Null	#Null	409.0759	40.2994				
MP	Disagree	#Null	#Null	359.0057	4.2875				
MP	Difference			50.0701	40.8439				
NC	Agree	#Null	#Null	377.2758	11.7838				
NC	Disagree	#Null	#Null	355.8009	7.9328				
NC	Difference			21.4749	14.1502				
NW	Agree	#Null	#Null	380.4235	23.2105				
NW	Disagree	#Null	#Null	345.1568	6.0499				
NW	Difference			35.2667	24.8168				
WC	Agree	438.4355	41.3532	403.0751	14.3051	35.3604	43.7576	0.8081	0.4190
WC	**Disagree**	**468.4567**	**40.5687**	**367.7975**	**10.7832**	**100.6593**	**41.9774**	**2.3979**	**0.0165**
WC	Difference	-30.0212	57.9192	35.2776	18.4631	-65.2989	60.7908	-1.0742	0.2828

Note: **Red** formatting indicates a statistically significant t-test and p-value

In TIMSS 2011 the responses from educators in three of the nine provinces (KZ, NC, NW) were all grouped as either *Agree* or *Disagree* so the calculation of a standard deviation was not possible. In four other provinces (EC, FS, LP, MP) the response rate was too low for the calculation of a standard deviation.

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). When looking at the statistical significance of the changes in mathematics achievement, both provinces with usable statistical data (GT; WC), returned statistically significant-tests and p-values. Both Gauteng and the Western Cape provinces will therefore be discussed in this section.

The mathematics achievement of **Gauteng** learners from schools where educators *agreed* that they received adequate support for the integration of technology in teaching and learning, decreased from an average of 512 points in 2011 to an average of 429 points in 2015. Since the p-value was less than 0.05, the difference of 83 points was statistically significant ($t = 4.14$; $p = 0.0000$). During the same time the percentage of learners whose educators agreed that they received adequate support for the integration of technology, increased by 22.23% from 35.41% to 57.64%. The means (2011 = 512; 2015 = 429) indicate a negative difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant decrease in achievement. A decrease in achievement of 28 points for learners in schools where their educators *disagreed* that they received adequate support for the integration of technology in teaching and learning was not statistically significant. It is interesting to note that the decrease in achievement was higher in schools where educators *agreed* that they received adequate support for the integration of technology in teaching and learning.

The mathematics achievement of **Western Cape** learners from schools where educators *disagreed* that they received adequate support for the integration of technology in teaching and learning, decreased from an average of 468 points in 2011 to an average of 368 points in 2015. Since the p-value was less than 0.05, the difference of 101 points in mathematics achievement in the Western Cape in schools where educators *disagreed* that they received adequate support for integrating technology in teaching and learning, was statistically significant ($t = 2.40$; $p = 0.0165$). During the same time the percentage of learners whose educators agreed that they received adequate support for the integration of technology, decreased by 11.37% from 44.53% to 33.16%. The means (2011 = 468; 2015 = 368) indicate a negative difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant decrease in achievement. A decrease in achievement of 35 points for learners in schools where their educators *agreed* that they received adequate support for the integration of technology in teaching and learning, was not statistically significant. Unlike Gauteng, the decrease in achievement was higher in schools where educators *disagreed* that they received adequate support for the integration of technology in teaching and learning.

It seems as if there is an effort in all nine provinces to increase the support available to educators for the integration of technology in teaching and learning. In 2011 educator response in only two provinces (GT; WC) were adequate for the calculation of a standard deviation. In 2015 this situation changed completely and educator responses from all nine provinces allowed for the calculation of a standard deviation. This may be an indication that support for the integration of technology in teaching and learning increased beyond Gauteng and the Western Cape in the period of 2011 to 2015 and this change may be worth investigating further.

The average mathematics achievement of both Gauteng and Western Cape learners in relation to the availability of support for integrating technology in teaching and learning, decreased from 2011 to 2015. Taking into account that the average mathematics achievement of South African learners between 2011 and 2015 increased by 20 points, it was surprising that both Gauteng and the Western Cape recorded statistically significant decreases in achievement. It is not clear from the ICT-related variables in the 2011 Eighth Grade *Mathematics Teacher* Questionnaire what may have caused this decrease in achievement, but this could be a topic for further research. Out of 27 statistical calculations in Table 6.3, only two calculations were statistically significant. This may therefore indicate that the availability of support for integrating technology in teaching and learning had a small influence on the 20 point increase between 2011 and 2015.

6.3. Availability of computers during mathematics lessons (BTBM22A and BTBM20A)

A lack of ICT for teaching and learning is not an issue confined to South Africa. Many other developing countries also experience a lack of ICT for teaching and learning (Hansen et al., 2012; Law et al., 2008). South African educators indicated a lack of access to ICT in their classrooms as some of their main challenges in integrating ICT in their teaching and learning (Mdlongwa, 2012; Mofokeng & Mji, 2010). Before ICT can make a difference in the teaching and learning of any subject, mathematics included, it needs to be available for regular use by the educator and learners (Goktas et al., 2013; Hassan & Geys, 2016).

The IEA included a question related to the availability of computers for mathematics teaching and learning in both the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires. Mathematics educators were asked whether **computers for teaching and learning were available during mathematics lessons**. The questions asked in the Eighth Grade *Mathematics Teacher* Questionnaire on the availability of ICT during mathematics lessons (variables BTBM22A and BTBM20A) are similar to questions asked in the Eighth Grade *School* Questionnaire (variables BCBG09BB and BCBG13AH), with one main, and very important difference – the person/s expected to answer the question. In the Eighth Grade *School* Questionnaire school principals were asked if they felt that their schools had adequate computers for mathematics teaching and learning. In the Eighth Grade *Mathematics Teacher* Questionnaire a similar question was asked to educators who, due to the nature of their jobs, are on the implementation side of using ICT in teaching and learning in schools.

An interesting change in the wording of question BTBM20A in TIMSS 2015 was the addition of the words "including tablets" in the question text to broaden the application area of the specific question beyond personal computers, to also include tablets (Foy, 2017b, p. 56). The details of variables BTBM22A and BTBM20A are depicted in Table 6.4.

Table 6.4: Availability of computers during mathematics lessons (BTBM22A and BTBM20A)

Variable	Year	Question text	Original coding values	Recoded values
BTBM22A	2011	Do the students in this class have computer(s) available to use during their mathematics lessons?	1 = Yes	101 = Yes - available
			2 = No	102 = No – not available
			9 = Omitted or invalid	9 = Omitted or invalid
BTBM20A	2015	Do the students in this class have computers (including tablets) available to use during their mathematics lessons?	1 = Yes	101 = Yes - available
			2 = No	102 = No – not available
			9 = Omitted or invalid	9 = Omitted or invalid

6.3.1. Descriptive statistics – Availability of computers during mathematics lessons (BTBM22A and BTBM20A)

Variables BTBM22A (TIMSS 2011) and BTBM20A (TIMSS 2015) dealt with the question of the availability of computers to learners during their mathematics lessons. The descriptive statistical analysis of BTBM22A and BTBM20A is depicted in Figure 6.4.

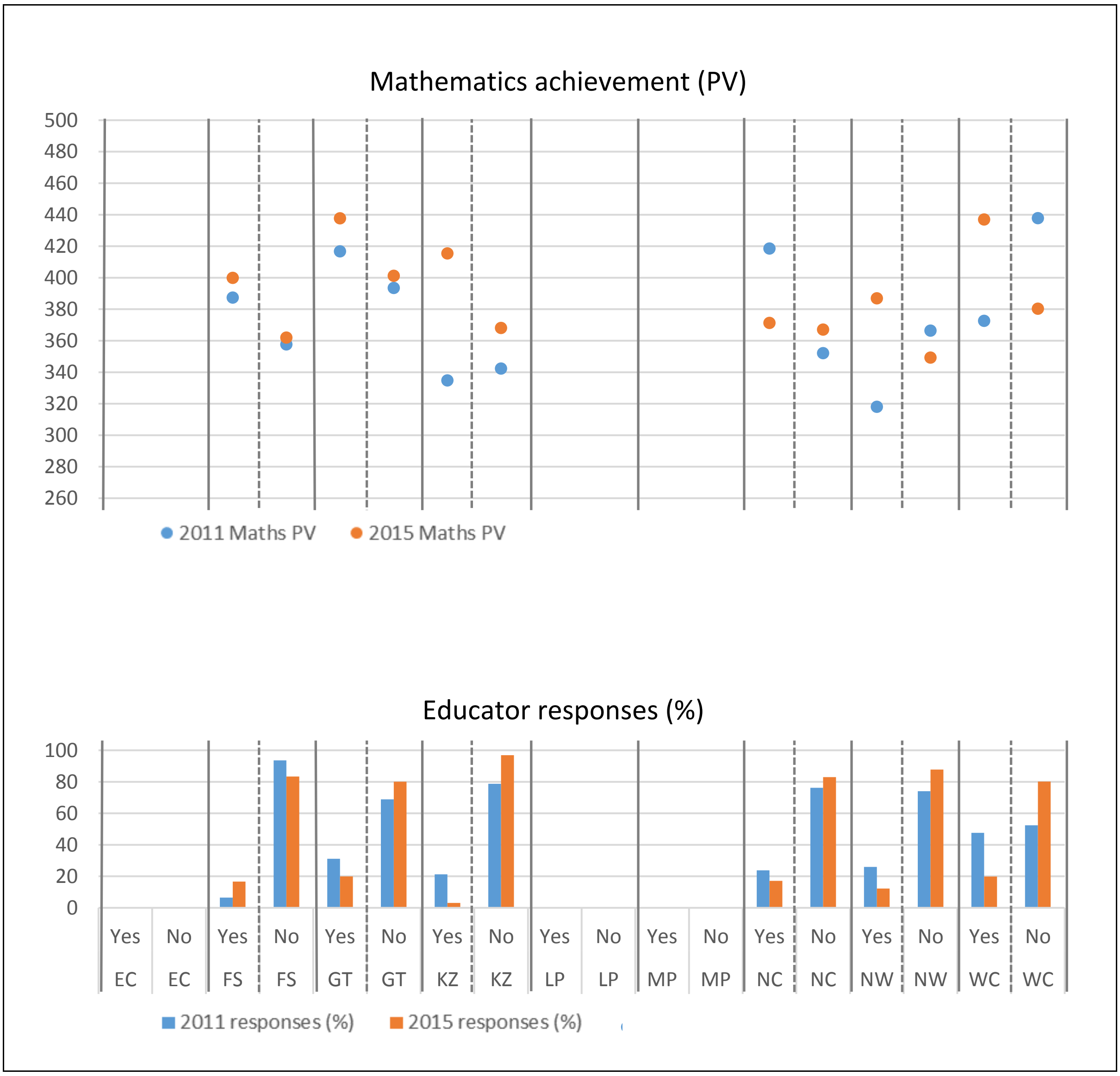

Figure 6.4: Availability of computers during mathematics lessons (BTBM22A and BTBM20A) – mathematics achievement and educator responses per province

A standard deviation was not calculable with the available data from 2015 for the Eastern Cape, Limpopo and Mpumalanga (see Table 6.5). The available data for the other six provinces allowed for the calculation of a standard deviation and the results are therefore captured in Figure 6.4 and discussed in Sections 6.3.1 and 6.3.2.

Mathematics achievement in relation to the availability of computers during mathematics lessons

As part of the study, the relationship between the availability of computers during mathematics lessons and the average mathematics achievement of learners on the TIMSS achievement scale was examined. In general it seems as if mathematics achievement is higher in schools where educators indicated that computers were available during mathematics lessons.

In 2011 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, came from schools in the Northern Cape (PV = 419) where educators indicated computers were *available* during mathematics lessons, and from Western Cape schools (PV = 438) where educators indicated that computers were *not available* during mathematics. It is not clear from the ICT-related variables in the 2011 Eighth Grade *Mathematics Teacher* Questionnaire what may have caused this anomaly in the Western Cape and may be the topic for further research. In 2015 the two groups of learners that achieved the two highest average scores came from schools in Gauteng (PV = 438) and the Western Cape (PV = 437) where educators indicated that computers were *available* during mathematics lessons.

In 2011 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in KwaZulu-Natal (PV = 335) and the North West (PV = 318) where educators indicated that computers were *available* during mathematics lessons. In 2015 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale came from schools in the Free State (PV = 362) and the North West (PV = 349) where educators indicated that computers were *not available* during mathematics lessons. It is interesting to note that in 2015 learners from schools where educators indicated that computers were *available* during mathematics lessons scored an average of 57 points higher on the TIMSS achievement scale than learners from schools where educators indicated that computers were *not available* during mathematics lessons.

An interesting observation is that in TIMSS 2011 learners from three provinces (KZ, NW, WC) achieved better scores if computers were *not available* during mathematics lessons. Very little support for the integration of technology was available to educators in these provinces in 2011 (see Figure 6.3). A possible explanation for these responses may therefore be that *if* educators used computers in 2011, very few had the skills to use computers to optimally support mathematics teaching and learning. It therefore seems as if many learners benefited more from traditional mathematics teaching methods than from using computers. This situation changed completely in TIMSS 2015 where all learners achieved better scores if they had computers available during their mathematics lessons. This seems to support the notion that by 2015 educators could support one another with the integration of technology in mathematics classrooms and that the availability of computers could actually have a positive influence on achievement. However, one should not forget that the availability of computers is usually a good indicator of the general socioeconomic position of a school and that this alone may be an explanation for the higher mathematics achievement in schools where computers are available.

The way in which this question is crafted does not give an indication whether the available computers are used for mathematics teaching and learning. The details of the actual use of computers in the mathematics classrooms in South Africa is addressed in Section 6.4, Section 6.5, Section 6.6 and Section 6.7 of this chapter.

Mathematics educator responses in relation to the availability of computers during mathematics lessons

In 2011 the majority of educators in all six provinces for which statistical data was available (FS = 93.55%; GT = 68.84%; KZ = 78.71%; NC = 76.20%; NW = 74.01%; WC = 52.42%), indicated that computers were *not available* during mathematics lessons. In 2015 the majority of educators in all six provinces for which statistical data was available (FS = 83.32%; GT = 80.06%; KZ = 96.86%; NC = 82.92%; NW = 87.73%; WC = 80.15%), again indicated that computers were *not available* during mathematics lessons. It is worrying that by 2015 reporting on the availability of computers for mathematics teaching and learning decreased to such an extent that computers were *not available* during mathematics lessons for more than 80% of learners and educators sampled for TIMSS in each of the provinces. A possible explanation may be that awareness of the affordances of computers in education increased in these provinces, leading to an increase in demand for computers during mathematics lessons. Unfortunately it is not clear from the ICT-related variables in the 2015 Eighth Grade *Mathematics Teacher* Questionnaire what may have caused this decrease in the availability of computers and this should be further investigated, especially in Gauteng and the Western Cape where large, province-wide ICT in schools projects have been running for several years.

In TIMSS 2011 the two provinces where the highest percentage of educators indicated that computers were *available* during mathematics lessons, were from Gauteng (31.16%) and the Western Cape (47.58%). In TIMSS 2015 educators from Gauteng (19.94%) and the Western Cape (19.85%) again reported the highest percentage of having computers *available* during mathematics lessons. On the other end of the spectrum, in 2011 the two provinces where the highest percentage of educators indicated that computers were *not available* during mathematics lessons, were the Free State (93.55%) and KwaZulu-Natal (78.71%). In 2015, educators from KwaZulu-Natal (96.86%) and North West (87.73%) reported the highest percentage of computers that were *not available* during mathematics lessons.

The availability of computers during mathematics lessons from 2011 to 2015 as reported by educators, decreased in all provinces except for the Free State. Surprisingly, the largest decrease in availability of computers during mathematics lessons was reported by educators in the Western Cape where the availability shrunk by 27.73% from 47.58% in 2011 to 19.85% in 2015. The reason for the decrease in availability of computers during mathematics lessons could be twofold: on the one hand educators could be more sensitised to the positive impact of technology on teaching and learning and therefore the demand for the existing infrastructure had increased over this period of time, leading to the unavailability during mathematics lessons. On the other hand PEDs and schools may have invested less in technology as the South African economy gradually worsened since 2008 (National Treasury, 2017a), choosing to rather focus limited financial resources on basic educational needs.

6.3.2. Inferential statistics – Availability of computers during mathematics lessons (BTBM22A and BTBM20A)

The IEA IDB Analyzer was used to explore the relationship between the availability of computers during mathematics lessons, and the mathematics achievement of learners in both categories (computers *available* for mathematics lessons; computers *not available* for mathematics lessons) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between TIMSS 2011 and TIMSS 2015 by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BTBM22A and BTBM20A is depicted in Table 6.5.

Table 6.5: Availability of computers during mathematics lessons (BTBM22A and BTBM20A) – means, differences, t-tests and p-values

		TIMSS 2011 BTBM22A		**TIMSS 2015 BTBM20A**		**Inferential statistics results**			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Yes	327.7907	10.6207	#Null	#Null				
EC	No	318.2408	11.2985	#Null	#Null				
EC	Difference	9.5499	14.4358						
FS	Yes	387.3687	120.2708	399.8792	54.6554	-12.5105	132.1071	-0.0947	0.9246
FS	No	357.6615	8.3805	361.9452	11.5533	-4.2837	14.2728	-0.3001	0.7641
FS	Difference	29.7072	120.4991	37.9340	53.8054	-8.2268	131.9661	-0.0623	0.9503
GT	Yes	416.7215	14.3669	437.6672	22.7417	-20.9457	26.8997	-0.7787	0.4362
GT	No	393.5105	9.2386	401.1905	12.9464	-7.6800	15.9048	-0.4829	0.6292
GT	Difference	23.2110	18.6525	36.4767	26.2331	-13.2657	32.1884	-0.4121	0.6802
KZ	Yes	334.8162	15.4195	415.4143	135.1375	-80.5981	136.0143	-0.5926	0.5535
KZ	No	342.2753	7.2205	368.0755	12.3667	-25.8001	14.3203	-1.8016	0.0716
KZ	Difference	-7.4591	18.3765	47.3388	138.9273	-54.7979	140.1374	-0.3910	0.6958
LP	Yes	315.7602	30.4191	#Null	#Null				
LP	No	323.7188	7.4591	#Null	#Null				
LP	Difference	-7.9586	32.8095						
MP	Yes	331.0528	7.1497	#Null	#Null				
MP	No	344.0197	4.5840	#Null	#Null				
MP	Difference	-12.9669	7.0267						
NC	Yes	418.5068	67.4690	371.3119	15.4583	47.1949	69.2172	0.6818	0.4953
NC	No	352.1097	8.6375	367.0595	8.7541	-14.9498	12.2980	-1.2156	0.2241

		TIMSS 2011 BTBM22A		TIMSS 2015 BTBM20A		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
NC	Difference	66.3972	68.2009	4.2524	16.6156	62.1448	70.1957	0.8853	0.3760
NW	**Yes**	**318.0710**	**17.4158**	**386.8958**	**30.3172**	**-68.8248**	**34.9634**	**-1.9685**	**0.0490**
NW	No	366.4137	11.2548	349.2965	7.1627	17.1172	13.3407	1.2831	0.1995
NW	**Difference**	**-48.3427**	**22.8710**	**37.5993**	**31.1921**	**-85.9420**	**38.6785**	**-2.2220**	**0.0263**
WC	**Yes**	**372.6472**	**8.1583**	**436.9637**	**27.9004**	**-64.3165**	**29.0687**	**-2.2126**	**0.0269**
WC	**No**	**437.7957**	**17.0739**	**380.2956**	**9.2335**	**57.5001**	**19.4107**	**2.9623**	**0.0031**
WC	**Difference**	**-65.1485**	**19.8518**	**56.6681**	**27.2267**	**-121.8166**	**33.6955**	**-3.6152**	**0.0003**

Note: **Red** formatting indicates a statistically significant t-test and p-value

In TIMSS 2015 the response rate from educators in three provinces (EC, LP, MP) was too low for the calculation of a standard deviation and therefore no statistical analysis was impossible. Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). However, when looking at the statistical significance of the changes in mathematics achievement in relation to the availability of computers during mathematics lessons, only two provinces (NW, WC) returned statistically significant t-tests and p-values. Only these two provinces will therefore be discussed in this section.

The achievement of **North West** learners from schools where educators reported that computers were *available* during mathematics lessons, increased from an average of 318 points in 2011 to 387 points in 2015. Since the p-value was less than 0.05, the difference of 69 points was statistically significant (t = -1.97; p = 0.0490). During the same time the percentage of learners that had a computer *available* during mathematics lessons, decreased by 13.72% from 25.99% (2011) to 12.27% (2015). The means (2011 = 318; 2015 = 387) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 17 points for learners in schools where their educators indicated that computers were *not available* during mathematics lessons, was not statistically significant. In 2011, North West learners from schools where educators reported that computers were *available* during mathematics lessons, scored an average of 48 points lower than learners from schools where computers were *not available* during mathematics lessons.

In 2015, learners from schools where educators reported that computers were *available* during mathematics lessons, scored an average of 38 points higher than learners from schools where computers were *not available* during mathematics lessons. This difference of 86 points was statistically significant (t = -2.22; p = 0.0263). In North West the increase in mathematics achievement between 2011 and 2015 was higher in schools where computers were *available* during mathematics lessons.

The achievement of **Western Cape** learners from schools where educators reported that computers were *available* for mathematics lessons, increased from an average of 373 points in 2011 to 437 points in 2015. Since the p-value was less than 0.05, the difference of 64 points was statistically significant (t = -2.21; p = 0.0269). During the same time the percentage of learners that had a computer *available* during mathematics lessons, decreased by 27.73% from 47.58% (2011) to 19.85% (2015). The means (2011 = 373; 2015 = 437) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The achievement of Western Cape learners from schools where educators reported that computers were *not available* for mathematics lessons, decreased from an average of 438 points in 2011 to 380 points in 2015. Since the p-value was less than 0.05, the difference of 58 points was also statistically significant (t = 2.96; p = 0.0031). During the same time the percentage of learners whose educators reported that computers were *not available* during mathematics lessons, increased by 27.73% from 52.42% (2011) to 80.15% (2015). The means (2011 = 438; 2015 = 380) indicate a negative difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant decrease in achievement. In 2011, Western Cape learners from schools where educators reported that computers were *available* for mathematics lessons, scored an average of 65 points lower than learners from schools where computers were *not available* during mathematics lessons. In 2015, learners from schools where educators reported that computers were *available* for mathematics lessons, scored an average of 57 points higher than learners from schools where computers were *not available* during mathematics lessons. This difference of 122 points was statistically significant (t = -3.62; p = 0.0003). In the Western

Cape the increase in mathematics achievement between the years was higher in schools where computers were *available* during mathematics lessons.

The average mathematics achievement of South African learners in relation to the availability of computers during mathematics lessons, increased by 36 points from 359 points (2011) to 395 points (2015). Again, taking into account the relatively large jump in the average mathematics achievement of South African learners between 2011 and 2015, it was surprising how few of the increases in achievement were actually statistically significant. Out of 27 statistical calculations in Table 6.5, only five were statistically significant. This may indicate that the availability of computers during mathematics lessons statistically had a relatively small influence on the overall 20 point increase between 2011 and 2015.

It is interesting to note that in TIMSS 2011, learners from both provinces achieved better results on the TIMSS achievement scale if their educators reported that computers were *not available* for mathematics lessons. In 2015 the situation changed completely whereby learners achieved better results if computers were *available* during mathematics lessons. A possible reason for this change may be that computer integration in these schools reached an amount of maturity, whereby educators started using computers selectively in their teaching, instead of relying on the computer to teach all aspects of mathematics. Another possibility may be that educators have been sensitised about the benefits of using computers to support teaching and learning and were then willing to start using computers in their teaching to support their traditional teaching methods.

However, it is important to note that just because computers were available, it did not necessarily translate into computer use during mathematics lessons as we will see from the statistical analysis further on in this chapter. It seems that the variables on computer availability may be a better indicator of school milieu rather than the actual use of computers in the schools.

6.4. Exploration of mathematics principles and concepts on computers (BTBM22CA and BTBM20CA)

The use of ICT in teaching and learning leads to the development of learner autonomy, higher order thinking skills, metacognitive skills and self-regulation (Condie & Munro, 2007; Hansen et al., 2012), all important attributes of successful mathematics learners (Gauvain & Munroe, 2009; Stols, 2012). The development of these skills lead to improved learning and achievement. Many educators believe that integrating ICT in teaching and learning will assist in making teaching and learning more effective and efficient (Wurst et al., 2008).

In order to ascertain to which extent mathematics educators use ICT in the teaching of basic mathematics principles and concepts, the IEA included a question related to the **exploration of mathematics principles and concepts on computers** in both the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires. Mathematics educators were asked how often they let the learners explore mathematics principles and concepts on a computer. It is important to keep in mind that this question refers to computers available in the school, and not necessarily to computers in the mathematics classrooms. It is also important to note that these variables were logically related to variables BTBM22A (2011) and BTBM20A (2015) and were dependent on the educators' responses – educators were instructed to only complete this question if their learners had access to computers in the school. The details of variables BTBM22CA and BTBM20CA are depicted in Table 6.6.

Table 6.6: Exploration of mathematics principles and concepts on computers (BTBM22CA and BTBM20CA)

Variable	Year	Question text	Original coding values	Recoded values
BTBM22CA	2011	How often do you have the students explore mathematics principles and concepts on the computer?	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid

Variable	Year	Question text	Original coding values	Recoded values
BTBM20CA	2015	How often do you have the students do the following activities on computers during mathematics lessons? • Explore mathematics principles and concepts	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid

6.4.1. Descriptive statistics - Exploration of mathematics principles and concepts on computers (BTBM22CA and BTBM20CA)

Variable BTBM22CA (TIMSS 2011) and variable BTBM20CA (TIMSS 2015) dealt with how often educators let the learners explore mathematics principles and concepts on a computer. The statistical analysis of BTBM22CA and BTBM20CA is depicted in Figure 6.5.

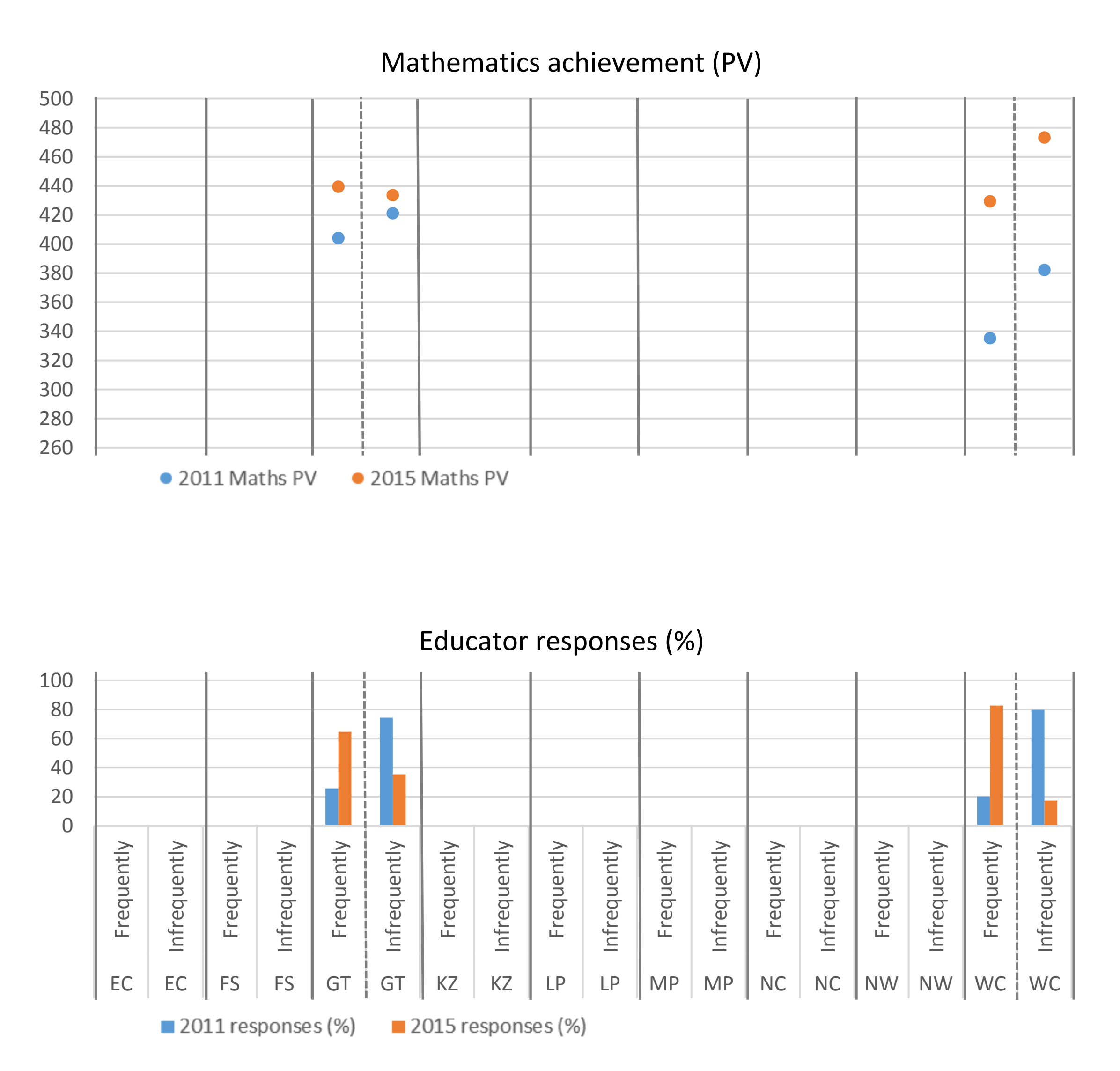

Figure 6.5: Exploration of mathematics principles and concepts on computers (BTBM22CA and BTBM20CA) – mathematics achievement and educator responses per province

A standard deviation was not calculable for seven of the nine provinces in 2011 and six of the nine provinces in 2015 (see Table 6.7). The available data for Gauteng and the Western Cape allowed for the calculation of a standard deviation and the results are therefore captured in Figure 6.5 and discussed in Sections 6.4.1 and 6.4.2.

Mathematics achievement in relation to the exploration of mathematics principles and concepts on computers

An interesting observation is that in both 2011 and 2015, the learners that achieved the highest scores on the TIMSS achievement scale came from schools where the majority of educators indicated that they *infrequently* allowed learners to explore mathematics principles and concepts on the computer. In 2011, learners from both provinces achieved higher scores if their educators indicated that they *infrequently* explored mathematics principles and concepts on the computer (GT *Frequently* PV = 404; GT *Infrequently* PV = 421. WC *Frequently* PV = 335; WC *Infrequently* PV = 382). In TIMSS 2015, learners from the Western Cape achieved higher scores if their educators indicated that they *infrequently* explored mathematics principles and concepts on the computer (WC *Frequently* PV = 429; WC *Infrequently* PV = 473). Gauteng learners achieved similar scores, whether they *frequently* or *infrequently* explored mathematics principles and concepts on the computer (GT *Frequently* PV = 439; GT *Infrequently* PV = 433).

A possible explanation for the increased achievement if computers were *infrequently* used to explore mathematics principles and concepts may be that the baseline mathematical comprehension of the average learner was so low, that they benefitted more from a structured, traditional face-to-face interaction with an educator who could explain concepts in a language and on a level that they understood. This idea seems to be supported by the low mathematics results from the National Senior Certificate examinations of the past few years (DBE, 2016a, 2017b). Previous studies found very low levels of mathematics content knowledge among South African mathematics educators (De Kock, 2015; Plotz, Froneman & Nieuwoudt, 2012; Stols, 2013). The results from this variable seem to suggest that educators who relied on the computer to teach mathematics principles and concepts were not comfortable with the teaching of mathematics themselves and the learners' achievement seemed to corroborate this.

Another possible explanation why learners achieved better scores if their educators *infrequently* allowed them to explore mathematics principles and concepts on the computer, may be the choice of educational software available. In order for technology integration to be successful, the software needs to be aligned with the needs and developmental stage and language of the learner (Bai et al., 2016; Butcher, 2011; Higgins et al., 2012; Kolikant, 2012). If the software was not suitable, optimal learning could not take place. Research has also shown that many educators believe that the most effective way to use educational mathematics software is for drill-and-practise exercises (Blackwell et al., 2016; Stols & Kriek, 2011, p. 148). It is therefore possible that mathematics educators preferred traditional teaching practices to teach mathematics principles and concepts. Again it is not clear from the ICT-related variables in the Eighth Grade *Mathematics Teacher* Questionnaires why computers were not used to teach mathematics principles and concepts, and this could be a topic for further research

Mathematics educator responses in relation to the exploration of mathematics principles and concepts on computers

In both Gauteng and the Western Cape there was a dramatic increase from 2011 to 2015 in educators that indicated that their learners *frequently* explored mathematics principles and concepts on the computer. The responses of Gauteng educators that indicated that their learners *frequently* explored mathematics principles and concepts on the computer, increased by 38.92% from 25.70% to 64.62%. During the same time the responses of Western Cape educators that indicated that their learners *frequently* explored mathematics principles and concepts on the computer, increased by 62.47% from 20.22% to 82.69%. This finding seems to be closely related to the support that educators receive for the integration of technology in teaching and learning (BTBG09BC and BTBG08G). This finding seems to support the idea that technology integration in schools in Gauteng and the Western Cape reached a measure of maturity over the five years between 2011 and 2015 and that educators started supporting each other to take the plunge and start using technology in their classrooms.

6.4.2. Inferential statistics - Exploration of mathematics principles and concepts on computers (BTBM22CA and BTBM20CA)

The IEA IDB Analyzer was used to explore the relationship between the learners' exploration of mathematics principles and concepts on a computer, and the mathematics achievement of these learners in both categories (*frequently* explore mathematics principles and concepts on a computer; *infrequently* explore mathematics principles and concepts on a computer) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015 was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BTBM22CA and BTBM20CA is depicted in Table 6.7.

Table 6.7: Exploration of mathematics principles and concepts on computers (BTBM22CA and BTBM20CA) – means, differences, t-tests and p-values

		TIMSS 2011 BTBM22CA		TIMSS 2015 BTBM20CA		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Frequently	#Null	#Null	#Null	#Null				
EC	Infrequently	#Null	#Null	#Null	#Null				
EC	Difference								
FS	Frequently	#Null	#Null	328.1016	3.8227				
FS	Infrequently	#Null	#Null	456.3869	78.4865				
FS	Difference			-128.2853	78.6179				
GT	Frequently	404.0549	42.8434	439.4782	30.5185	-35.4233	52.6016	-0.6734	0.5007
GT	Infrequently	421.1027	22.2355	433.6017	87.4798	-12.4990	90.2614	-0.1385	0.8899
GT	Difference	-17.0477	55.7396	5.8765	102.6800	-22.9242	116.8336	-0.1962	0.8444
KZ	Frequently	#Null	#Null	#Null	#Null				
KZ	Infrequently	#Null	#Null	#Null	#Null				
KZ	Difference								
LP	Frequently	#Null	#Null	#Null	#Null				
LP	Infrequently	#Null	#Null	#Null	#Null				
LP	Difference								
MP	Frequently	#Null	#Null	#Null	#Null				
MP	Infrequently	#Null	#Null	#Null	#Null				
MP	Difference								
NC	Frequently	#Null	#Null	#Null	#Null				
NC	Infrequently	#Null	#Null	#Null	#Null				
NC	Difference								
NW	Frequently	#Null	#Null	#Null	#Null				
NW	Infrequently	#Null	#Null	#Null	#Null				
NW	Difference								

		TIMSS 2011 BTBM22CA		TIMSS 2015 BTBM20CA		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
WC	**Frequently**	**335.2032**	**5.5462**	**429.3572**	**33.4199**	**-94.1540**	**33.8770**	**-2.7793**	**0.0054**
WC	**Infrequently**	**382.1374**	**11.6193**	**473.3016**	**33.3763**	**-91.1642**	**35.3410**	**-2.5796**	**0.0099**
WC	Difference	-46.9342	13.4748	-43.9444	47.1950	-2.9898	49.0810	-0.0609	0.9514

Note: **Red** formatting indicates a statistically significant t-test and p-value

In TIMSS 2011 the number of responses from educators in seven provinces (EC, FS, KZ, LP, MP, NC, NW) was too low for the calculation of a standard deviation and therefore no statistical analysis was possible. In TIMSS 2015 the number of responses from educators in six provinces (EC, KZ, LP, MP, NC, NW) was too low for the calculation of a standard deviation and therefore no statistical analysis was possible.

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). However, when looking at the statistical significance of the changes in mathematics achievement in relation to the exploration of mathematics principles and concepts on computers, only one province (WC) returned statistically significant t-tests and p-values. Accordingly only the Western Cape will be discussed in this section.

The achievement of **Western Cape** learners from schools where educators reported that they *frequently* allowed learners to explore mathematics principles and concepts on the computer, increased from an average of 335 points in 2011 to 429 points in 2015. Since the p-value was less than 0.05, the difference of 94 points was statistically significant ($t = -2.78$; $p = 0.0054$). During the same time the percentage of learners that *frequently* explored mathematics principles and concepts on the computer, increased by 62.47% from 20.22% (2011) to 82.69% (2015). The means (2011 = 335; 2015 = 429) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The achievement of Western Cape learners from schools where educators reported that they *infrequently* allowed learners to explore mathematics principles and concepts on the computer, increased from an average of

382 points in 2011 to 473 points in 2015. Since the p-value was less than 0.05, the difference of 91 points was also statistically significant ($t = 2.58$; $p = 0.0099$). During the same time the percentage of learners that *infrequently* explored mathematics principles and concepts on the computer, decreased by 62.47% from 79.78% (2011) to 17.31% (2015). The means (2011 = 382; 2015 = 473) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The increase in achievement was higher in Western Cape schools where learners *infrequently* explored mathematics principles and concepts on the computer.

The average mathematics achievement of South African learners in relation to the exploration of mathematics principles and concepts on the computer, increased by 42 points from 371 points (2011) to 413 points (2015). Again, taking into account the relatively large jump in the average mathematics achievement of South African learners between 2011 and 2015, it was surprising how few of the increases in achievement were actually statistically significant. Out of 27 statistical calculations in Table 6.7, only two were statistically significant. This may indicate that the exploration of mathematics principles and concepts on the computer, statistically had a very small influence on the overall 20 point increase between 2011 and 2015.

6.5. Practise mathematics skills and procedures on the computer (BTBM22CB and BTBM20CB)

Integrating ICT in teaching and learning changes the teaching approach to that of a learner-centred classroom (Law, 2009) and provides learners with new tools to explore and understand subject matter (Gauvain & Munroe, 2009; Wurst et al., 2008). There is a wide belief that the availability of ICT in schools may assist with the teaching and learning of basic skills (Bonaveri et al., 2015). Additionally integrating ICT in the curriculum also assist learners with barriers to learning to become more confident in expressing their own ideas and thoughts (Ferrer et al., 2011).

In order to ascertain to which extent mathematics educators use ICT to assist learners to practise basic mathematics skills and procedures, the IEA included a question related to the practise of mathematics skills and procedures on computers in both the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires. Mathematics educators were asked how often they let the learners **practise mathematics skills and procedures on a computer**. It is important to note that this question refers to computers available in the school, and not necessarily to computers in the mathematics classrooms. These variables were logically related to variables BTBM22A (2011) and BTBM20A (2015) and were dependent on the educators' responses – educators were instructed to only complete this question if their learners had access to computers in the school. The details of variables BTBM22CB and BTBM20CB are depicted in Table 6.8.

Table 6.8: Practise mathematics skills and procedures on the computer (BTBM22CB and BTBM20CB)

Variable	Year	Question text	Original coding values	Recoded values
BTBM22CB	2011	How often do you have the students practice skills and procedures on the computer?	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid
BTBM20CB	2015	How often do you have the students do the following activities on computers during mathematics lessons? • Practice skills and procedures	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid

6.5.1. Descriptive statistics - Practise mathematics skills and procedures on the computer (BTBM22CB and BTBM20CB)

In TIMSS 2011 variable BTBM22CB dealt with how often educators let the learners practise mathematics skills and procedures on a computer, while variable BTBM20CB addressed the same issue in TIMSS 2015. The descriptive statistical analysis of BTBM22CB and BTBM20CB is depicted in Figure 6.6.

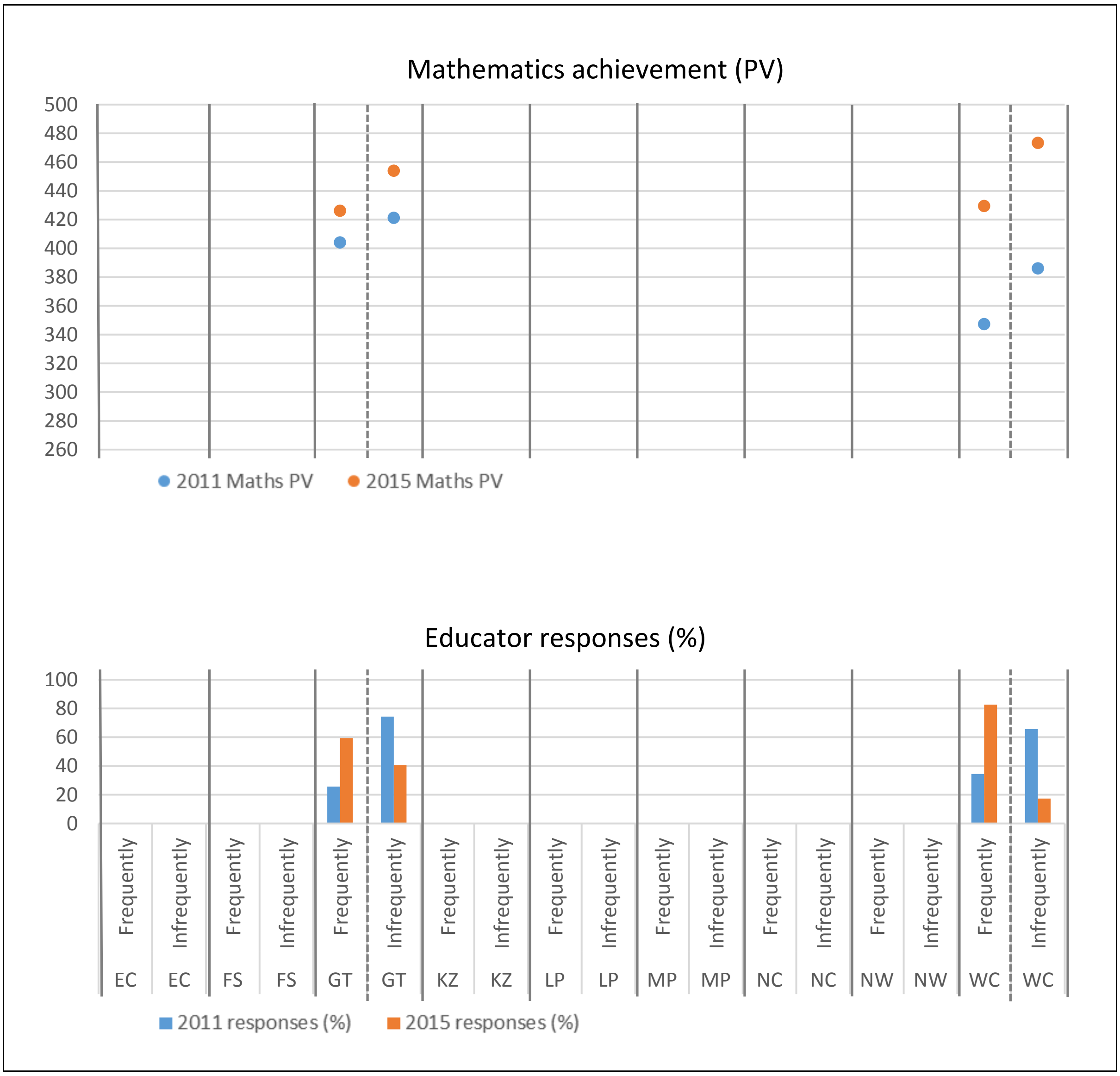

Figure 6.6: Practise mathematics skills and procedures on the computer (BTBM22CB and BTBM20CB) – mathematics achievement and educator responses per province

A standard deviation was not calculable with the available data for seven of the nine provinces in 2011 and 2015 (see Table 6.9). The available data for Gauteng and the Western Cape allowed for the calculation of a standard deviation and the results are therefore captured in Figure 6.6 and discussed in Sections 6.5.1 and 6.5.2.

Mathematics achievement in relation to practising mathematics skills and procedures on the computer

In 2011 learners in both Gauteng and the Western Cape achieved higher scores on the TIMSS achievement scale if they came from schools where the majority of educators indicated that their learners *infrequently* practised mathematics skills and procedures on a computer. In Gauteng learners who *infrequently* practised mathematics skills and procedures on a computer scored an average of 17 points higher than learners who *frequently* practised mathematics skills and procedures on a computer (GT *Frequently* PV = 404; GT *Infrequently* PV = 421). In the Western Cape learners who *infrequently* practised mathematics skills and procedures on a computer scored an average of 39 points higher than learners who *frequently* practised mathematics skills and procedures on a computer (WC *Frequently* PV = 347; WC *Infrequently* PV = 384).

In 2015 learners in both Gauteng and the Western Cape again achieved higher scores on the TIMSS achievement scale if they came from schools where the majority of educators indicated that their learners *infrequently* practised mathematics skills and procedures on a computer. In Gauteng learners who *infrequently* practised mathematics skills and procedures on a computer scored an average of 28 points higher than learners who *frequently* practised mathematics skills and procedures on a computer (GT *Frequently* PV = 426; GT *Infrequently* PV = 454). In the Western Cape learners who *infrequently* practised mathematics skills and procedures on a computer scored an average of 44 points higher than learners who *frequently* practised mathematics skills and procedures on a computer (WC *Frequently* PV = 429; WC *Infrequently* PV = 473).

An explanation for this finding may be the mathematical comprehension of the average learner in Gauteng and the Western Cape was so low, that they benefitted more from a structured interaction with an educator who could explain concepts on a level that they understood. Additionally, the educational software available may have been problematic and it may have been misaligned with the needs, the developmental stages, and the language of the learners (Higgins et al., 2012; Kolikant, 2012). If unsuitable educational software is used to *frequently* practise mathematics skills and procedures, it may have a detrimental effect on learners' mathematics achievement (Smith & Hardman, 2014).

Mathematics educator responses in relation to practising mathematics skills and procedures on the computer

An observation from the descriptive data is that in both Gauteng and the Western Cape there was an increase from 2011 to 2015 in educators that indicated that their learners *frequently* practised mathematics skills and procedures on a computer. The responses of Gauteng educators indicating that their learners *frequently* practised mathematics skills and procedures on a computer, increased by 33.69% from 25.70% to 59.39%. During the same time the responses of Western Cape educators that indicated their learners *frequently* practised mathematics skills and procedures on a computer, increased by 48.24% from 34.45% to 82.69%. This finding seems to support the idea that the province-wide ICT in schools projects in Gauteng and the Western Cape reached a measure of maturity over the five years between 2011 and 2015 and that more educators started integrating the available technology in mathematics teaching and learning.

However, there seems to be a marked difference in achievement between learners who *frequently* practised mathematics skills and procedures on a computer and those that did not. Unfortunately it is not clear from the ICT-related variables taken from the Eighth Grade *Mathematics Teacher* Questionnaires why this difference in achievement exists, and this could be a topic for future research.

6.5.2. Inferential statistics - Practise mathematics skills and procedures on the computer (BTBM22CB and BTBM20CB)

The IEA IDB Analyzer was used to explore the relationship between practising mathematics skills and procedures on a computer, and the mathematics achievement of learners in both groups (*frequently* practise mathematics skills and procedures on a computer; *infrequently* practise mathematics skills and procedures on a computer) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015 was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BTBM22CB and BTBM20CB is depicted in Table 6.9.

Table 6.9: Practise mathematics skills and procedures on the computer (BTBM22CB and BTBM20CB) – means, differences, t-tests and p-values

		TIMSS 2011 BTBM22CB		TIMSS 2015 BTBM20CB		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Frequently	#Null	#Null	#Null	#Null				
EC	Infrequently	#Null	#Null	#Null	#Null				
EC	Difference								
FS	Frequently	#Null	#Null	#Null	#Null				
FS	Infrequently	#Null	#Null	#Null	#Null				
FS	Difference								
GT	Frequently	404.0549	42.8434	426.0887	32.8153	-22.0338	53.9667	-0.4083	0.6831
GT	Infrequently	421.1027	22.2355	453.9403	81.5169	-32.8377	84.4951	-0.3886	0.6975
GT	Difference	-17.0477	55.7396	-27.8517	96.9339	10.8039	111.8172	0.0966	0.9230
KZ	Frequently	#Null	#Null	#Null	#Null				
KZ	Infrequently	#Null	#Null	#Null	#Null				
KZ	Difference								
LP	Frequently	#Null	#Null	#Null	#Null				
LP	Infrequently	#Null	#Null	#Null	#Null				
LP	Difference								
MP	Frequently	#Null	#Null	#Null	#Null				
MP	Infrequently	#Null	#Null	#Null	#Null				
MP	Difference								
NC	Frequently	#Null	#Null	#Null	#Null				
NC	Infrequently	#Null	#Null	#Null	#Null				
NC	Difference								
NW	Frequently	#Null	#Null	#Null	#Null				
NW	Infrequently	#Null	#Null	#Null	#Null				
NW	Difference								

		TIMSS 2011 BTBM22CB		TIMSS 2015 BTBM20CB		Inferential statistics results			
Prov	Code	Maths PV (mean)	Maths PV s.e.	Maths PV (mean)	Maths PV s.e.	Difference of diff	Error of Diff	t-test	p-value
WC	**Frequently**	**347.2306**	**10.2962**	**429.3572**	**33.4199**	**-82.1265**	**34.9701**	**-2.3485**	**0.0189**
WC	**Infrequently**	**386.0031**	**16.5149**	**473.3016**	**33.3763**	**-87.2985**	**37.2387**	**-2.3443**	**0.0191**
WC	Difference	-38.7725	16.2183	-43.9444	47.1950	5.1720	49.9040	0.1036	0.9175

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). However, when looking at the statistical significance of the changes in mathematics achievement in relation to the practising of mathematics skills and procedures on a computer, only one province (WC) returned statistically significant t-tests and p-values. Therefore only the Western Cape will be discussed in this section.

The achievement of **Western Cape** learners from schools where educators reported that their learners *frequently* practised mathematics skills and procedures on a computer, increased from an average of 347 points in 2011 to 429 points in 2015. Since the p-value was less than 0.05, the difference of 82 points was statistically significant (t = -2.35; p = 0.0189). During the same time the percentage of learners that *frequently* practised mathematics skills and procedures on a computer, increased by 48.24% from 34.45% (2011) to 82.69% (2015). The means (2011 = 347; 2015 = 429) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The achievement of Western Cape learners from schools where educators reported that they *infrequently* allowed learners to practise mathematics skills and procedures on a computer, increased from an average of 386 points in 2011 to 473 points in 2015. Since the p-value was less than 0.05, the difference of 87 points was also statistically significant (t = -2.34; p = 0.0191). During the same time the percentage of learners that *infrequently* practised mathematics skills and procedures on the computer, decreased by 48.24% from 65.55% (2011) to 17.31% (2015). The means (2011 = 386; 2015 = 473) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. In the Western Cape the increase in mathematics achievement between 2011 and 2015 was higher in schools where educators reported that they *infrequently* allowed learners to practise mathematics skills and procedures on a computer.

The average mathematics achievement of South African learners in relation to the practising of mathematics skills and procedures on the computer, increased by 44 points from 373 points (2011) to 416 points (2015). Again, taking into account the relatively large jump in the average mathematics achievement of South African learners between 2011 and 2015, it was surprising how few of the increases in achievement were actually statistically significant. Out of 27 statistical calculations in Table 6.9, only two were statistically significant. This may indicate that the practising of mathematics skills and procedures on the computer, statistically had a small influence on the overall 20 point increase between 2011 and 2015.

6.6. Look up ideas and information on the computer (BTBM22CC and BTBM20CC)

The integration of ICT in teaching and learning is most effective if technology is used to support learner-centred teaching and learning (Blackwell et al., 2016). ICT enables educators to shift the focus to content, pace and learning activities most appropriate for a learner's interests and abilities (Carneiro & Gordon, 2013). Barkatsas et al. (2009) found a strong correlation between learners' mathematics self-confidence and their achievement in mathematics. They found that the use of ICT in mathematics education increased the mathematics self-confidence of low achieving learners. Additionally, the ability to use ICT to find and filter new information in order to creatively solve problems is one of the most important skills required for the optimal functioning in a knowledge society (Anderson, 2008, p. 7; ISTE, 2016).

In order to ascertain to which extent mathematics educators use ICT to assist learners to look up ideas and information on the computer, the IEA included a question related to the use of computers to look up ideas and information in both the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires. Mathematics educators were asked how often they let the learners **look up ideas and information on the computer**. It is important to note that this question refers to computers available in the school, and not necessarily to computers in the mathematics classrooms. It is also important to note that these variables were logically related to variables BTBM22A (2011) and BTBM20A (2015) and were dependent on the educators' responses – educators were instructed to only complete this question if their learners had access to computers in the school. The details of variables BTBM22CC and BTBM20CC are depicted in Table 6.10.

Table 6.10: Look up ideas and information on the computer (BTBM22CC and BTBM20CC)

Variable	Year	Question text	Original coding values	Recoded values
BTBM22CC	2011	How often do you have the students look up ideas and information on the computer?	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid
BTBM20CC	2015	How often do you have the students do the following activities on computers during mathematics lessons? • Look up ideas and information	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid

6.6.1. Descriptive statistics – Look up ideas and information on the computer (BTBM22CC and BTBM20CC)

Variables BTBM22CC (TIMSS 2011) and BTBM20CB (TIMSS 2015) dealt with how often educators allowed learners to look up ideas and information on a computer. The statistical analysis of BTBM22CB and BTBM20CB is depicted in Figure 6.7.

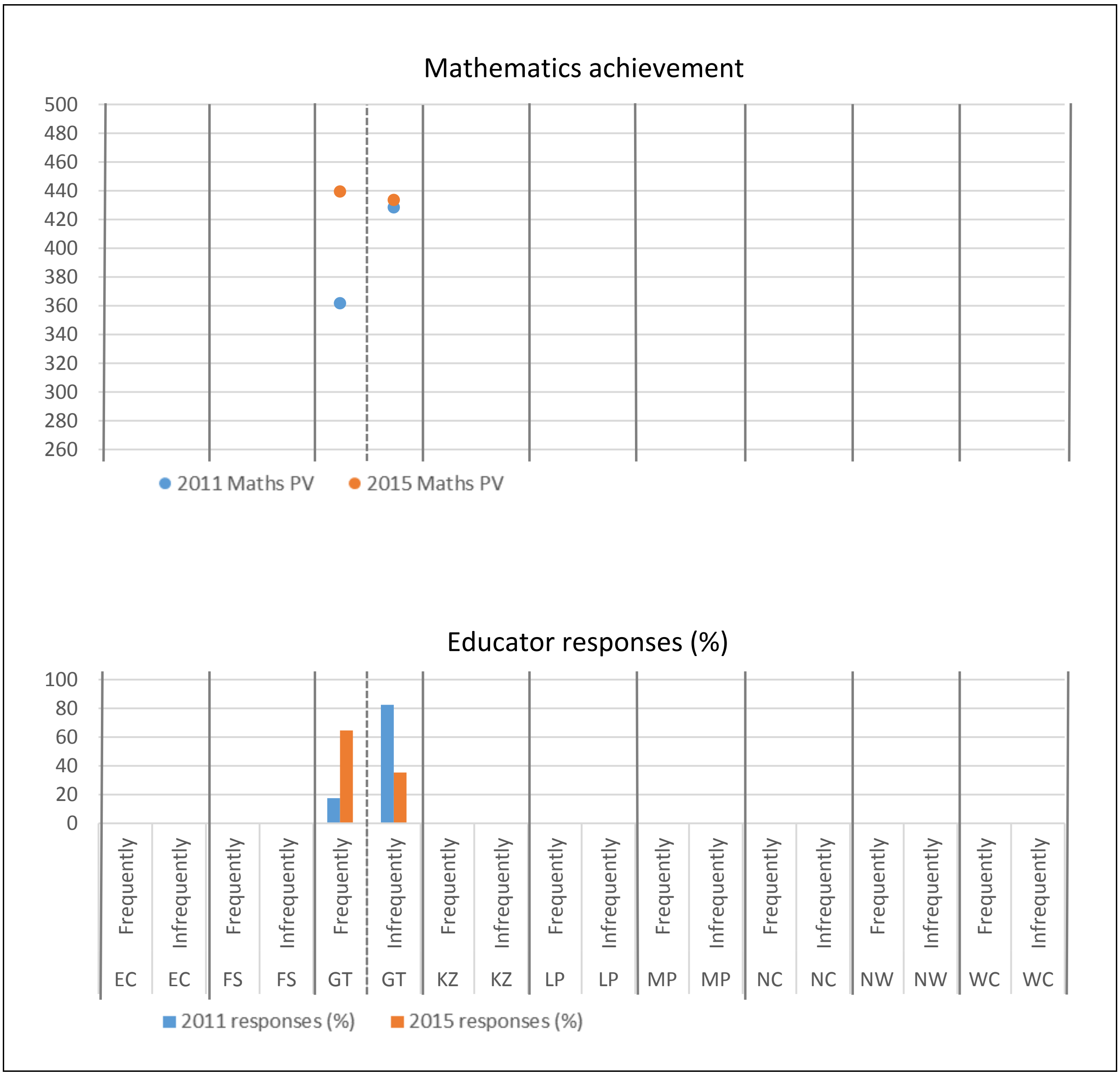

Figure 6.7: Look up ideas and information on the computer (BTBM22CC and BTBM20CC) – mathematics achievement and educator responses per province

A standard deviation was not calculable with the available data for seven of the nine provinces in 2011 and for eight of the nine provinces in 2015 (see Table 6.11). The available data for Gauteng allowed for the calculation of a standard deviation and the results are therefore captured in Figure 6.7 and included for discussion in Sections 6.6.1 and 6.6.2.

Mathematics achievement in relation to the looking up of ideas and information on the computer

In 2011 Gauteng learners that *frequently* used computers to look up ideas and information scored an average of 67 points lower than learners that *infrequently* used computers to look up ideas and information (GT *Frequently* PV = 362; GT *Infrequently* PV = 428). In 2015 the situation changed and Gauteng learners that *frequently* used computers to look up ideas and information scored an average of 6 points higher than learners that *infrequently* used computers to look up ideas and information (GT *Frequently* PV = 439; GT *Infrequently* PV = 434).

The mathematics achievement of Gauteng learners that *frequently* used computers to look up ideas and information, increased by 77 points from 362 points in 2011 to 439 points in 2015. Over the same period the mathematics achievement of Gauteng learners that *infrequently* used computers to look up ideas and information, increased only marginally by 6 points, from 428 points in 2011 to 434 points in 2015.

It seems as if by 2015 there was an increased reporting of the *frequent* use of computers to look up ideas and information. This may indicate that educators were starting to feel more comfortable with integrating technology in their classrooms in order to support teaching and learning.

Mathematics educator responses in relation to the looking up of ideas and information on the computer

In Gauteng there was an increase from 2011 to 2015 in educators that indicated that they allowed learners to *frequently* look up ideas and information on a computer. The responses of Gauteng educators allowing their learner to *frequently* look up ideas and information on a computer, increased by 47.11% from 17.51% to 64.62%. This increase in the use of computers to *frequently* look up ideas and information may indicate that educators became more confident in the use of the available technology. It may also indicate that informal support for the integration and use of technology was increasing among educators, thereby creating a supportive environment for educators that were new to technology in teaching and learning.

If one looks at the increase in the *frequent* use of computers to look up ideas and information in relation to the increase in the mathematics achievement of these learners, it seems as if the use of computers to look up ideas and information had a positive effect on mathematics achievement in Gauteng. The reasons for the increase in the frequent use of computers to look up ideas and information as well as the increase in mathematics achievement in Gauteng are not clear from the ICT-related variables from the Eighth Grade *Mathematics Teacher* Questionnaires. These topics could be addressed in future research projects.

6.6.2. Inferential statistics – Look up ideas and information on the computer (BTBM22CC and BTBM20CC)

The IEA IDB Analyzer was used to explore the relationship between learners looking up ideas and information on the computer, and the mathematics achievement of these learners in both categories (*frequently* look up ideas and information on a computer; *infrequently* look up ideas and information on a computer) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015 was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BTBM22CC and BTBM20CC is depicted in Table 6.11.

Table 6.11: Look up ideas and information on the computer (BTBM22CC and BTBM20CC) – means, differences, t-tests and p-values

		TIMSS 2011 BTBM22CC		TIMSS 2015 BTBM20CC		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Frequently	#Null	#Null	#Null	#Null				
EC	Infrequently	#Null	#Null	#Null	#Null				
EC	Difference								
FS	Frequently	#Null	#Null	#Null	#Null				
FS	Infrequently	#Null	#Null	#Null	#Null				
FS	Difference								
GT	**Frequently**	**361.7707**	**15.5113**	**439.4782**	**30.5185**	**-77.7075**	**34.2342**	**-2.2699**	**0.0232**
GT	Infrequently	428.3863	20.4814	433.6017	87.4798	-5.2154	89.8454	-0.0580	0.9537
GT	Difference	-66.6155	29.7614	5.8765	102.6800	-72.4920	106.9062	-0.6781	0.4977
KZ	Frequently	#Null	#Null	#Null	#Null				
KZ	Infrequently	#Null	#Null	#Null	#Null				
KZ	Difference								
LP	Frequently	#Null	#Null	#Null	#Null				
LP	Infrequently	#Null	#Null	#Null	#Null				
LP	Difference								
MP	Frequently	#Null	#Null	#Null	#Null				
MP	Infrequently	#Null	#Null	#Null	#Null				
MP	Difference								
NC	Frequently	#Null	#Null	#Null	#Null				
NC	Infrequently	#Null	#Null	#Null	#Null				
NC	Difference								
NW	Frequently	#Null	#Null	#Null	#Null				
NW	Infrequently	#Null	#Null	#Null	#Null				
NW	Difference								
WC	Frequently	352.1626	15.5441	#Null	#Null				
WC	Infrequently	379.7295	14.2850	#Null	#Null				
WC	Difference	-27.5669	20.9411						

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). However, when looking at the statistical significance of the changes in mathematics achievement in relation to the look-up of ideas and information on a computer, only one province (GT) returned a statistically significant t-test and p-value. Accordingly only Gauteng will be discussed in this section.

The mathematics achievement of **Gauteng** learners from schools where educators indicated that their learners *frequently* looked-up of ideas and information on a computer, increased from an average of 362 points in 2011 to 439 points in 2015. Since the p-value was less than 0.05, the difference of 78 points was statistically significant (t = -2.27; p = 0.0232). During the same time the percentage of learners whose educators indicated that their learners *frequently* looked-up of ideas and information on a computer, increased by 47.11% from 17.51% to 64.62%. The means (2011 = 362; 2015 = 439) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 5 points for learners in schools where educators indicated that their learners *frequently* looked-up of ideas and information on a computer was not statistically significant. It is interesting to note that the increase in achievement was higher in schools where their learners *frequently* looked-up of ideas and information on a computer.

The average mathematics achievement of South African learners in relation to the look-up of ideas and information on a computer, increased by 48 points from 371 (2011) to 420 (2015). Out of 27 statistical calculations in Table 6.11, only one calculation was statistically significant. This may indicate that the look-up of ideas and information on a computer, statistically had a small influence on the overall 20 point increase between 2011 and 2015.

6.7. Process and analyse data on the computer (BTBM22CD and BTBM20CD)

While using ICT for learning, learners are constantly required to expand their existing understanding and apply it to a totally new environment (Hansen et al., 2012; Mayer, 1997). In a South African study Sujee (2015) found that the use of ICT may lead to the creation of a challenging learning environment that is conducive to the development of higher order thinking skills and deep learning. The expectation of the DBE is also that South African learners need to be able to use ICT to "access, analyse, evaluate, integrate, present and communicate" information (DOE, 2004, p. 14) and "identify and solve problems and make decisions using critical and creative thinking… collect, analyse, organise and critically evaluate information" (DBE, 2011, p. 5).

In order to ascertain to which extent mathematics educators use ICT to assist learners to process and analyse data on the computer, the IEA included a question related to the processing and analysis of data on computers in both the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires. Mathematics educators were asked how often they allowed their learners to **process and analyse data on a computer**. It is important to note that this question refers to computers available in the school, and not necessarily to computers in the mathematics classrooms. It is also important to note that these variables were logically related to variables BTBM22A (2011) and BTBM20A (2015) and were dependent on the educators' responses – educators were instructed to only complete this question if their learners had access to computers in the school. The details of variables BTBM22CD and BTBM20CD are depicted in Table 6.12.

Table 6.12: Process and analyse data on the computer (BTBM22CD and BTBM20CD)

Variable	Year	Question text	Original coding values	Recoded values
BTBM22CD	2011	How often do you have the students process and analyze data on the computer?	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid
BTBM20CD	2015	How often do you have the students do the following activities on computers during mathematics lessons? • Process and analyze data	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid

6.7.1. Descriptive statistics – Process and analyse data on the computer (BTBM22CD and BTBM20CD)

In TIMSS 2011 variable BTBM22CD dealt with how often educators allow learners to process and analyse data on a computer. In TIMSS 2015 variable BTBM20CB addressed the same issue. The statistical analysis of BTBM22CD and BTBM20CD is depicted in Figure 6.8.

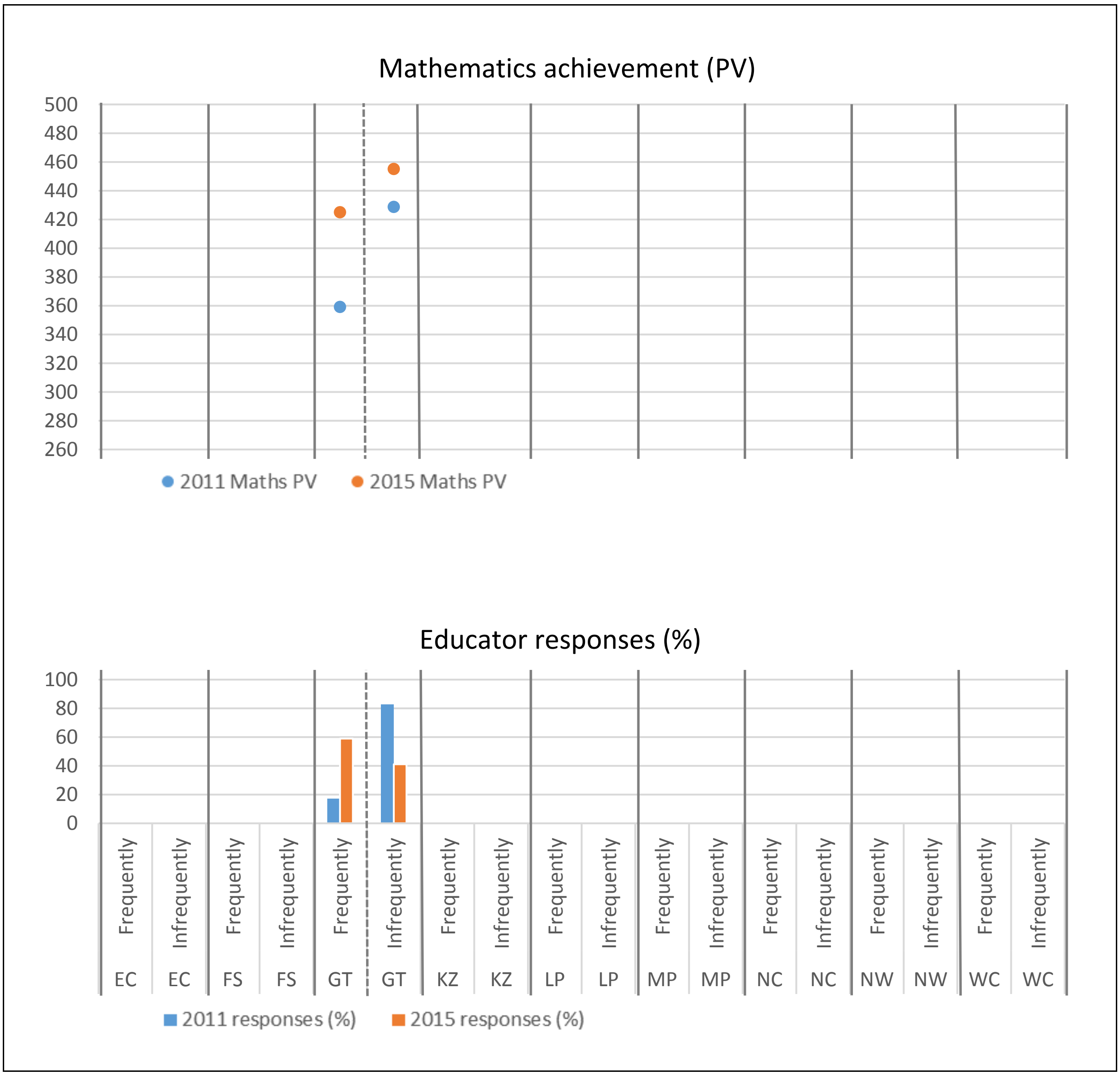

Figure 6.8: Process and analyse data on the computer (BTBM22CD and BTBM20CD) – mathematics achievement and educator responses per province

In TIMSS 2011 a standard deviation was not calculable with the available data for seven of the nine provinces in 2011 and for eight of the nine provinces in 2015 (see Table 6.13). The available data for Gauteng allowed for the calculation of a standard deviation and the results are therefore captured in Figure 6.8 and discussed in Sections 6.7.1 and 6.7.2.

Mathematics achievement in relation to the processing and analysis of data on the computer

In both 2011 and 2015, the Gauteng learners that achieved the highest scores on the TIMSS achievement scale came from schools where educators indicated that their learners *infrequently* used computers to process and analyse data. In 2011 Gauteng learners that *frequently* used computers to process and analyse data scored an average of 70 points lower than learners that *infrequently* used computers to process and analyse data (GT *Frequently* PV = 359; GT *Infrequently* PV = 429). In 2015 Gauteng learners that *frequently* used computers to process and analyse data scored an average of 30 points lower than learners that *infrequently* used computers to process and analyse data (GT *Frequently* PV = 425; GT *Infrequently* PV = 470).

The average mathematics achievement of learners that *frequently* used computers to process and analyse data increased by 66 points, from 359 points in 2011 to 425 points in 2015. Over the same period the mathematics achievement of Gauteng learners that *infrequently* used computers to process and analyse data increased by 26 points, from 429 points in 2011 to 455 points in 2015. It seems as if the *frequent* use of computers to process and analyse data had a larger influence on the change in mathematics achievement between 2011 and 2015. In Gauteng this may support the idea that there was a maturity in the integration of technology in teaching and learning whereby educators were able to better use technology to support teaching and learning. It is interesting to note that in both 2011 and 2015 learners who *infrequently* used computers to process and analyse data still achieved better mathematics results on the TIMSS achievement scale.

Mathematics educator responses in relation to the processing and analysis of data on the computer

In Gauteng there was an increase from 2011 to 2015 in educators that indicated that they *frequently* allowed learners to process and analyse data on a computer. The responses of

Gauteng educators allowing learners to *frequently* process and analyse data on a computer increased by 41.68% from 17.22% to 58.90%. This increase in the use of computers to *frequently* process and analyse data may support the idea that educators became more confident in the use of the available technology. It may also support the idea that informal support for the integration and use of technology increased among educators, thereby creating a supportive environment for educators new to technology in teaching and learning.

6.7.2. Inferential statistics – Process and analyse data on the computer (BTBM22CD and BTBM20CD)

The IEA IDB Analyzer was used to explore the relationship between learners processing and analysing data on computers and the mathematics achievement of these learners in both categories (*frequently* process and analyse data on computers; *infrequently* process and analyse data on computers) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015 was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of variables BTBM22CD and BTBM20CD is depicted in Table 6.13.

Table 6.13: Process and analyse data on the computer (BTBM22CD and BTBM20CD) – means, differences, t-tests and p-values

		TIMSS 2011 BTBM22CD		TIMSS 2015 BTBM20CD		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Frequently	#Null	#Null	#Null	#Null				
EC	Infrequently	#Null	#Null	#Null	#Null				
EC	Difference								
FS	Frequently	#Null	#Null	#Null	#Null				
FS	Infrequently	#Null	#Null	#Null	#Null				
FS	Difference								
GT	Frequently	359.1550	15.7001	425.0530	33.4416	-65.8980	36.9437	-1.7837	0.0745
GT	Infrequently	428.7004	20.5154	455.0932	80.8240	-26.3928	83.3870	-0.3165	0.7516
GT	Difference	-69.5454	29.7804	-30.0402	96.5737	-39.5052	101.0611	-0.3909	0.6959
KZ	Frequently	#Null	#Null	#Null	#Null				
KZ	Infrequently	#Null	#Null	#Null	#Null				

		TIMSS 2011 BTBM22CD		TIMSS 2015 BTBM20CD		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
KZ	Difference								
LP	Frequently	#Null	#Null	#Null	#Null				
LP	Infrequently	#Null	#Null	#Null	#Null				
LP	Difference								
MP	Frequently	#Null	#Null	#Null	#Null				
MP	Infrequently	#Null	#Null	#Null	#Null				
MP	Difference								
NC	Frequently	#Null	#Null	#Null	#Null				
NC	Infrequently	#Null	#Null	#Null	#Null				
NC	Difference								
NW	Frequently	#Null	#Null	#Null	#Null				
NW	Infrequently	#Null	#Null	#Null	#Null				
NW	Difference								
WC	Frequently	352.1626	15.5441	#Null	#Null				
WC	Infrequently	379.7295	14.2850	#Null	#Null				
WC	Difference	-27.5669	20.9411						

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in 2011 to an average of 372 points in 2015 (Reddy, Visser, et al., 2016). However, when looking at the statistical significance of the changes in mathematics achievement in relation to the processing and analysing of data on the computer, Gauteng did not return any statistically significant t-test or p-value. Accordingly, there will be no discussion on significant differences in achievement between 2011 and 2015 for these variables.

6.8. Professional development in integrating ICT in mathematics (BTBM29D and BTBM24D)

The levels of success when integrating ICT in teaching and learning rely heavily on the educator in the class (Drent & Meelissen, 2008; Kennisnet Foundation, 2015). Goktas et al. (2013) and Pelgrum (2001) found educators' confidence to use ICT in their classrooms as a significant indicator of educators' willingness to use ICT in their classrooms. The responsibility for creating a suitable environment for ICT implementation in schools and encouraging teaching staff to collaborate in the development of ICT-friendly teaching and learning materials lies to a large extent with the school itself (Lakkala & Ilomäki, 2015). Kozma (2008) suggests continuous professional development programmes for educators focusing on the specific skills that need to be acquired as one of his five specific operational components to be included in national ICT-related education policies. However, in the SITES 2006 study, fewer than 8% of the South African educators interviewed indicated that they have attended ICT-related professional development interventions (Law et al., 2008).

In order to determine to which extent mathematics educators received professional development in the integration of ICT in mathematics in the previous two years, the IEA included a question related to professional development in the integration of ICT in both the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires. Mathematics educators were asked if they attended any **professional development interventions aimed at the integration of ICT in mathematics** teaching and learning in the previous two years. The details of variables BTBM29D and BTBM24D are depicted in Table 6.14.

Table 6.14: Professional development in integrating ICT in mathematics (BTBM29D and BTBM24D)

Variable	Year	Question text	Original coding values	Recoded values
BTBM29D	2011	In the past two years, have you participated in professional development in integrating information technology into mathematics?	1 = Yes	101 = Yes - agree
			2 = No	102 = No - disagree
			9 = Omitted or invalid	9 = Omitted or invalid
BTBM24D	2015	In the past two years, have you participated in professional development in any of the following? Integrating information technology into mathematics	1 = Yes	101 = Yes - agree
			2 = No	102 = No - disagree
			9 = Omitted or invalid	9 = Omitted or invalid

6.8.1. Descriptive statistics – Professional development in integrating ICT in mathematics (BTBM29D and BTBM24D)

Variable BTBM29D (TIMSS 2011) and variable BTBM29D (TIMSS 2015) dealt with the extent to which mathematics educators received professional development in the integration of ICT in mathematics in the previous two years. The descriptive statistical analysis of BTBM29D and BTBM24D is depicted in Figure 6.9.

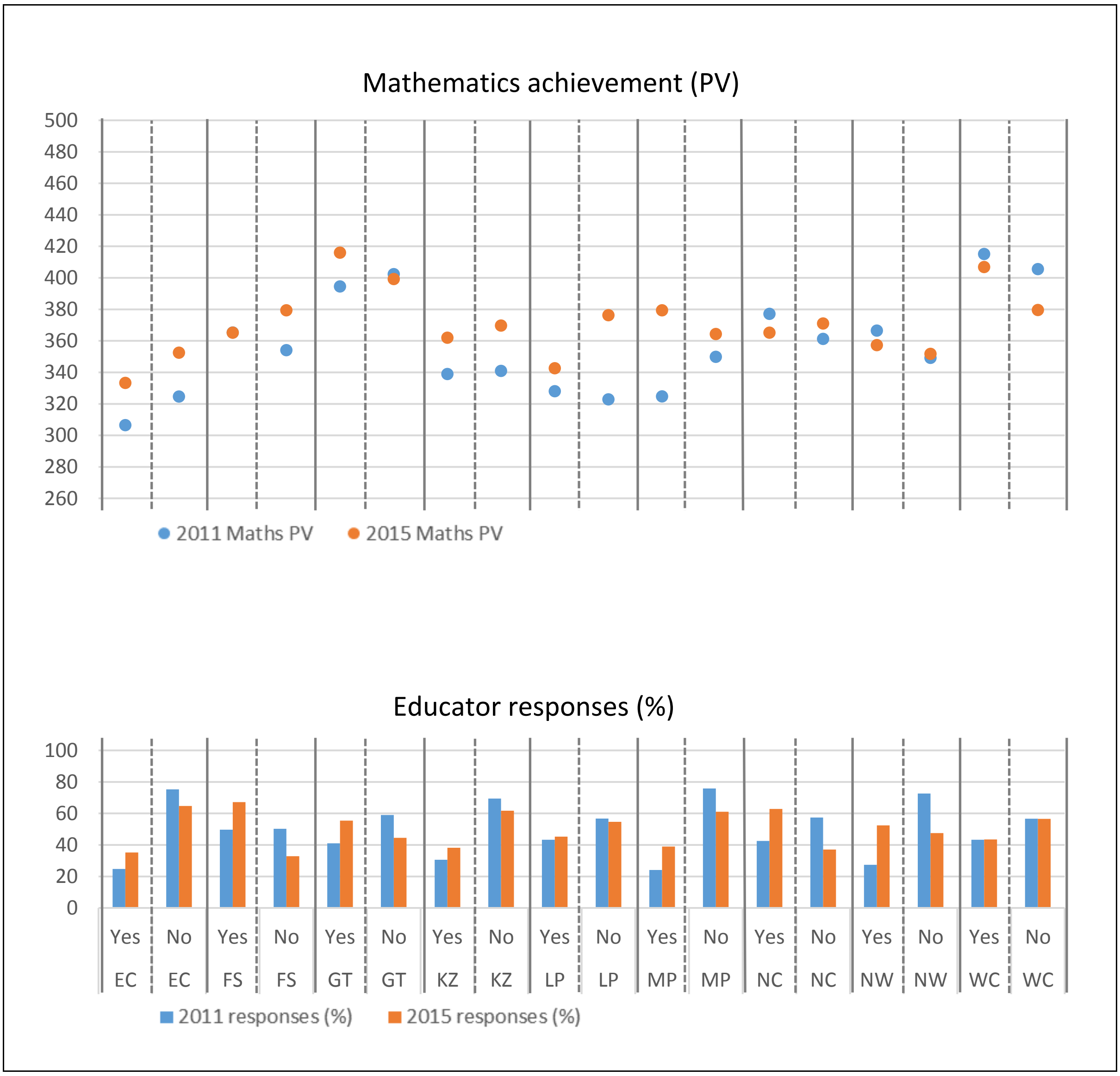

Figure 6.9: Professional development in integrating ICT in mathematics (BTBM29D and BTBM24D) – mathematics achievement and educator responses per province

Mathematics achievement in relation to professional development in integrating ICT in mathematics

In both 2011 and 2015, the learners that achieved the highest average scores on the TIMSS achievement scale came from schools in Gauteng (2015 PV = 416) and the Western Cape (2011 PV = 415) where educators *agreed* that they received professional development in the integration of ICT in the previous two years. In 2011, Western Cape learners from schools where educators *agreed* that they received professional development in the integration of ICT in the previous two years, scored an average of 10 points higher than learners from schools where educators *disagreed* that they received professional development (WC *Agree* PV = 415; WC *Disagree* PV = 405). In 2015, Gauteng learners from schools where educators *agreed* that they received professional development in the integration of ICT in the previous two years, scored an average of 17 points higher than learners from schools where educators *disagreed* that they received professional development (GT *Agree* PV = 416; GT *Disagree* PV = 399).

In both 2011 and 2015, the learners that achieved the lowest average scores on the TIMSS achievement scale came from schools in the Eastern Cape (2011 PV = 306; 2015 PV = 333) where educators *agreed* that they received professional development in the integration of ICT in the previous two years. It is interesting that in both 2011 (2011 EC *Agree* PV = 306; 2011 EC *Disagree* PV = 325) and 2015 (2015 EC *Agree* PV = 333; 2015 EC *Disagree* PV = 352), Eastern Cape learners from schools where educators *agreed* that they received professional development in the integration of ICT in the previous two years, scored an average of 19 points lower than learners from schools where educators *disagreed* that they received professional development.

There does not seem to be a clear relationship between educators attending professional development interventions in the integration of ICT and learner achievement. Educator professional development in the integration of ICT in mathematics seems to have little bearing on actual learner achievement in mathematics. A possible explanation for this may be that many South African educators indicated that limited computers were available for teaching and learning (see variables BTBM22A and BTBM20A – Availability of computers during mathematics lessons) and therefore many educators could not implement knowledge and skills gained by attending professional development interventions in the integration of ICT in their classrooms. Also it seems as if in many provinces professional development in the integration of ICT in mathematics is done in schools where technology is in any case not available. Professional development in the integration of technology seems to be meaningless without the implementation of some sort of technology where new skills can be applied (Drent & Meelissen, 2008; Kozma, 2008).

Mathematics educator responses in relation to professional development in integrating ICT in mathematics

In 2011 the majority of educators in all nine provinces *disagreed* that they received professional development in integrating ICT in their mathematics classrooms in the previous two years. In TIMSS 2015 the majority of educators in only four of the nine provinces (EC, KZ, LP, MP) *disagreed* that they received professional development in integrating ICT in their mathematics classrooms in the previous two years. It therefore seems as if there was an increased effort towards 2015 in making professional development interventions in integrating ICT available to educators.

The percentage of educators that *agreed* that they received professional development in the integration of ICT in mathematics in the previous two years, increased between 2011 and 2015 in all nine provinces. Surprisingly, the two provinces with the largest increase in percentage of educators that *agreed* that they received professional development in the integration of ICT in mathematics in the previous two years were the Northern Cape and North West. The percentage of educators that *agreed* that they received professional development in the integration of ICT in the previous two years in the Northern Cape increased by 20.32% from 42.57% to 62.89%, and in North West with 25.08% from 27.38% to 52.46%. This seems to indicate that PEDs are starting to recognise the need for ICT in schools and are starting to prepare educators for using such technologies. Schools need to actively market themselves and in many cases this marketing refers to the availability of ICT in the school. It could also be that in instances where the PEDs lag behind in rolling out professional development activities to educators, principals and school governing bodies foot the bill for such activities themselves. This again ties in with the important role of an effective principal in identifying such needs in their schools.

The increase in professional development in the integration of ICT in mathematics seems to go hand-in-hand with the increased support available to educators for the integration of technology in teaching and learning as reported earlier in this chapter (BTBG09BC and BTBG08G – Support for integrating technology in teaching and learning). It seems that support for the integration of technology in teaching and learning is moving beyond Gauteng and the Western Cape and this may be worth investigating further.

6.8.2. Inferential statistics – Professional development in integrating ICT in mathematics (BTBM29D and BTBM24D)

The IEA IDB Analyzer was used to explore the relationship between the professional development of mathematics educators in the integration of ICT in mathematics in the previous two years, and the mathematics achievement of the learners in these schools in both categories (*agreed* that they attended professional development in ICT integration; *disagreed* that they attended professional development in ICT integration) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015 was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BTBM22CB and BTBM20CB is depicted in Table 6.15.

Table 6.15: Professional development in integrating ICT in mathematics (BTBM29D and BTBM24D) – means, differences, t-tests and p-values

		TIMSS 2011 BTBM29D		TIMSS 2015 BTBM24D		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Yes	306.4394	18.1605	333.2460	14.9484	-26.8066	23.5214	-1.1397	0.2544
EC	No	324.5701	13.4668	352.3970	17.4689	-27.8269	22.0571	-1.2616	0.2071
EC	Difference	-18.1307	24.1051	-19.1510	20.1886	1.0203	31.4426	0.0324	0.9741
FS	Yes	365.1907	13.0362	365.1444	14.9187	0.0463	19.8119	0.0023	0.9981
FS	No	354.0262	10.8546	379.2879	28.2488	-25.2617	30.2625	-0.8348	0.4039
FS	Difference	11.1644	16.7194	-14.1436	32.4890	25.3080	36.5386	0.6926	0.4885
GT	Yes	394.4188	16.0961	415.9377	16.7370	-21.5189	23.2209	-0.9267	0.3541
GT	No	402.2692	10.6810	399.1587	19.0401	3.1105	21.8314	0.1425	0.8867
GT	Difference	-7.8504	22.8140	16.7790	26.9055	-24.6294	35.2759	-0.6982	0.4851
KZ	Yes	338.8712	14.4847	361.9394	13.2540	-23.0682	19.6335	-1.1749	0.2400
KZ	No	340.8288	6.2768	369.6107	14.8725	-28.7819	16.1428	-1.7830	0.0746
KZ	Difference	-1.9577	16.5628	-7.6713	17.7840	5.7137	24.3022	0.2351	0.8141
LP	Yes	327.9504	13.9238	342.5463	6.2814	-14.5959	15.2751	-0.9555	0.3393
LP	**No**	**322.7594**	**10.4013**	**376.2327**	**23.2372**	**-53.4733**	**25.4589**	**-2.1004**	**0.0357**
LP	Difference	5.1909	18.7244	-33.6864	23.9805	38.8773	30.4247	1.2778	0.2013
MP	**Yes**	**324.6847**	**10.7104**	**379.2913**	**17.9547**	**-54.6066**	**20.9065**	**-2.6119**	**0.0090**
MP	No	349.7928	4.7487	364.2182	10.0568	-14.4254	11.1216	-1.2971	0.1946
MP	Difference	-25.1081	11.4800	15.0731	22.8088	-40.1812	25.5349	-1.5736	0.1156
NC	Yes	377.0757	40.9194	365.0926	8.4763	11.9831	41.7881	0.2868	0.7743
NC	No	361.1236	13.4088	370.9534	12.3521	-9.8298	18.2310	-0.5392	0.5898
NC	Difference	15.9522	44.0653	-5.8608	13.6752	21.8129	46.1385	0.4728	0.6364
NW	Yes	366.4535	26.3761	357.2108	12.1816	9.2427	29.0532	0.3181	0.7504
NW	No	349.0980	10.7377	351.7006	11.0186	-2.6027	15.3853	-0.1692	0.8657
NW	Difference	17.3555	30.5576	5.5102	16.6364	11.8454	34.7928	0.3405	0.7335
WC	Yes	415.0382	21.7602	406.7726	17.7684	8.2656	28.0932	0.2942	0.7686
WC	No	405.4175	14.1457	379.5387	9.4249	25.8788	16.9979	1.5225	0.1279
WC	Difference	9.6207	29.5362	27.2339	18.7817	-17.6132	35.0020	-0.5032	0.6148

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). However, when looking at the statistical significance of the changes in mathematics achievement in relation to educator professional development in integrating ICT in mathematics, only two provinces (LP, MP) returned statistically significant t-tests and p-values. Accordingly only these two provinces will be discussed in this section.

The achievement of **Limpopo** learners from schools where educators *disagreed* that they attended professional development in integrating ICT in mathematics in the previous two years, increased from an average of 323 points in 2011 to 376 points in 2015. Since the p-value was less than 0.05, the difference of 53 points was statistically significant (t = -2.10; p = 0.0357). During the same time the percentage of learners whose educators *disagreed* that they attended professional development in integrating ICT in mathematics in the previous two years, decreased by 2.01% from 56.72% (2011) to 54.71% (2015). The means (2011 = 323; 2015 = 376) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 15 points of Limpopo learners from schools where educators *agreed* that they attended professional development in integrating ICT in mathematics in the previous two years, was not statistically significant. The increase in mathematics achievement from 2011 to 2015 was higher in Limpopo schools where educators *disagreed* that they attended professional development in integrating ICT in mathematics in the previous two years.

The achievement of **Mpumalanga** learners from schools where educators *agreed* that they attended professional development in integrating ICT in mathematics, increased from an average of 325 points in 2011 to 379 points in 2015. Since the p-value was less than 0.05, the difference of 55 points was statistically significant (t = -2.61; p = 0.0090). During the same time the percentage of learners whose educators *agreed* that they attended professional development in integrating ICT in mathematics in the previous two years, increased by 14.84% from 24.12% (2011) to 38.96% (2015). The means (2011 = 325; 2015 = 379) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in achievement of 14 points of Mpumalanga learners from schools where educators *disagreed* that they attended professional development in integrating ICT in mathematics in the previous two years, was not statistically significant. The increase in mathematics achievement from 2011 to 2015 was higher in Mpumalanga schools where educators *agreed* that they attended professional development in integrating ICT in mathematics in the previous two years.

The average mathematics achievement of South African learners in relation to educator professional development in integrating ICT in mathematics, increased by 14 points from 357 points (2011) to 371 points (2015). Out of 27 statistical calculations in Table 6.15, only two calculations were statistically significant. This may indicate that educator professional development in integrating ICT in mathematics, statistically had a very small influence on the overall 20 point increase between 2011 and 2015.

It is interesting to note that the increase in mathematics achievement from 2011 to 2015 was higher in Limpopo schools where educators *disagreed* that they attended professional development in integrating ICT in mathematics in the previous two years. In Mpumalanga schools the increase in mathematics achievement from 2011 to 2015 was higher where educators *agreed* that they attended professional development in integrating ICT in mathematics in the previous two years. When comparing these results with the results of variables BTBM22A and BTBM20A (Availability of computers during mathematics lessons), it seems to support the idea that professional development in the integration of technology is meaningless without available technology on which to apply new skills.

6.9. Findings from the statistical analysis of the Eighth Grade *Mathematics Teacher* Questionnaires

This chapter focused on the secondary data analysis of fourteen ICT-related variables from the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires, seven from 2011 and seven from 2015. If one takes a global overview of the mathematics results of learners in relation to responses from educators to the Eighth Grade *Mathematics Teacher* Questionnaires, it seems as if learners from schools where educators did not rely heavily on ICT for mathematics teaching and learning, achieved better results in the TIMSS assessments.

It is a concern that only two variables (Professional development in integrating ICT in mathematics – BTBM29D and BTBM24D) contained a full set of responses for all nine provinces for both 2011 and 2015. Only one province, Gauteng, contained a full data set for all variables for both 2011 and 2015. The data sets of the rest of the provinces were incomplete for either 2011, 2015, or both, and the statistical analysis could therefore not be completed. In almost all the cases, the reason for these incomplete data sets were that the number of responses per province were simply too low for the calculation of a standard deviation. This may indicate that the actual availability of ICT in classrooms in South Africa is very thinly spread outside of Gauteng and the Western Cape.

There seem to have been an increase in support available to Gauteng and Western Cape educators for the integration of technology between 2011 and 2015. A possible explanation for the increase in educators that *agreed* they received adequate support for the integration of technology, may be that the province-wide ICT in schools projects reached a measure of maturity over the five years between 2011 and 2015 and that educators started supporting each other with the integration of technology. Additionally, many schools seem to have identified the positive contribution that ICT can add to teaching and learning, and it seems as if more schools are willing to invest in ICT even though they may not be part of the planned province-wide ICT in schools projects. Support for the integration of technology in teaching and learning relies on the identification of this type of support as important by school management. It seems as if learners achieve higher mathematics scores if they come from schools where the school management identified support for the integration of technology as important and also acted upon this information to arrange such support. This seems to endorse findings from the Eighth Grade *School* Questionnaires where a principal's ability to accurately identify strengths and weaknesses in their school seemed to have a positive impact on teaching and learning in the school.

The percentage of educators countrywide that *agreed* that they received professional development in the integration of ICT in mathematics in the previous two years, increased between 2011 and 2015 in all nine provinces. This seems to indicate that PEDs were slowly starting to recognise the positive role that ICT can play in effective teaching and learning and were starting to prepare educators for using such technologies. It could also be that in instances where the PEDs lag behind in rolling out professional development activities to educators, principals and school governing bodies footed the bill for such activities themselves. Schools need to actively market themselves and in many cases this marketing refers to the availability of ICT in the school. This again ties in with the important role of an effective principal in identifying such needs for the educators in their schools.

According to the educators, there was a general decrease in the availability of computers during mathematics lessons. A possible reason for the decrease in availability of computers during mathematics lessons could be twofold: on the one hand educators could be more sensitised to the positive impact of technology on teaching and learning and therefore the demand for the existing infrastructure has increased over this period of time, leading to the unavailability during mathematics lessons. On the other hand PEDs and schools may have invested less in technology in schools as the South African economy gradually worsened, choosing to rather focus limited financial resources on basic educational needs. Another reason for this decrease may be that while many schools have technology for teaching and learning, it is locked away for protection against breakage and theft.

It remains a concern that responses from educators to questions on the availability of ICT for teaching and learning in the Eighth Grade *Mathematics Teacher* Questionnaires do not seem to correspond with the responses of school principals to similar questions on shortages of ICT in schools in the Eighth Grade *School* Questionnaires. A good example of this discrepancy is the difference in responses of school principals and educators to the question of the availability of computers. Figure 6.10 depicts the responses of school principals to questions in the Eighth Grade *School* Questionnaire on the effect that a shortage of computers for mathematics instruction has on teaching and learning in their schools (variables BCBG09BB and BCBG13AH).

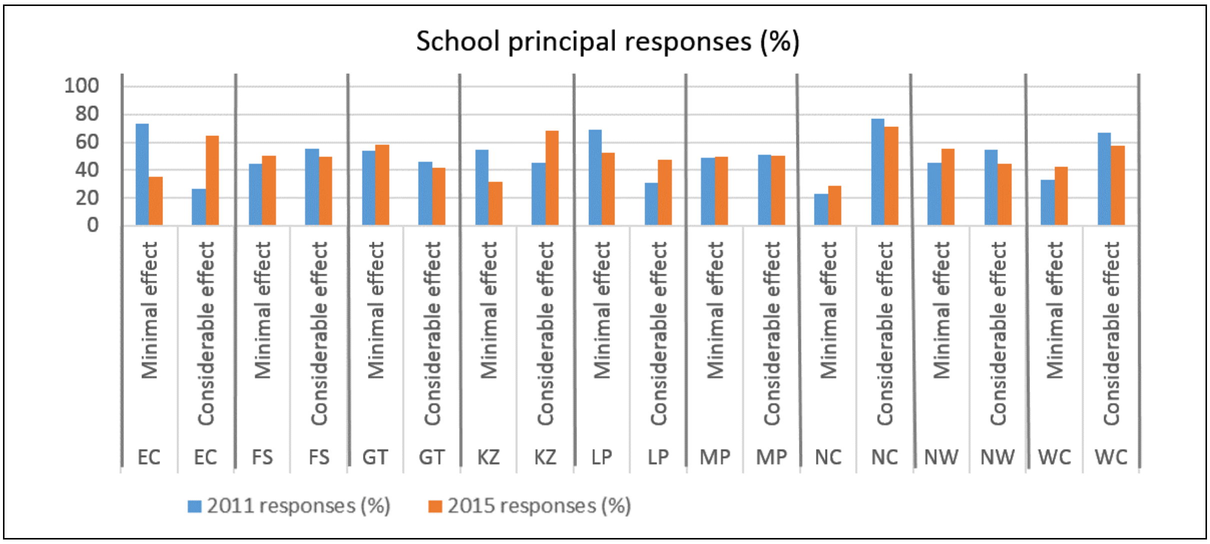

Figure 6.10: School principal responses on a shortage of computers for mathematics instruction (BCBG09BB and BCBG13AH)

Figure 6.11 depicts the responses of educators to questions in the Eighth Grade *Mathematics Teacher* Questionnaires on the availability of computers during mathematics lessons (variables BTBM22A and BTBM20A). It is interesting to note the differences between the responses of school principals and educators.

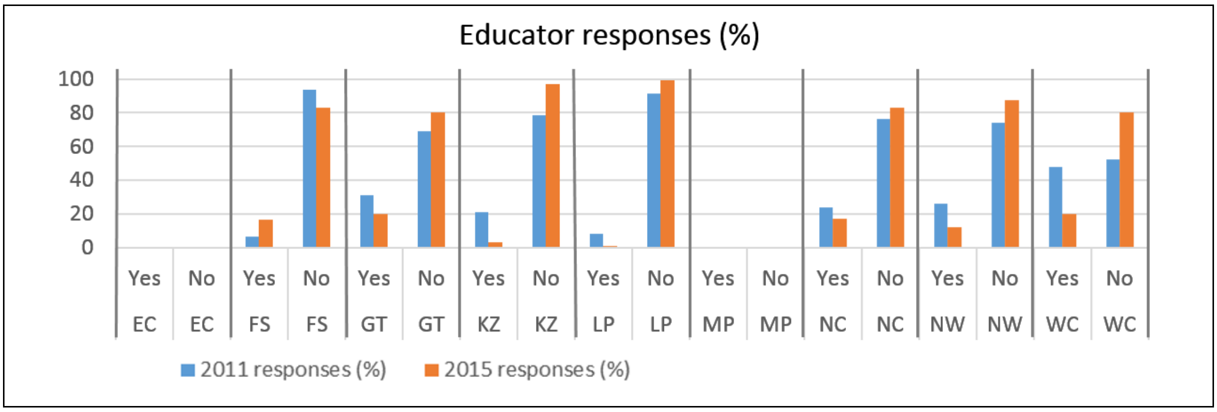

Figure 6.11: Educator responses on the availability of computers during mathematics lessons (BTBM22A and BTBM20A)

A possible explanation for this discrepancy in responses could be that even though computers were available in the school, educators perceived these as not available to them for use during mathematics lessons. Another explanation may be that school principals did not perceive a shortage of ICT as a challenge in the school, and therefore did not report on it as a challenge. Unfortunately it is not clear from the ICT-related variables in the Eighth Grade *School*

Questionnaires and the Eighth Grade *Mathematics Teacher* Questionnaires what may have caused this discrepancy and this could be further investigated.

An interesting observation is that in both 2011 and 2015 the Gauteng and Western Cape learners that achieved the highest scores on the TIMSS achievement scale, came from schools where the majority of educators indicated that they *infrequently* allowed learners to explore mathematics principles and concepts on the computer, practise mathematics skills and procedures on the computer, look up ideas and information on the computer, and process and analyse data on the computer. A possible explanation why learners achieved better scores if their educators *infrequently* allowed them to use the computer during mathematics lessons, may be the choice of educational software available. In order for technology integration to be successful, the educational software needs to be aligned with the needs and developmental stage of the learner. If the software was not suitable, optimal learning could not take place. A danger of huge computer integration projects seem to be the delivery of a 'one-size-fits-all' solution, without taking the context of the end users into consideration. Another explanation may be that the mathematical comprehension of the average learner was so low, that they benefitted more from a structured, traditional face-to-face interaction with an educator who could explain concepts in a language familiar to them.

The mathematics achievement of South African Grade 9 learners increased by 20 points on the TIMSS achievement scale from 2011 to 2015 (Reddy, Visser, et al., 2016). The study also explored the relationship between ICT-related variables and the difference in mathematics achievement between 2011 and 2015. It was surprising how few of the calculations regarding the difference in mathematics achievement were actually statistically significant. Table 6.16 depicts the number of statistically significant findings for the ICT-related variables identified from the Eighth Grade *Mathematics Teacher* Questionnaires.

Table 6.16: Statistically significant findings for ICT-related variables from the Eighth Grade *Mathematics Teacher* Questionnaires

TIMSS 2011 variables	TIMSS 2015 variables	Variable description	Number of statistically significant findings	Reference to statistics
BTBG09BC	BTBG08G	GEN\PC USE**ADEQUATE SUPPORT**	2 out of 27	See Table 6.3
BTBM22A	BTBM20A	MATH**COMPUTER AVAILABILITY DURING MATH**	5 out of 27	See Table 6.5
BTBM22CA	BTBM20CA	MATH\COMPUTER ACTIVITIES**EXPLORE CONCEPT**	2 out of 27	See Table 6.7
BTBM22CB	BTBM20CB	MATH\COMPUTER ACTIVITIES**DO PROCEDURES**	2 out of 27	See Table 6.9
BTBM22CC	BTBM20CC	MATH\COMPUTER ACTIVITIES**LOOK UP IDEAS**	1 out of 27	See Table 6.11
BTBM22CD	BTBM20CD	MATH\COMPUTER ACTIVITIES**PROCESS DATA**	0 out of 27	See Table 6.13
BTBM29D	BTBM24D	MATH**PROF DEVELOPMENT\IT**	2 out of 27	See Table 6.15

It seems as if the availability of computers during mathematics lessons (BTBM22A and BTBM20A) had the greatest influence/effect on the difference in mathematics achievement between 2011 and 2015. Five out of 27 statistical calculations in Table 6.5 were statistically significant. This finding seems to correspond with findings from the Eighth Grade *School* Questionnaires that learners from better resourced schools achieved better results in TIMSS.

However, it is interesting to note that when school principals were asked a similar question in the Eighth Grade *School* Questionnaires (Shortage of computers for mathematics instruction – BCBG09BB and BCBG13AH) only four out of 27 statistical calculations in Table 5.3 were statistically significant. This may support the idea that many school principals are not in touch with the realities that educators and learners in their schools are faced with on a daily basis.

6.10. Summary

This chapter focused on the secondary data analysis of ICT-related variables from the 2011 and 2015 Eighth Grade *Mathematics Teacher* Questionnaires. Fourteen ICT-related variables were identified from the Eighth Grade *Mathematics Teacher* Questionnaires.

The data analysis of the 2011 and the 2015 Eighth Grade *School* Questionnaires were discussed in Chapter 5. The data analysis of the 2011 and the 2015 Eighth Grade *Student* Questionnaire will be discussed in Chapter 7.

7. CHAPTER 7 – TIMSS EIGHTH GRADE *STUDENT* QUESTIONNAIRES DATA ANALYSIS AND RESULTS

7.1. Introduction

This chapter reports on the results of the secondary data analysis of ICT-related variables from the Eighth Grade *Student* Questionnaires. The Eighth Grade *Student* Questionnaires focused on the context in which the learners sampled for the TIMSS assessments functioned – this included learner-related information such as learners' home environment, learners' academic motivation and application, as well as background on learners' parents and the support available at home (Mullis et al., 2009). The variables discussed in this chapter emanate from ICT-related questions identified in the 2015 Eighth Grade *Student* Questionnaire (Mullis & Martin, 2013) and the 2011 Eighth Grade *Student* Questionnaire (Mullis et al., 2009). All Grade 9 learners from the classes sampled for the TIMSS assessments were requested to complete the Eighth Grade *Student* Questionnaires.

Five ICT-related variables were identified from the 2015 Eighth Grade *Student* Questionnaire for inclusion in this study. Using the information supplied in Supplement 1 of the TIMSS 2015 User Guide for the International Database (Foy, 2017b) on the relationships between variables in 2015 and 2011, four related variables were identified in the 2011 Eighth Grade *Student* Questionnaire. Figure 7.1 depicts an extract from Supplement 1 of the TIMSS 2015 User Guide for the International Database indicating the way related variables in the Eighth Grade *Student* Questionnaires were identified.

Exhibit S1.6: Index of International Background Variables for the TIMSS 2015 Student Questionnaire - Eighth Grade

This table includes all questions in both versions of the eighth grade student questionnaire—the general/integrated science version and the separate science subjects version. Question numbers beginning with "SQG-" are in both versions. Question numbers beginning with "SQIS-" are in only the general/integrated science version. Question numbers beginning with "SQSS-" are in only the separate science subjects version.

TIMSS 2015 Question Number	TIMSS 2015 Variable Name	TIMSS 2015 Variable Description (See questionnaire for full item text)	TIMSS 2011 Variable Name	Notes
SQG-01	BSBG01	Are you a girl or a boy?	BSBG01	
SQG-02a	BSBG02A	When were you born? Month	BSBG02A	
SQG-02b	BSBG02B	When were you born? Year	BSBG02B	
SQG-03	BSBG03	How often do you speak <language of test> at home?	BSBG03	

Figure 7.1: Example of the relationships between similar variables in TIMSS 2011 and TIMSS 2015 (Foy, 2017b)

The ICT-related variables from the Eighth Grade *Student* Questionnaires used in the study and their original IEA Likert-type response coding values are depicted in Table 7.1. Variables that are related to the same question in 2011 and 2015 are discussed jointly in the same sub-section in this chapter.

Table 7.1: ICT-related variables from the Eighth Grade *Student* Questionnaires

TIMSS 2011 variables	**TIMSS 2015 variables**	**Variable description**	**Original IEA Likert response coding values**
BSBG05A	BSBG06A BSBG06B	GEN\HOME POSSESS**COMPUTER\ TABLET** GEN\HOME POSSESS**COMPUTER\ TABLET SHARED**	1 = Yes 2 = No 9 = Omitted or invalid
BSBG10A BSBG10B BSBG10C	BSBG13A BSBG13B BSBG13C	GEN\HOW OFTEN**USE COMPUTER\ HOME** GEN\HOW OFTEN**USE COMPUTER\ SCHOOL** GEN\HOW OFTEN**USE COMPUTER\ OTHER**	1 = Every day or almost every day 2 = Once or twice a week 3 = Once or twice a month 4 = Never or almost never 9 = Omitted or invalid

Variables identified from Foy (2017b), Mullis et al. (2009) and Mullis and Martin (2013)

The nine variables, four from TIMSS 2011 and five from TIMSS 2015, were statistically analysed using SPSS syntax generated by the IEA IDB Analyzer. The SPSS output was organised according to the recoded dichotomous scales. Each variable group was analysed per province and per response, taking the weighting of the mathematics achievement (expressed as the plausible value – PV) of learners in that province into account.

TIMSS results are reported on the TIMSS achievement scale with a range of 0 to 1 000 points (Mullis, Martin, Foy, et al., 2012; Mullis, Martin, Foy, et al., 2016). The IEA uses 500 points as centrepoint of the achievement scale across all TIMSS projects. South African Grade 9 learners achieved an average of 352 points on the TIMSS achievement scale in the 2011 assessments (Mullis, Martin, Foy, et al., 2012). In the 2015 assessments South African Grade 9 learners achieved a slightly higher average score of 372 points on the TIMSS achievement scale (Mullis, Martin, Foy, et al., 2016).

7.2. Availability of computer technology at home – an expansion of the TIMSS 2011 variable

In order to gauge the availability of computers to learners, a question related to the availability of **a computer at home** was included in both the 2011 and 2015 Eighth Grade *Student* Questionnaires. An interesting change in the wording of the question in the 2015 Eighth Grade *Student* Questionnaire was the expansion of the question to include the words "computer or tablet of your own" (Foy, 2017b, p. 162). A second question was added to the 2015 Eighth Grade *Student* Questionnaire referring specifically to a "computer or tablet that is shared with other people at home" (Foy, 2017b, p. 162). The change in question from TIMSS 2011 to TIMSS 2015 is depicted in Table 7.2.

Table 7.2: Change of BSBG05A (TIMSS 2011) to BSBG06A and BSBG06B (TIMSS 2015)

TIMSS 2011		**TIMSS 2015**	
BSBG05A	Do you have a computer at your home?	BSBG06A	Do you have any of these things at your home? A computer or tablet of your own
		BSBG06B	Do you have any of these things at your home? A computer or tablet that is shared with other people at home

Foy (2017b, p. 162)

These three variables will be discussed in two separate sections in this chapter. The availability of a computer at home will be discussed in relation to variable BSBG05A (TIMSS 2011) and variable BSBG06A (TIMSS 2015). The availability of a shared computer at home will be discussed in relation to variable BSBG05A (TIMSS 2011) and variable BSBG06B (TIMSS 2015).

7.3. Availability of an own computer at home (BSBG05A and BSBG06A)

The ISTE identifies seven ICT-related skills and qualities that learners need to engage in a digitally, connected world. The seven ISTE Standards for Students include the skill of “Global collaborator” – the ability to use ICT to broaden their perspectives and enrich their own learning (ISTE, 2016, para. 7). Learners are regularly confronted with new information that could have a direct impact on their cognitive growth (Gauvain & Munroe, 2009) if they possess the requisite skills to make sense of the new information (Flynn, 1999). Mdlongwa (2012) found that South African learners often acquire non-academic computer literacy skills during ICT lessons at school that can be used outside of the classroom as well. Hansen et al. (2012) found that in their project the primary impact of laptop use was on the learners’ cognitive performance rather than on their school performance.

In South Africa, it is especially important to note that the availability of ICT for personal use is usually closely linked to the country’s levels of economic and social development (Bialobrzeska & Cohen, 2005; Plomp et al., 2007; World Bank, 2016). The availability of ICT for personal use has increased over the past decade, but many South Africans still do not have access to ICT outside schools or the workplace. According to the General Household Survey conducted by Statistics South Africa in 2016, only 21.4% of South African households indicated that they possess at least one computer (Statistics South Africa, 2017).

Variable BSBG05A from TIMSS 2011 was expanded into two questions in 2015, namely variables BSBG06A and BSBG06B. Variable BSBG05A in TIMSS 2011 asked if learners had a computer at home. In TIMSS 2015, variable BSBG06A was expanded and learners were asked if they had a computer or tablet *of their own* at home. The details of variables BSBG05A and BSBG06A are depicted in Table 7.3.

Table 7.3: Availability of an own computer at home (BSBG05A and BSBG06A)

Variable	Year	Question text	Original coding values	Recoded values
BSBG05A	2011	Do you have a computer at your home?	1 = Yes	101 = Yes
			2 = No	102 = No
			9 = Omitted or invalid	9 = Omitted or invalid
BSBG06A	2015	Do you have any of these things at your home? • A computer or tablet of your own	1 = Yes	101 = Yes
			2 = No	102 = No
			9 = Omitted or invalid	9 = Omitted or invalid

7.3.1. Descriptive analysis – Availability of an own computer at home (BSBG05A and BSBG06A)

The availability of a computer at the learner's home was addressed by variables BSBG05A (TIMSS 2011) and BSBG06A (TIMSS 2015). Variable BSBG06A (TIMSS 2015) focused specifically on the availability of a computer or tablet that belongs to the learner and is not shared. The descriptive statistical analysis of BSBG05A and BSBG06A is depicted in Figure 7.2.

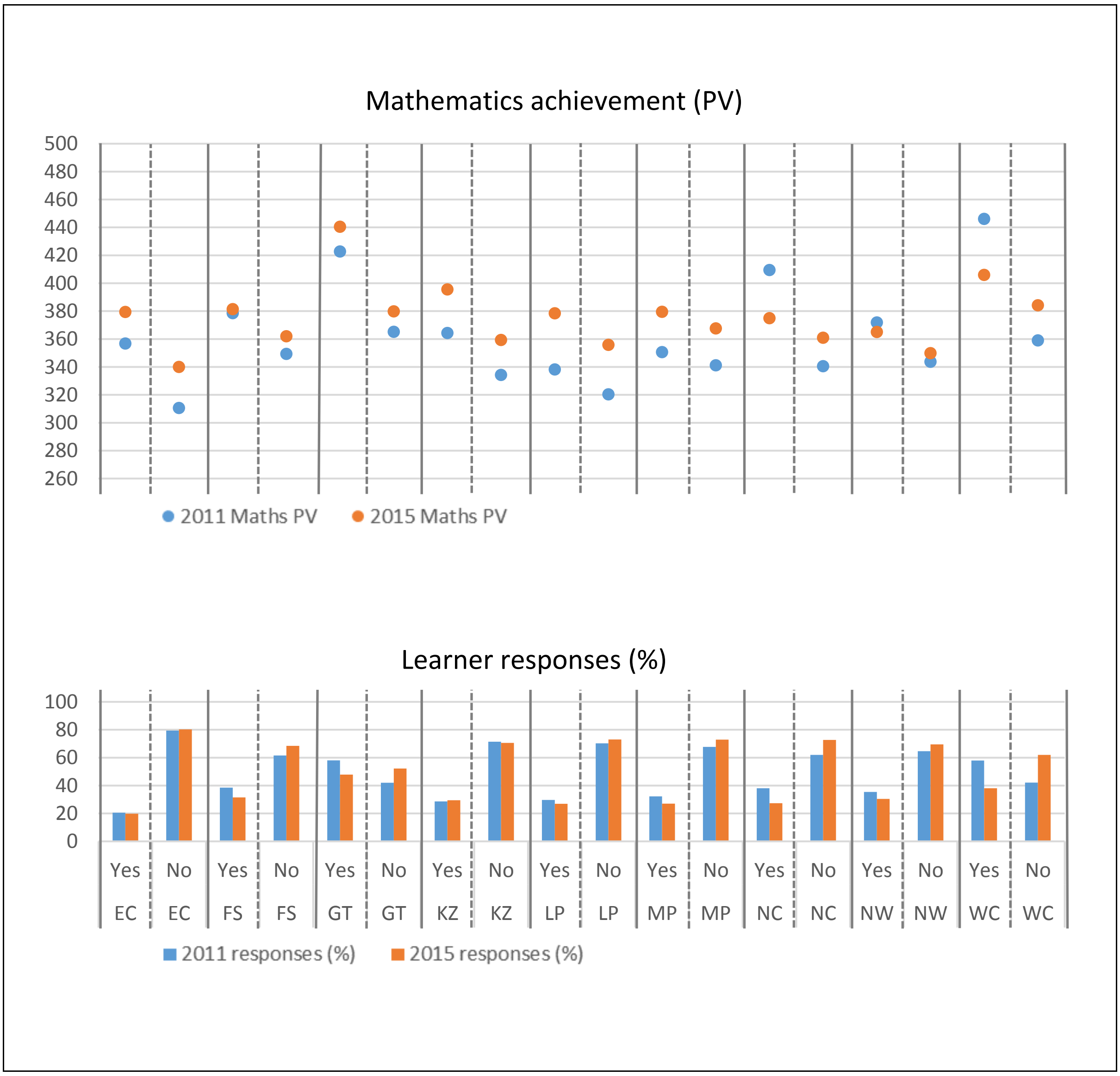

Figure 7.2: Availability of an own computer at home (BSBG05A and BSBG06A) – mathematics achievement and learner responses per province

Mathematics achievement in relation to the availability of an own computer at home

In 2011 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, came from schools in Gauteng (PV = 423) and the Western Cape (PV = 446) where learners indicated that they *had a computer at home*. In 2015 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, also came from schools in Gauteng (PV = 440) and the Western Cape (PV = 446) where learners indicated that they *had a computer or tablet of their own at home*.

In TIMSS 2011 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in the Eastern Cape (PV = 311) and Limpopo (PV = 320) where learners indicated that they *did not have a computer at home*. In TIMSS 2015 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in the Eastern Cape (PV = 340) and North West (PV = 350) where learners indicated that they *did not have a computer or tablet of their own at home*. These findings correspond with the findings of Statistics South Africa (Statistics South Africa, 2013, 2017) that identified the Eastern Cape and North West as two of the poorest provinces in South Africa.

An interesting observation is that in both 2011 and 2015 the learners that achieved the highest scores on the TIMSS achievement scale came from homes where learners indicated that they *had a computer or tablet at home*. Also, out of the descriptive data for the nine provinces in 2011 and 2015, learners from all provinces achieved higher scores if they indicated that they *had a computer or tablet at home*. Computer ownership is generally linked to a higher SES, and this may explain the difference in achievement between learners who *had a computer or tablet at home* and those that *did not have a computer or tablet at home.* The literature has shown that learners from a higher SES enjoy more support at home and may even attend 'better' schools (Gauvain & Munroe, 2009; Mdlongwa, 2012; Plomp et al., 2007).

Learner responses in relation to the availability of an own computer at home

In TIMSS 2011 the two provinces where the highest percentage of learners indicated that they *had a computer at home* were Gauteng (58.00%) and the Western Cape (57.89%). In TIMSS 2015 the highest percentage of learners from Gauteng (47.84%) and the Western Cape (38.04%) again indicated that they *had a computer or tablet of their own at home*. On the other hand, in 2011 the two provinces where the highest percentage of learners indicated that they *did not have computer at home* were the Eastern Cape (20.58%) and KwaZulu-Natal (28.58%). In 2015 the highest percentage of learners from the Eastern Cape (19.78%), Limpopo (26.96%), Mpumalanga (27.06%) and the Northern Cape (27.34%) indicated that they *did not have a computer or tablet of their own at home*. These findings seem to correspond with the Statistics South Africa General Household Surveys of 2012 and 2016 that found that only 19.5% of households owned a computer in 2012 (Statistics South Africa, 2013, p. 39), and 21.4% owned a computer in 2016 (Statistics South Africa, 2017, p. 56). According to the Statistics South Africa General Household Surveys of 2012 and 2016 computer ownership seems to be closely linked to the SES and the location of a household. Computer ownership seem to be much more common in urban and metropolitan areas, such as Gauteng and the Western Cape, and much less common in rural areas, such as the Eastern Cape, KwaZulu-Natal, Mpumalanga and the Northern Cape.

Another interesting observation is that between 2011 and 2015 the percentage of learners who *had a computer or tablet at home* seems to have stayed relatively constant in KwaZulu-Natal (28.58% and 29.47%), but decreased in all the other provinces. This decrease in the availability of computers or tablets at home does not align with the data available from Statistics South Africa (Statistics South Africa, 2013, 2017) as well as data from the other variables in this questionnaire. A possible explanation for this decrease seems to be the addition of the words "of your own" in the TIMSS 2015 question (Foy, 2017b, p. 162). Therefore the 2015 results from this variable should be seen in conjunction with variable BSBG06B – "Do you have any of these things at your home? A computer or tablet that is shared with other people at home" (Foy, 2017b, p. 162). This should give a clearer picture of the availability of computers and tablets at home.

7.3.2. Inferential analysis – Availability of an own computer at home (BSBG05A and BSBG06A)

SPSS syntax generated by the IEA IDB Analyzer was used to explore the relationship between the availability of a computer or tablet of at home in the nine South African provinces, and the mathematics achievement of these learners in both categories (*had a computer/tablet* at home; *did not have a computer/tablet* at home) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015, was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BSBG05A and BSBG06A is depicted in Table 7.4.

Table 7.4: Availability of an own computer at home (BSBG05A and BSBG06A) – means, differences, t-tests and p-values

		TIMSS 2011 BSBG05A		TIMSS 2015 BSBG06A		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Yes	356.7790	20.7741	379.3630	29.4943	-22.5841	36.0760	-0.6260	0.5313
EC	**No**	**310.6103**	**8.9947**	**339.9623**	**10.9040**	**-29.3520**	**14.1351**	**-2.0765**	**0.0378**
EC	Difference	46.1687	20.6770	39.4008	22.9005	6.7679	30.8540	0.2194	0.8264
FS	Yes	378.5338	15.1231	381.3708	18.6806	-2.8370	24.0348	-0.1180	0.9060
FS	No	349.3478	7.1728	361.9716	10.0562	-12.6238	12.3522	-1.0220	0.3068
FS	Difference	29.1860	15.3781	19.3992	12.2664	9.7868	19.6710	0.4975	0.6188
GT	Yes	422.7666	8.2628	440.4608	14.3304	-17.6942	16.5419	-1.0697	0.2848
GT	No	365.2035	3.7617	379.8295	8.0705	-14.6260	8.9041	-1.6426	0.1005
GT	Difference	57.5631	8.7778	60.6313	12.4226	-3.0682	15.2109	-0.2017	0.8401
KZ	Yes	364.3276	8.1043	395.5543	18.3928	-31.2266	20.0991	-1.5536	0.1203
KZ	**No**	**334.2718**	**4.7521**	**359.3674**	**9.0403**	**-25.0956**	**10.2132**	**-2.4572**	**0.0140**
KZ	Difference	30.0558	6.8395	36.1869	12.7426	-6.1311	14.4622	-0.4239	0.6716
LP	Yes	338.1510	14.3201	378.4201	18.3244	-40.2691	23.2561	-1.7315	0.0834
LP	**No**	**320.3731**	**5.6425**	**355.8699**	**11.4880**	**-35.4968**	**12.7989**	**-2.7734**	**0.0055**
LP	Difference	17.7779	16.3526	22.5503	9.1663	-4.7724	18.7464	-0.2546	0.7991
MP	Yes	350.6655	4.5563	379.4813	19.5697	-28.8157	20.0932	-1.4341	0.1515
MP	**No**	**341.2208**	**4.6804**	**367.6596**	**5.0585**	**-26.4388**	**6.8916**	**-3.8364**	**0.0001**
MP	Difference	9.4447	3.7307	11.8217	17.6824	-2.3769	18.0717	-0.1315	0.8954
NC	Yes	409.5083	28.7449	374.9893	11.4408	34.5190	30.9381	1.1157	0.2645
NC	**No**	**340.5660**	**3.8607**	**360.8756**	**6.4807**	**-20.3096**	**7.5435**	**-2.6923**	**0.0071**
NC	Difference	68.9422	28.1924	14.1137	9.0474	54.8286	29.6086	1.8518	0.0641
NW	Yes	371.8939	17.3238	365.0689	14.6745	6.8250	22.7036	0.3006	0.7637
NW	No	343.6984	8.2344	349.9334	5.8589	-6.2350	10.1060	-0.6170	0.5373
NW	Difference	28.1955	16.5864	15.1355	11.9132	13.0600	20.4214	0.6395	0.5225
WC	**Yes**	**446.0513**	**10.3142**	**405.9085**	**13.6288**	**40.1428**	**17.0917**	**2.3487**	**0.0188**
WC	**No**	**359.0427**	**4.5649**	**384.2259**	**10.1650**	**-25.1831**	**11.1430**	**-2.2600**	**0.0238**
WC	**Difference**	**87.0086**	**13.0000**	**21.6826**	**10.2002**	**65.3260**	**16.5241**	**3.9534**	**0.0001**

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). When looking at the statistical significance of the changes in mathematics achievement in relation to having a computer or tablet at home, six provinces

(EC, KZ, LP, MP, NC, WC) returned statistically significant t-tests and p-values. Accordingly only these six provinces will be discussed in this section.

The mathematics achievement of **Eastern Cape** learners who indicated that they *did not have a computer* at home increased from an average of 311 points in 2011 to an average of 340 points in 2015. Since the p-value was less than 0.05, the difference of 29 points was statistically significant (t = -2.08; p = 0.0378). The percentage of learners that indicated that they *did not have a computer* at home increased by 0.81% from an average of 79.42% in 2011 to an average of 80.22% in 2015. The means (2011 = 311; 2015 = 340) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 23 points by Eastern Cape learners who indicated that they *had a computer* at home was not statistically significant. The increase in mathematics achievement was higher in Eastern Cape schools where learners indicated that they *did not have a computer* at home.

The mathematics achievement of **KwaZulu-Natal** learners who indicated that they *did not have a computer* at home increased from an average of 334 points in 2011 to an average of 359 points in 2015. Since the p-value was less than 0.05, the difference of 25 points was statistically significant (t = -2.46; p = 0.0140). The percentage of learners that indicated that they *did not have a computer* at home decreased by 0.89% from an average of 71.42% in 2011 to an average of 70.53% in 2015. The means (2011 = 334; 2015 = 359) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 31 points by KwaZulu-Natal learners who indicated that they *had a computer* at home was not statistically significant. The increase in mathematics achievement was higher in KwaZulu-Natal schools where learners indicated that they *had a computer* at home.

The mathematics achievement of **Limpopo** learners who indicated that they *did not have a computer* at home increased from an average of 320 points in 2011 to an average of 356 points in 2015. Since the p-value was less than 0.05, the difference of 35 points was statistically significant (t = -2.77; p = 0.0055). The percentage of learners that indicated that they *did not have a computer* at home increased by 2.77% from an average of 70.27% in 2011 to an average of 73.04% in 2015. The means (2011 = 320; 2015 = 356) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 40 points by Limpopo learners who indicated that they *had a computer* at home was not statistically significant. The increase in mathematics achievement was higher in Limpopo schools where learners indicated that they *had a computer* at home.

The mathematics achievement of **Mpumalanga** learners who indicated that they *did not have a computer* at home increased from an average of 341 points in 2011 to an average of 368 points in 2015. Since the p-value was less than 0.05, the difference of 26 points was statistically significant (t = -3.84; p = 0.0001). The percentage of learners that indicated that they *did not have a computer* at home increased by 5.19% from an average of 67.75% in 2011 to an average of 72.94% in 2015. The means (2011 = 341; 2015 = 368) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 29 points by Mpumalanga learners who indicated that they *had a computer* at home was not statistically significant. The increase in mathematics achievement was higher in Mpumalanga schools where learners indicated that they *had a computer* at home.

The mathematics achievement of **Northern Cape** learners who indicated that they *did not have a computer* at home increased from an average of 341 points in 2011 to an average of 361 points in 2015. Since the p-value was less than 0.05, the difference of 20 points was statistically significant (t = -2.69; p = 0.0071). The percentage of learners that indicated that they *did not have a computer* at home increased by 10.70% from an average of 61.95% in 2011 to an average of 72.66% in 2015. The means (2011 = 341; 2015 = 361) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 35 points by Northern Cape learners who indicated that they *had a computer* at home was not statistically significant. The increase in mathematics achievement was higher in Northern Cape schools where learners indicated that they *had a computer* at home.

The mathematics achievement of **Western Cape** learners who indicated that they *had a computer* at home decreased from an average of 446 points in 2011 to an average of 406 points in 2015. Since the p-value was less than 0.05, the difference of 40 points was statistically significant ($t = 2.35$; $p = 0.0188$). The percentage of learners that indicated that they *had a computer* at home decreased by 19.85% from an average of 57.89% in 2011 to an average of 38.04% in 2015. The means (2011 = 446; 2015 = 406) indicate a negative difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant decrease in achievement. The mathematics achievement of Western Cape learners who indicated that they *did not have a computer* at home increased from an average of 359 points in 2011 to an average of 384 points in 2015. Since the p-value was less than 0.05, the difference of 25 points was statistically significant ($t = -2.26$; $p = 0.0238$). The percentage of learners that indicated that they *did not have a computer* at home increased by 19.85% from an average of 42.11% in 2011 to an average of 61.96% in 2015. The means (2011 = 359; 2015 = 384) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. In 2011, Western Cape learners who indicated that they *had a computer* at home, scored an average of 87 points higher than learners who indicated that they *did not have a computer* at home. In 2015, learners who indicated that they *had a computer* at home, scored an average of 22 points higher than learners who indicated that they *did not have a computer* at home. This difference of 65 points was statistically significant ($t = 3.95$, $p = 0.0001$). In the Western Cape the increase in mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *did not have a computer* at home.

The average mathematics achievement of South African learners in relation to the availability of computers at home, increased by 14 points from 361 points (2011) to 376 points (2015). Taking into account the relatively large jump in the average mathematics achievement of South African learners between 2011 and 2015, it was surprising how few of the increases in achievement were actually statistically significant. Out of 27 statistical calculations in Table 7.4, only eight were statistically significant. This may indicate that the availability of computers at home, statistically had a small influence on the overall 20 point increase between 2011 and 2015.

It is interesting to note that in both 2011 and 2015, learners from all six provinces achieved better results on the TIMSS achievement scale if they *had a computer or tablet at home*. However, in only one of the six provinces discussed in this section (WC) there was a statistically significant decrease in achievement by learners who *had a computer or tablet at home*. On the other hand, in all six provinces discussed in this section there was a statistically significant increase in achievement by learners who *did not have a computer or tablet at home*. One would expect learners who *had computers or tablets at home* to display statistically significant increases in achievement. This result therefore seems to not fully support previous studies that found that learners from higher SES households generally displayed better academic achievement (Ferrer et al., 2011; Pagani et al., 2016; Shank & Cotten, 2014). The reason for this discrepancy in the results from this study is not clear from the ICT-related variables examined from the Eighth Grade *Student* Questionnaires and further investigation may be warranted.

7.4. Availability of a shared computer at home (BSBG05A and BSBG06B)

Variable BSBG05A from TIMSS 2011 was expanded into two questions in TIMSS 2015, namely variable BSBG06A and BSBG06B. In TIMSS 2011 learners were asked if they had a computer at home. In TIMSS 2015 the second part of the expanded question asked learners if they had a *shared computer or tablet* at home. The details of variables BSBG05A and BSBG06B are depicted in Table 7.5.

Table 7.5: Availability of a shared computer at home (BSBG05A and BSBG06B)

Variable	Year	Question text	Original coding values	Recoded values
BSBG05A	2011	Do you have a computer at your home?	1 = Yes	101 = Yes
			2 = No	102 = No
			9 = Omitted or invalid	9 = Omitted or invalid
BSBG06B	2015	Do you have any of these things at your home? • A computer or tablet that is shared with other people at home	1 = Yes	101 = Yes
			2 = No	102 = No
			9 = Omitted or invalid	9 = Omitted or invalid

7.4.1. Descriptive statistics – Availability of a shared computer at home (BSBG05A and BSBG06B)

While the availability of any computer at the learner's home is addressed by variable BSBG05A in TIMSS 2011, variable BSBG06B in TIMSS 2015 focuses on the availability of a *shared computer or tablet* at the learner's home. The descriptive statistical analysis of BSBG05A and BSBG06B is depicted in Figure 7.3.

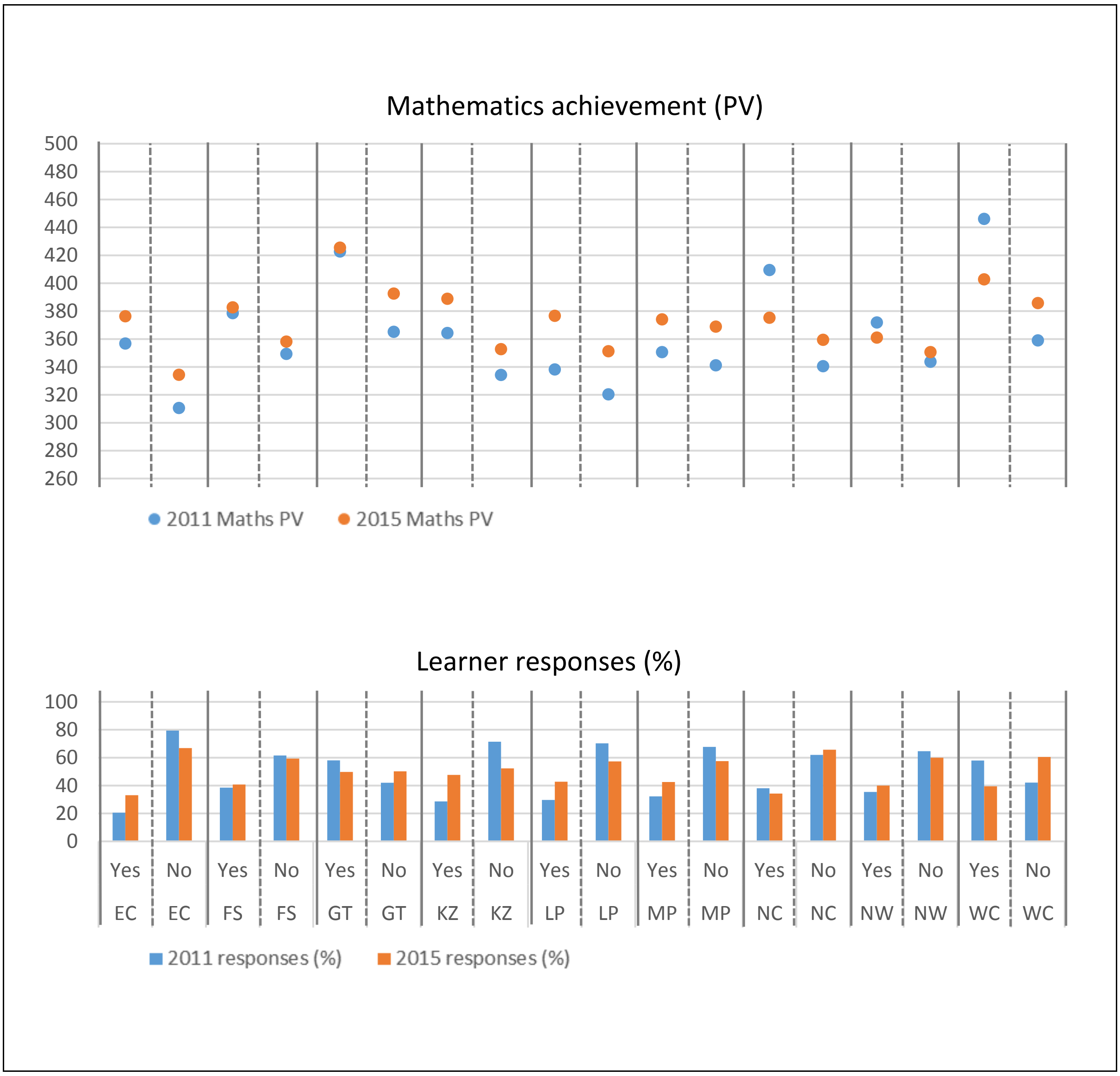

Figure 7.3: Availability of a shared computer at home (BSBG05A and BSBG06B) – mathematics achievement and learner responses per province

Mathematics achievement in relation to the availability of a shared computer at home

In 2011 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, came from schools in Gauteng (PV = 423) and the Western Cape (PV = 446) where learners indicated that they *had a computer* at home. In TIMSS 2015 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, also came from schools in Gauteng (PV = 425) and the Western Cape (PV = 403) where learners indicated that they *had a shared computer or tablet* at home.

In TIMSS 2011 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in the Eastern Cape (PV = 311) and Limpopo (PV = 320) where learners indicated that they *did not have a computer* at home. In TIMSS 2015 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in the Eastern Cape (PV = 334), Limpopo (PV = 351) and North West (PV = 351) where learners indicated that they *did not have a shared computer or tablet* at home.

An interesting observation is that, similarly to variable BSBG06A, in both 2011 and 2015 the learners that achieved the highest scores on the TIMSS achievement scale came from homes where learners indicated that they *had a shared computer or tablet* at home. Also, out of the descriptive data for the nine provinces in 2011 and 2015, again learners from all provinces achieved higher scores if they indicated that they *had a shared computer or tablet* at home. This corresponds with the finding in the previous section (Availability of a computer at home – BSBG05A and BSBG06A) that a computer at home, even if it is shared among household members, is a good indication of household SES. Again learners that had *a shared computer or tablet* at home seem to be from higher SES households and seem to have had access to better schools and academic support at home and therefore achieved higher scores on the TIMSS achievement scale.

Learner responses in relation to the availability of a shared computer at home

In 2011 the two provinces where the highest percentage of learners indicated that they *had a computer at home* were Gauteng (58.00%) and the Western Cape (57.89%). In 2015 the highest percentage of learners from Gauteng (49.76%) and KwaZulu-Natal (47.64%) indicated that they *had a shared computer or tablet* at home.

On the other hand, in 2011 the two provinces where the highest percentage of learners indicated that they *did not have computer at home* were the Eastern Cape (20.58%) and KwaZulu-Natal (28.58%). In 2015 the highest percentage of learners from the Eastern Cape (33.10%) and the Northern Cape (34.29%) indicated that they *did not have a shared computer or tablet* at home. The percentages reported for 2015 seem to be slightly higher than the 2015 percentages reported in the previous section (Availability of a computer at home – BSBG05A and BSBG06A). A possible explanation for this change could be that while more households own computers, these computers are generally shared among members of the household and do not belong to a single person.

Another interesting observation is that the percentage of learners who indicated that they *had a shared computer or tablet* at home seem to have increased in most provinces (EC, FS, KZ, LP, MP, NW), but decreased in three provinces (GT, NC, WC) over the period between 2011 and 2015. Again this decrease in the percentage of learners who indicated that they *had a shared computer or tablet* at home does not correlate with data available from Statistics South Africa (Statistics South Africa, 2013, 2017) as well as data from the other variables in this questionnaire. Again the possible explanation for this decrease seems to be the addition of the words "of your own" in the TIMSS 2015 BSBG06A question (Foy, 2017b, p. 162). The TIMSS 2015 results from this variable should also be seen in conjunction with variable BSBG06A – "Do you have any of these things at your home? A computer or tablet of your own" (Foy, 2017b, p. 162).

The change in wording of variables BSBG06A and BSBG06B in 2015 makes the quasi-longitudinal comparison with variable BSBG05A in 2011 very difficult as it seems as if many learners answered both questions in the affirmative. It seems as if many learners own a computer or tablet but also shares it with other people in the household. I would therefore suggest careful consideration of the wording of questions in future to eliminate any confusion, especially among second- or third language English speakers.

7.4.2. Inferential statistics – Availability of a shared computer at home (BSBG05A and BSBG06B)

The IEA IDB Analyzer was used to explore the relationship between the availability of a *shared computer or tablet at home*, and the mathematics achievement of South African learners in both categories (*had a shared computer/tablet* at home; *did not have a shared computer/tablet* at home) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015, was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BSBG05A and BSBG06B is depicted in Table 7.6.

Table 7.6: Availability of a shared computer at home (BSBG05A and BSBG06B) – means, differences, t-tests and p-values

		TIMSS 2011 BSBG05A		TIMSS 2015 BSBG06B		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Yes	356.7790	20.7741	376.3239	24.8279	-19.5450	32.3726	-0.6037	0.5460
EC	No	310.6103	8.9947	334.3898	9.7221	-23.7795	13.2448	-1.7954	0.0726
EC	Difference	46.1687	20.6770	41.9341	19.9191	4.2345	28.7107	0.1475	0.8827
FS	Yes	378.5338	15.1231	382.6689	17.7699	-4.1350	23.3340	-0.1772	0.8593
FS	No	349.3478	7.1728	358.1333	8.8533	-8.7854	11.3943	-0.7710	0.4407
FS	Difference	29.1860	15.3781	24.5356	11.4752	4.6504	19.1876	0.2424	0.8085
GT	Yes	422.7666	8.2628	425.4686	13.9995	-2.7020	16.2560	-0.1662	0.8680
GT	**No**	**365.2035**	**3.7617**	**392.5968**	**9.5359**	**-27.3933**	**10.2511**	**-2.6722**	**0.0075**
GT	Difference	57.5631	8.7778	32.8718	9.0913	24.6913	12.6373	1.9538	0.0507
KZ	Yes	364.3276	8.1043	388.8615	15.3767	-24.5339	17.3817	-1.4115	0.1581
KZ	No	334.2718	4.7521	352.7664	8.4669	-18.4946	9.7093	-1.9048	0.0568
KZ	Difference	30.0558	6.8395	36.0952	9.0687	-6.0393	11.3587	-0.5317	0.5949
LP	Yes	338.1510	14.3201	376.6761	18.5888	-38.5251	23.4650	-1.6418	0.1006
LP	**No**	**320.3731**	**5.6425**	**351.2425**	**9.2697**	**-30.8694**	**10.8520**	**-2.8446**	**0.0044**
LP	Difference	17.7779	16.3526	25.4336	11.0669	-7.6556	19.7455	-0.3877	0.6982
MP	**Yes**	**350.6655**	**4.5563**	**374.0838**	**11.0427**	**-23.4183**	**11.9458**	**-1.9604**	**0.0500**
MP	**No**	**341.2208**	**4.6804**	**368.9286**	**6.1935**	**-27.7078**	**7.7631**	**-3.5692**	**0.0004**
MP	Difference	9.4447	3.7307	5.1553	6.9695	4.2895	7.9052	0.5426	0.5874
NC	Yes	409.5083	28.7449	375.2567	11.6200	34.2516	31.0048	1.1047	0.2693
NC	**No**	**340.5660**	**3.8607**	**359.4237**	**5.5070**	**-18.8576**	**6.7255**	**-2.8039**	**0.0050**

		TIMSS 2011 BSBG05A		TIMSS 2015 BSBG06B		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
NC	Difference	68.9422	28.1924	15.8330	9.0947	53.1092	29.6231	1.7928	0.0730
NW	Yes	371.8939	17.3238	361.0120	11.1946	10.8819	20.6260	0.5276	0.5978
NW	No	343.6984	8.2344	350.6520	6.6497	-6.9536	10.5841	-0.6570	0.5112
NW	Difference	28.1955	16.5864	10.3600	7.2676	17.8355	18.1087	0.9849	0.3247
WC	**Yes**	**446.0513**	**10.3142**	**402.8035**	**13.5215**	**43.2478**	**17.0063**	**2.5430**	**0.0110**
WC	**No**	**359.0427**	**4.5649**	**385.7886**	**9.9108**	**-26.7459**	**10.9116**	**-2.4511**	**0.0142**
WC	**Difference**	**87.0086**	**13.0000**	**17.0149**	**7.3695**	**69.9937**	**14.9436**	**4.6839**	**0.0000**

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). When looking at the statistical significance of the changes in mathematics achievement, five provinces (GT, LP, MP, NC, WC) returned statistically significant t-tests and p-values. Accordingly only these five provinces will be discussed in this section.

The mathematics achievement of **Gauteng** learners who indicated that they *did not have a shared computer or tablet* at home increased from an average of 365 points in 2011 to an average of 393 points in 2015. Since the p-value was less than 0.05, the difference of 27 points was statistically significant (t = -2.67; p = 0.0075). The percentage of learners that indicated that they *did not have a shared computer or tablet* at home increased by 8.24% from an average of 42.00% in 2011 to an average of 50.24% in 2015. The means (2011 = 365; 2015 = 393) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 3 points by Gauteng learners who indicated that they *had a shared computer or tablet* at home was not statistically significant. In Gauteng the increase in mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *did not have a shared computer or tablet* at home.

The mathematics achievement of **Limpopo** learners who indicated that they *did not have a shared computer or tablet* at home increased from an average of 320 points in 2011 to an average of 351 points in 2015. Since the p-value was less than 0.05, the difference of 31 points was statistically significant (t = -2.84; p = 0.0044). The percentage of learners that indicated that they *did not have a shared computer or tablet* at home decreased by 13.01% from an average of 70.27% in 2011 to an average of 57.27% in 2015. The means (2011 = 320; 2015 = 351) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 39 points by Limpopo learners who indicated that they *had a shared computer or tablet* at home was not statistically significant. The increase in mathematics achievement of Limpopo learners between 2011 and 2015 was higher for learners who indicated that they *had a shared computer or tablet* at home.

The mathematics achievement of **Mpumalanga** learners who indicated that they *had a shared computer or tablet* at home increased from an average of 351 points in 2011 to an average of 374 points in 2015. Since the p-value was less than 0.05, the difference of 23 points was statistically significant (t = -1.96; p = 0.0500). The percentage of learners that indicated that they *had a shared computer or tablet* at home increased by 10.29% from an average of 32.25% in 2011 to an average of 42.54% in 2015. The means (2011 = 351; 2015 = 374) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The mathematics achievement of Mpumalanga learners who indicated that they *did not have a shared computer or tablet* at home increased from an average of 341 points in 2011 to an average of 369 points in 2015. Since the p-value was less than 0.05, the difference of 28 points was statistically significant (t = -3.57; p = 0.0004). The percentage of learners that indicated that they *did not have a shared computer or tablet* at home decreased by 10.29% from an average of 67.75% in 2011 to an average of 57.46% in 2015. The means (2011 = 341; 2015 = 369) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. In Mpumalanga the increase in mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *did not have a shared computer or tablet* at home.

The mathematics achievement of **Northern Cape** learners who indicated that they *did not have a shared computer or tablet* at home increased from an average of 341 points in 2011 to an average of 359 points in 2015. Since the p-value was less than 0.05, the difference of 19 points was statistically significant (t = -2.80; p = 0.0050). The percentage of learners that indicated that they *did not have a shared computer or tablet* at home increased by 3.75% from an average of 61.95% in 2011 to an average of 65.71% in 2015. The means (2011 = 341; 2015 = 359) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. A decrease in mathematics achievement of 34 points by Northern Cape learners who indicated that they *had a shared computer or tablet* at home was not statistically significant. The increase in Northern Cape mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *did not have a shared computer or tablet* at home.

The mathematics achievement of **Western Cape** learners who indicated that they *had a shared computer or tablet* at home decreased from an average of 446 points in 2011 to an average of 403 points in 2015. Since the p-value was less than 0.05, the difference of 43 points was statistically significant (t = 2.54; p = 0.0110). The percentage of learners that indicated that they *had a shared computer or tablet* at home decreased by 18.40% from an average of 57.89% in 2011 to an average of 39.49% in 2015. The means (2011 = 446; 2015 = 403) indicate a negative difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant decrease in achievement. The mathematics achievement of Western Cape learners who indicated that they *did not have a shared computer or tablet* at home increased from an average of 359 points in 2011 to an average of 386 points in 2015. Since the p-value was less than 0.05, the difference of 27 points was statistically significant (t = -2.45; p = 0.0142). The percentage of learners that indicated that they *did not have a shared computer or tablet* at home increased by 18.40% from an average of 42.11% in 2011 to an average of 60.51% in 2015. The means (2011 = 359; 2015 = 386) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. In 2011, Western Cape learners who indicated that they *had a shared computer* *or tablet* at home, scored an average of 87 points higher than learners who indicated that they *did not have a shared computer or tablet* at home. In 2015, learners who indicated that they *had a shared computer or tablet* at home, scored an average of 17 points higher than learners who indicated that they *did not have a shared computer or tablet* at home. This difference of 70 points was statistically significant ($t = 4.68$, $p = 0.0000$). The increase in Western Cape mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *did not have a shared computer or tablet* at home.

The average mathematics achievement of South African learners in relation to the availability of a shared computer or tablet at home, increased by 12 points from 361 points (2011) to 373 points (2015). Out of 27 statistical calculations in Table 7.6, only eight were statistically significant. This may indicate that the availability of computers at home, statistically had a small influence on the overall 20 point increase between 2011 and 2015.

It is interesting to note that in both 2011 and 2015, learners from all five provinces achieved better results on the TIMSS achievement scale if they *had a shared computer or tablet at home*. However, in only two of the five provinces discussed in this section (MP, WC) there was a statistically significant change in achievement by learners who *had a shared computer or tablet at home* – in Mpumalanga there was an increase of 23 points and in the Western Cape there was a 43 point decrease. On the other hand, in all five provinces discussed in this section there was a statistically significant increase in achievement by learners who *did not have a shared computer or tablet at home*. This finding is similar to the finding regarding the availability of a computer at home in the previous section. One would expect learners who *had shared computers or tablets at home* to display statistically significant increases in achievement. Again the reason for this discrepancy in the results from this study is not clear from the ICT-related variables examined from the Eighth Grade *Student* Questionnaires and further investigation may be encouraged.

7.5. Use of computers by South African learners

The availability of ICT for personal use is closely linked to a country's levels of economic and social development – the more ICT available for personal use, the higher a country's levels of economic and social development (Bialobrzeska & Cohen, 2005; Plomp et al., 2007; World Bank, 2016). In South Africa the availability of ICT for personal use slowly increased over the recent past. In the period from 2012 to 2016 the availability of at least one computer in homes increased by a meagre 1.9% from 19.5% in 2012 (Statistics South Africa, 2013) to 21.4% in 2016 (Statistics South Africa, 2017). However, in order to use ICT for their own benefit, learners need to acquire specific skills, such as using ICT to aid knowledge construction and being able to use ICT to interpret, understand and solve everyday problems (ISTE, 2016). If learners do not acquire these skills for optimal functioning in a knowledge society (Anderson, 2008), they tend to use ICT as a *toy*, and not as a tool for learning (Barrera-Osorio & Linden, 2009).

In an attempt to determine to which extent learners used ICT, the IEA included a set of questions related to the **use of computers at home, at school** and **at other places** in both the 2011 and 2015 Eighth Grade *Student* Questionnaires. An interesting change in the wording of the questions in the 2015 Eighth Grade *Student* Questionnaire was the expansion of the questions to include the words "for schoolwork" (Foy, 2017b, p. 162). Grade 9 learners were asked how often they used computers or tablets at home, at school and at other places.

7.6. Computer use at home (BSBG10A and BSBG13A)

Variable BSBG10A from TIMSS 2011 dealt with the question of how often learners used a computer at home. In TIMSS 2015, variable BSBG13A was expanded and asked learners specifically how often they **used a computer or tablet at home for schoolwork**. The details of variables BSBG10A and BSBG13A are depicted in Table 7.7.

Table 7.7: Computer use at home (BSBG10A and BSBG13A)

Variable	Year	Question text	Original coding values	Recoded values
BSBG10A	2011	How often do you use a computer at home?	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid
BSBG13A	2015	How often do you use a computer or tablet in each of these places for schoolwork? • At home	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid

7.6.1. Descriptive statistics - Computer use at home (BSBG10A and BSBG13A)

In TIMSS 2011 variable BTBG10A dealt with the question of how often the learners used a computer at home. In TIMSS 2015 variable BTBG13A expanded the question to refer to the frequency of use at home of a computer or tablet for school work. The descriptive statistical analysis of BTBG10A and BTBG13A is depicted in Figure 7.4.

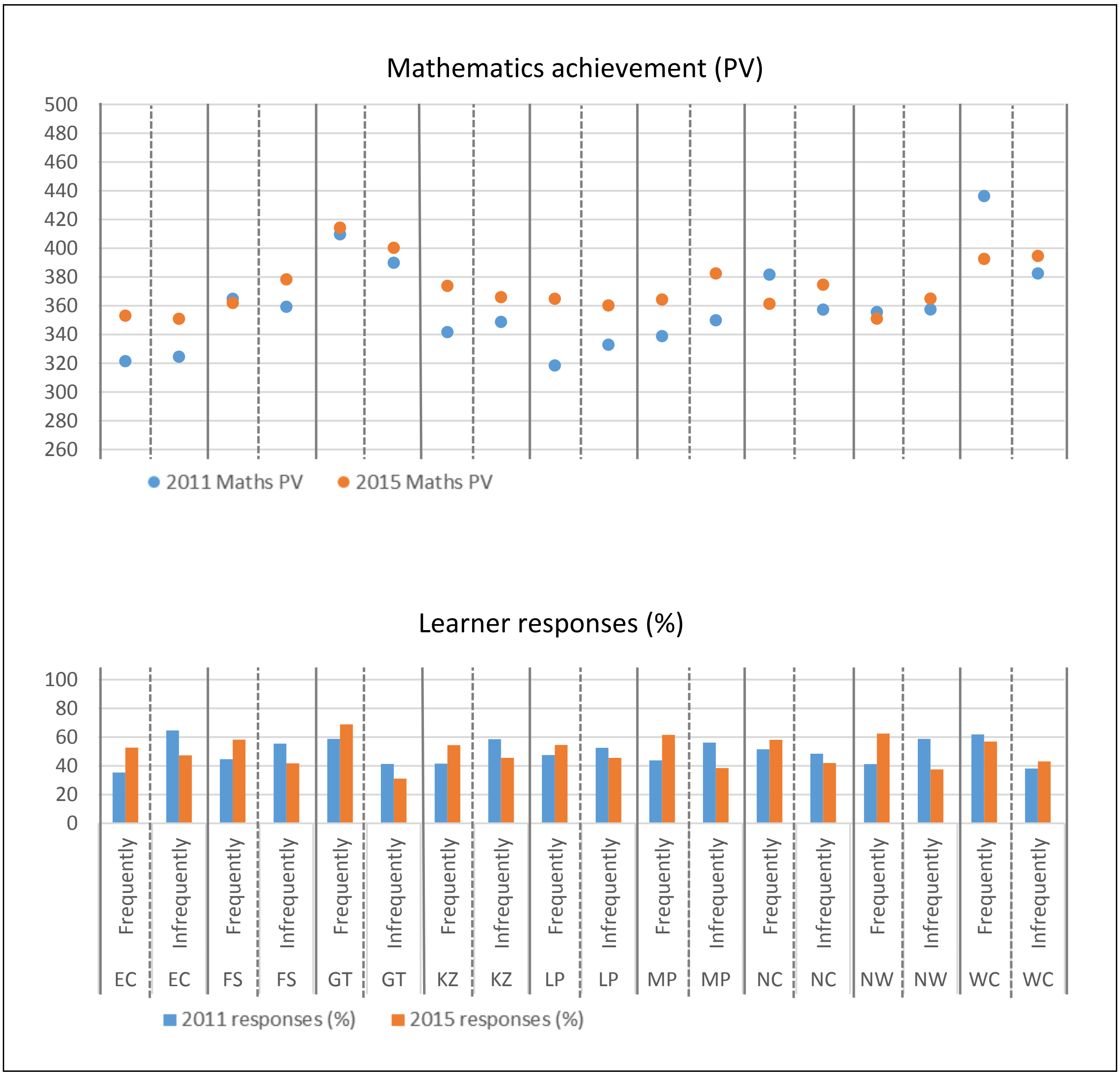

Figure 7.4: Computer use at home (BSBG10A and BSBG13A) – mathematics achievement and learner responses per province

Mathematics achievement in relation to computer use at home

In TIMSS 2011 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, came from schools in Gauteng (PV = 410) and the Western Cape (PV = 436) where learners indicated that they *frequently* used a computer at home. In TIMSS 2015 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, both came from schools in Gauteng. Learners that *frequently* used a computer or tablet at home scored an average of 414 points on the TIMSS achievement scale, while learners that *infrequently* used computers at home scored an average of 400 points.

In TIMSS 2011 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in the Eastern Cape (PV = 321) and Limpopo (PV = 318) where learners indicated that they *frequently* used a computer at home. In TIMSS 2015 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in the Eastern Cape (PV = 351) where learners indicated that they *infrequently* used a computer at home, and from schools in North West (PV = 351) where learners indicated that they *frequently* used a computer at home.

An interesting observation, which seems to be related to variable BSBG06A, is that in both 2011 and 2015 the learners that achieved the highest scores on the TIMSS achievement scale came from homes where computers or tablets were *frequently* used. This may support the idea that computers at home are a good indication of a higher SES and these learners therefore receive more academic support from home.

In the 2011 descriptive data, learners from four provinces (FS, GT, NC, WC) achieved better scores if they *frequently* used computers or tablets at home. Learners from Gauteng (PV difference = 20), the Northern Cape (PV difference = 25) and the Western Cape (PV difference = 57) recorded the biggest difference in achievement between learners who *frequently* used computers at home, and those that *infrequently* use computers at home. This may indicate that learners who have been exposed to province-wide ICT integration programmes in schools are better able to use computers for learning by transferring skills learned in school to the home environment. In the 2015 descriptive data, learners from four provinces (EC, GT, KZ, LP, WC) achieved better scores if they *frequently* used computers or tablets at home, but while the average achievement of all learners increased, the difference in achievement between the two categories were much smaller. If one looks at this finding in relation with the findings on computer use at schools from the Eighth Grade *Mathematics Teacher* Questionnaires, this may indicate that computer use in schools have diminished over the period between 2011 and 2015 and therefore learners did not have the skills necessary to fully benefit from having a computer at home for schoolwork.

Learner responses in relation to computer use at home

In TIMSS 2011 the two provinces where learners indicated the highest percentage of *frequently* using a computer at home were Gauteng (58.70%) and the Western Cape (61.84%). In TIMSS 2015 learners from Gauteng (68.84%) and North West (62.49%) reported the highest percentage of *frequently* using a computer or tablet at home for schoolwork.

In 2011 the two provinces where the highest percentage of learners indicated that they *infrequently* used a computer at home, were KwaZulu-Natal (41.50%) and North West (41.26%). In 2015 the highest percentage of learners from the Eastern Cape (52.68%) and Limpopo (54.49%) indicated that they *infrequently* used a computer or tablet at home for schoolwork. It is interesting to note that these percentages closely resemble the results from the previous two sections in this chapter (Availability of a computer at home – BSBG05A and BSBG06A; Availability of a shared computer at home –BSBG05A and BSBG06B) and this seems to confirm the availability of computers as reported earlier.

Another interesting observation is that the percentage of learners that indicated that they *frequently* use computers or tablets at home seems to have increased in all provinces, except for the Western Cape. In the Western Cape there was a decrease of 5.42% in the frequent use of computers or tablets at home over this period of time. This seems to corroborate claims from the WCED that there was an influx of learners from other provinces into WCED government schools (WCED, 2016). These learners were mostly from disadvantaged backgrounds and the decrease in availability of computers at homes in the Western Cape seems to support this idea.

7.6.2. Inferential statistics - Computer use at home (BSBG10A and BSBG13A)

The IEA IDB Analyzer was used to explore the relationship between the frequency with which learners in the nine South African provinces used a computer at home, and the mathematics achievement of these learners in both categories (*frequently* used a computer/tablet at home; *infrequently* used a computer/tablet at home) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015, was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BSBG10A and BSBG13A is depicted in Table 7.8.

Table 7.8: Computer use at home (BSBG10A and BSBG13A) – means, differences, t-tests and p-values

		TIMSS 2011 BSBG10A		TIMSS 2015 BSBG13A		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Frequently	321.4530	14.3416	353.0932	20.7207	-31.6402	25.1997	-1.2556	0.2093
EC	Infrequently	324.5669	10.3774	350.9276	9.9569	-26.3607	14.3816	-1.8330	0.0668
EC	Difference	-3.1139	13.3560	2.1656	13.5971	-5.2795	19.0595	-0.2770	0.7818
FS	Frequently	364.8731	14.7475	361.9336	13.9222	2.9395	20.2810	0.1449	0.8848
FS	Infrequently	359.3058	6.3056	378.3349	11.4890	-19.0291	13.1056	-1.4520	0.1465
FS	Difference	5.5672	12.7197	-16.4014	6.4699	21.9686	14.2706	1.5394	0.1237
GT	Frequently	409.6186	9.2126	414.3244	13.6304	-4.7058	16.4518	-0.2860	0.7748
GT	Infrequently	389.8894	4.8578	400.2397	8.7009	-10.3502	9.9651	-1.0386	0.2990
GT	Difference	19.7291	8.7789	14.0847	9.4765	5.6444	12.9179	0.4369	0.6622
KZ	Frequently	341.6886	7.5762	373.8396	17.0483	-32.1509	18.6560	-1.7234	0.0848
KZ	Infrequently	348.8005	4.7062	365.9927	7.7055	-17.1922	9.0290	-1.9041	0.0569
KZ	Difference	-7.1119	5.8533	7.8469	13.1439	-14.9587	14.3883	-1.0396	0.2985
LP	**Frequently**	**318.4177**	**10.9202**	**364.8798**	**18.3941**	**-46.4621**	**21.3914**	**-2.1720**	**0.0299**
LP	**Infrequently**	**332.8711**	**5.7338**	**360.1445**	**9.2884**	**-27.2734**	**10.9156**	**-2.4986**	**0.0125**
LP	Difference	-14.4534	12.1368	4.7354	12.6305	-19.1887	17.5166	-1.0955	0.2733
MP	**Frequently**	**338.8906**	**4.4727**	**364.2707**	**8.8307**	**-25.3800**	**9.8988**	**-2.5640**	**0.0103**
MP	**Infrequently**	**349.9214**	**4.9402**	**382.4477**	**7.5367**	**-32.5263**	**9.0115**	**-3.6094**	**0.0003**
MP	Difference	-11.0307	4.3746	-18.1771	5.5129	7.1463	7.0377	1.0154	0.3099
NC	Frequently	381.6398	26.0681	361.3301	8.7677	20.3097	27.5031	0.7385	0.4602
NC	Infrequently	357.2674	8.7315	374.6183	6.2307	-17.3509	10.7266	-1.6176	0.1058
NC	Difference	24.3723	20.1862	-13.2883	5.6700	37.6606	20.9674	1.7961	0.0725
NW	Frequently	355.5532	16.1141	351.0522	9.4412	4.5010	18.6762	0.2410	0.8096
NW	Infrequently	357.3680	8.2580	364.9802	8.0322	-7.6122	11.5200	-0.6608	0.5088
NW	Difference	-1.8148	12.9087	-13.9280	5.9100	12.1132	14.1973	0.8532	0.3935
WC	**Frequently**	**436.2812**	**11.9362**	**392.5440**	**12.7020**	**43.7372**	**17.4303**	**2.5093**	**0.0121**

		TIMSS 2011 BSBG10A		TIMSS 2015 BSBG13A		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
WC	Infrequently	382.4480	5.3235	394.6436	10.0416	-12.1956	11.3655	-1.0730	0.2833
WC	**Difference**	**53.8332**	**13.7454**	**-2.0995**	**7.6618**	**55.9327**	**15.7365**	**3.5543**	**0.0004**

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). When looking at the statistical significance of the changes in mathematics achievement in relation to the frequency of use of a computer or tablet for schoolwork at home, three provinces (LP, MP, WC) returned statistically significant t-tests and p-values. Accordingly only these three provinces will be discussed in this section.

The mathematics achievement of **Limpopo** learners who indicated that they *frequently* used a computer or tablet for schoolwork at home increased from an average of 318 points in TIMSS 2011 to an average of 365 points in TIMSS 2015. Since the p-value was less than 0.05, the difference of 46 points was statistically significant (t = -2.17; p = 0.0299). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at home increased by 7.02% from an average of 47.47% in 2011 to an average of 54.49% in 2015. The means (2011 = 318; 2015 = 365) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The mathematics achievement of Limpopo learners who indicated that they *infrequently* used a computer or tablet for schoolwork at home increased from an average of 333 points in TIMSS 2011 to an average of 360 points in TIMSS 2015. Since the p-value was less than 0.05, the difference of 27 points was statistically significant (t = -2.50; p = 0.0125). The percentage of learners that indicated that they *infrequently* used a computer or tablet for schoolwork at home decreased by 7.02% from an average of 52.53% in 2011 to an average of 45.51% in 2015. The means (2011 = 333; 2015 = 360) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The increase in Limpopo mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *frequently* used a computer or tablet for schoolwork at home.

The mathematics achievement of **Mpumalanga** learners who indicated that they *frequently* used a computer or tablet for schoolwork at home increased from an average of 339 points in TIMSS 2011 to an average of 364 points in TIMSS 2015. Since the p-value was less than 0.05, the difference of 25 points was statistically significant (t = -2.56; p = 0.0103). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at home increased by 17.75% from an average of 43.79% in 2011 to an average of 61.54% in 2015. The means (2011 = 339; 2015 = 364) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The mathematics achievement of Mpumalanga learners who indicated that they *infrequently* used a computer or tablet for schoolwork at home increased from an average of 350 points in TIMSS 2011 to an average of 382 points in TIMSS 2015. Since the p-value was less than 0.05, the difference of 33 points was statistically significant (t = -3.61; p = 0.0003). The percentage of learners that indicated that they *infrequently* used a computer or tablet for schoolwork at home decreased by 17.75% from an average of 56.21% in 2011 to an average of 38.46% in 2015. The means (2011 = 350; 2015 = 382) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The increase in Mpumalanga mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *infrequently* used a computer or tablet for schoolwork at home.

The mathematics achievement of **Western Cape** learners who indicated that they *frequently* used a computer or tablet for schoolwork at home decreased from an average of 436 points in TIMSS 2011 to an average of 393 points in TIMSS 2015. Since the p-value was less than 0.05, the difference of 44 points was statistically significant (t = 2.51; p = 0.0121). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at home decreased by 4.91% from an average of 61.84% in 2011 to an average of 56.92% in

2015. The means (2011 = 436; 2015 = 393) indicate a negative difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant decrease in achievement. The increase in mathematics achievement of 12 points of Western Cape learners who indicated that they *infrequently* used a computer or tablet for schoolwork at home was not statistically significant. In 2011, Western Cape learners who indicated that they *frequently* used a computer or tablet for schoolwork at home, scored an average of 54 points higher than learners who indicated that they *infrequently* used a computer or tablet for schoolwork at home. In 2015, Western Cape learners who indicated that they *frequently* used a computer or tablet for schoolwork at home, scored an average of 2 points lower than learners who indicated that they *infrequently* used a computer or tablet for schoolwork at home. This difference of 56 points was statistically significant ($t = 3.55$, $p = 0.0004$).

The average mathematics achievement of South African learners in relation to the availability of shared computers or tablets at home, increased by 13 points from 359 points (2011) to 373 points (2015). Out of 27 statistical calculations in Table 7.8, only six calculations were statistically significant. This may indicate that the availability of shared computers or tablets at home, statistically had a small influence on the overall 20 point increase between 2011 and 2015.

It is interesting to note that in TIMSS 2011, only learners from the Western Cape achieved better results on the TIMSS achievement scale if they indicated that they *frequently* used a computer or tablet for schoolwork at home. In 2015 only learners from Limpopo achieved better results if they indicated that they *frequently* used a computer or tablet for schoolwork at home. A possible reason for this change may be because very few educators in these provinces actually use computers for mathematics instruction, these learners have not gained the necessary skills at school to use computers or tablets to support their own learning.

However, it is also important to note that just because a computer or tablet is available for schoolwork at home, does not necessarily translate into computer use for learning. Guidance is necessary in order to guide the use of computers or tablets to support learning and it seems as if many learners do not receive this support at home and therefore basically use the computer or tablet as a toy.

7.7. Computer use at school (BSBG10B and BSBG13B)

Variable BSBG10B from TIMSS 2011 dealt with the question of how often learners used a computer at school. In TIMSS 2015, variable BSBG13B was expanded and learners were asked specifically how often they used a computer or tablet at school for schoolwork. The details of variables BSBG10B and BSBG13B are depicted in Table 7.9.

Table 7.9: Computer use at school (BSBG10B and BSBG13B)

Variable	Year	Question text	Original coding values	Recoded values
BSBG10B	2011	How often do you use a computer at school?	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid
BSBG13B	2015	How often do you use a computer or tablet in each of these places for schoolwork? • At school	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid

7.7.1. Descriptive statistics - Computer use at school (BSBG10B and BSBG13B)

Variable BTBG10B in TIMSS 2011 dealt with the question of how often the learners used a computer at school. In TIMSS 2015 the question of variable BTBG13B was expanded to refer to the use of a computer or tablet at school for school work. The descriptive statistical analysis of BTBG10B and BTBG13B is depicted in Figure 7.5.

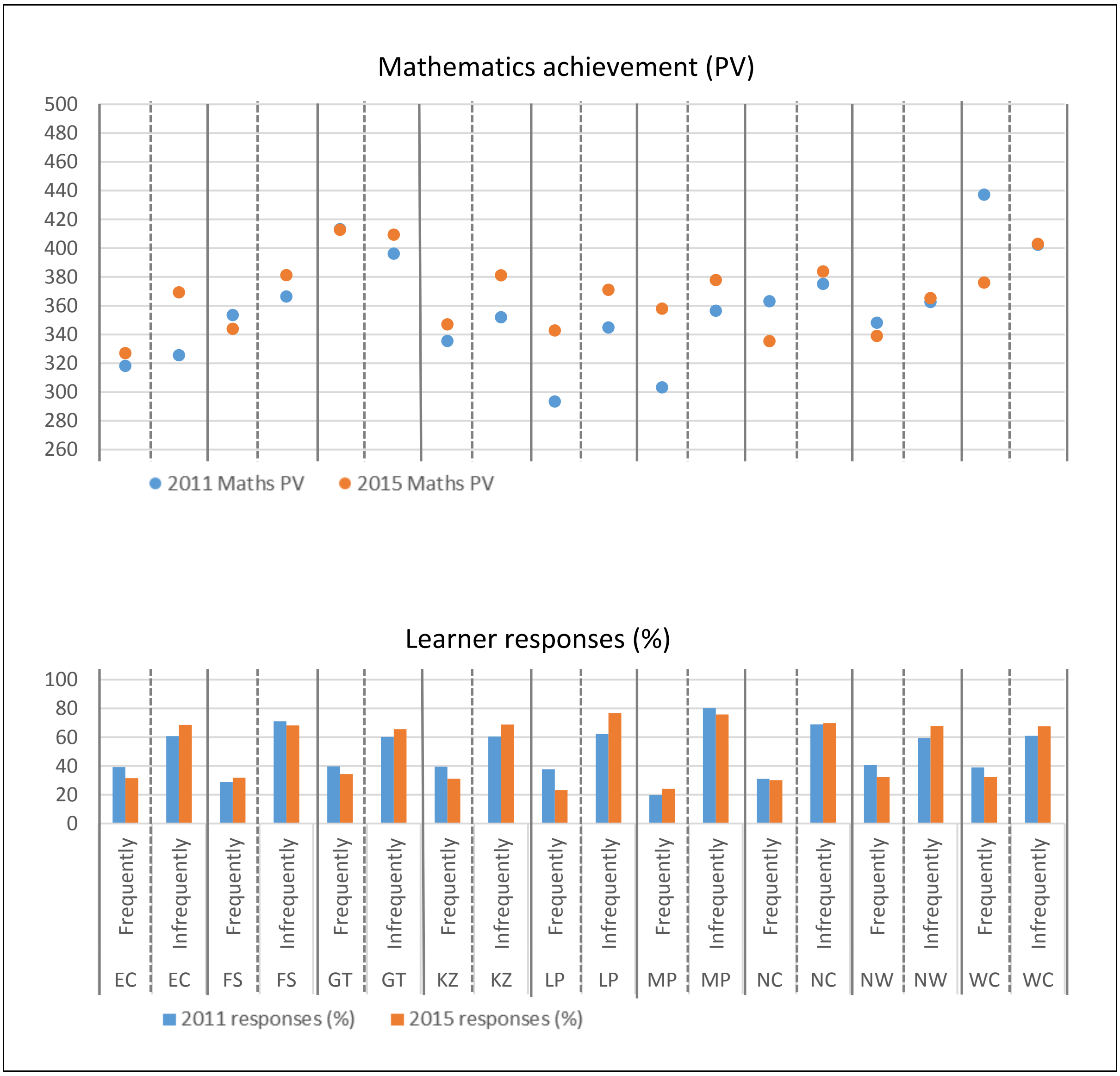

Figure 7.5: Computer use at school (BSBG10B and BSBG13B) – mathematics achievement and learner responses per province

Mathematics achievement in relation to computer use at school

In TIMSS 2011 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, came from schools in Gauteng (PV = 413) and the Western Cape (PV = 437) where learners indicated that they *frequently* used a computer at school. In TIMSS

2015 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, again both came from schools in Gauteng. Learners that *frequently* used a computer or tablet at school scored an average of 413 points on the TIMSS achievement scale, while learners that *infrequently* used computers or tablets at school scored an average of 409 points.

In TIMSS 2011 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in Mpumalanga (PV = 303) and Limpopo (PV = 293) where learners indicated that they *frequently* used a computer or tablet at school. Additionally, learners from only two provinces (GT, WC) achieved better scores if they *frequently* used computers or tablets at school for schoolwork. In TIMSS 2015 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in the Eastern Cape (PV = 327) and Northern Cape (PV = 335) where learners indicated that they *frequently* used a computer or tablet at school for schoolwork.

In the TIMSS 2015 descriptive data, learners from only one province (GT) achieved better scores if they *frequently* used computers or tablets at school for schoolwork. These results seem to indicate that the mere use of computers or tablets at school do not guarantee better achievement. ICT integration in the curriculum needs to be thoroughly planned and systematically implemented. During the study there was very little evidence of any coordinated effort to integrate ICT in the mathematics curriculum outside of Gauteng and the Western Cape. It therefore seems as if traditional mathematics teaching methods result in better results than when technology is used as teaching and learning tools in an uncoordinated way.

Learner responses in relation to computer use at school

In TIMSS 2011 the provinces where the highest percentage of learners indicated that they *frequently* used a computer at school for school work, were Gauteng (39.76%) and North

West (40.56%). In TIMSS 2015 the highest percentage of learners from Gauteng (34.42%) and the Western Cape (32.44%) indicated that they *frequently* used a computer or tablet at school for schoolwork. In 2011 the two provinces where the highest percentage of learners indicated that they *infrequently* used a computer at school were the Free State (71.10%) and Mpumalanga (80.11%). In 2015 learners from Limpopo (76.81%) and Mpumalanga (75.84%) reported the highest percentage of *infrequently* using a computer or tablet at school for schoolwork.

Another interesting observation is that the percentage of learners that indicated that they frequently used computers or tablets at school seems to have decreased in all provinces, except for the Free State and Mpumalanga. Even in the provinces where there was an increase in the *frequent* use of computers or tablets at school, these increases were marginally small (Free State = 2.96%; Mpumalanga = 4.27%). This finding corresponds with the findings from the Eighth Grade *Mathematics Teacher* Questionnaires where the vast majority of educators indicated that they do not use computers during mathematics lessons. This decrease in the use of computers at schools should be further investigated.

7.7.2. Inferential statistics - Computer use at school (BSBG10B and BSBG13B)

The IEA IDB Analyzer was used to explore the relationship between the frequency with which learners in the nine South African provinces used a computer or tablet at school, and the mathematics achievement of these learners in both categories (*frequently* used a computer/tablet at school; *infrequently* used a computer/tablet at school) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015, was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BSBG10B and BSBG13B is depicted in Table 7.10.

Table 7.10: Computer use at school (BSBG10B and BSBG13B) – means, differences, t-tests and p-values

		TIMSS 2011 BSBG10B		TIMSS 2015 BSBG13B		Inferential statistics results			
Prov	Code	Maths PV (mean)	Maths PV s.e.	Maths PV (mean)	Maths PV s.e.	Difference of diff	Error of Diff	t-test	p-value
EC	Frequently	318.0608	15.5185	326.9416	17.9587	-8.8808	23.7347	-0.3742	0.7083
EC	**Infrequently**	**325.5548**	**11.3215**	**369.2009**	**14.8557**	**-43.6461**	**18.6780**	**-2.3368**	**0.0195**
EC	Difference	-7.4940	16.9691	-42.2593	9.2244	34.7653	19.3143	1.8000	0.0719
FS	Frequently	353.4533	19.5174	343.8553	11.4842	9.5980	22.6454	0.4238	0.6717
FS	Infrequently	366.3381	6.5846	381.1722	13.1838	-14.8342	14.7367	-1.0066	0.3141
FS	Difference	-12.8848	16.6114	-37.3170	7.2799	24.4322	18.1366	1.3471	0.1779
GT	Frequently	413.1529	12.6387	412.7585	16.4207	0.3944	20.7214	0.0190	0.9848
GT	Infrequently	396.1235	6.0319	409.3371	11.0700	-13.2136	12.6067	-1.0481	0.2946
GT	Difference	17.0294	14.1611	3.4214	12.5061	13.6080	18.8929	0.7203	0.4714
KZ	Frequently	335.4197	8.2149	346.9441	20.9803	-11.5244	22.5313	-0.5115	0.6090
KZ	**Infrequently**	**351.9080**	**4.9143**	**381.1147**	**10.8066**	**-29.2067**	**11.8716**	**-2.4602**	**0.0139**
KZ	Difference	-16.4883	7.4694	-34.1707	16.9641	17.6824	18.5357	0.9540	0.3401
LP	**Frequently**	**293.3673**	**6.3526**	**342.7183**	**21.4325**	**-49.3510**	**22.3542**	**-2.2077**	**0.0273**
LP	Infrequently	344.8064	7.8023	371.0030	12.7632	-26.1966	14.9591	-1.7512	0.0799
LP	Difference	-51.4391	8.4245	-28.2847	13.7411	-23.1544	16.1180	-1.4366	0.1508
MP	**Frequently**	**303.1679**	**5.0933**	**357.8793**	**14.0333**	**-54.7114**	**14.9290**	**-3.6648**	**0.0002**
MP	**Infrequently**	**356.4064**	**4.0995**	**377.7715**	**6.8046**	**-21.3651**	**7.9441**	**-2.6894**	**0.0072**
MP	**Difference**	**-53.2385**	**5.7092**	**-19.8921**	**10.4405**	**-33.3464**	**11.8995**	**-2.8023**	**0.0051**
NC	Frequently	363.0305	18.8216	335.3137	6.1416	27.7169	19.7983	1.4000	0.1615
NC	Infrequently	375.0671	19.4327	383.7586	7.8352	-8.6916	20.9529	-0.4148	0.6783
NC	**Difference**	**-12.0365**	**16.2182**	**-48.4449**	**6.6649**	**36.4084**	**17.5343**	**2.0764**	**0.0379**
NW	Frequently	348.0874	17.7750	338.8981	11.8410	9.1893	21.3579	0.4303	0.6670
NW	Infrequently	362.5508	9.5365	365.2305	8.1510	-2.6797	12.5453	-0.2136	0.8309
NW	Difference	-14.4634	17.4405	-26.3324	8.1790	11.8690	19.2631	0.6161	0.5378
WC	**Frequently**	**437.1186**	**16.0302**	**376.0454**	**9.3013**	**61.0732**	**18.5332**	**3.2953**	**0.0010**
WC	Infrequently	402.2713	7.3169	402.9247	11.6336	-0.6534	13.7433	-0.0475	0.9621
WC	**Difference**	**34.8473**	**15.2671**	**-26.8793**	**5.4239**	**61.7266**	**16.2019**	**3.8098**	**0.0001**

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). When looking at the statistical significance of the changes in mathematics achievement, six provinces (EC, KZ, LP, MP, NC, WC) returned statistically significant t-tests and p-values. Accordingly only these six provinces will be discussed in this section.

The mathematics achievement of **Eastern Cape** learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school increased from an average of 326 points in 2011 to an average of 369 points in 2015. Since the p-value was less than 0.05, the difference of 44 points was statistically significant (t = -2.34; p = 0.0195). The percentage of learners that indicated that they *infrequently* used a computer or tablet for schoolwork at school, increased by 7.77% from an average of 60.79% in 2011 to an average of 68.56% in 2015. The means (2011 = 326; 2015 = 369) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 9 points by Eastern Cape learners who indicated that they *frequently* used a computer or tablet for schoolwork at school was not statistically significant. In the Eastern Cape the increase in mathematics achievement between the years was higher for learners that indicated that they *infrequently* used a computer or tablet for schoolwork at school.

The mathematics achievement of **KwaZulu-Natal** learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school increased from an average of 352 points in 2011 to an average of 381 points in 2015. Since the p-value was less than 0.05, the difference of 29 points was statistically significant (t = -2.46; p = 0.0139). The percentage of learners that indicated that they *infrequently* used a computer or tablet for schoolwork at school increased by 8.30% from an average of 60.48% in 2011 to an average of 68.78% in 2015. The means (2011 = 352; 2015 = 381) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 12 points by KwaZulu-Natal learners who indicated that they *frequently* used a computer or tablet for schoolwork at school was not statistically significant. In KwaZulu-Natal the increase in mathematics achievement between the years was higher for learners that indicated that they *infrequently* used a computer or tablet for schoolwork at school.

The mathematics achievement of **Limpopo** learners who indicated that they *frequently* used a computer or tablet for schoolwork at school increased from an average of 293 points in 2011 to an average of 343 points in 2015. Since the p-value was less than 0.05, the difference of 49 points was statistically significant (t = -2.21; p = 0.0273). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at school decreased by 14.46% from an average of 37.65% in 2011 to an average of 23.19% in 2015. The means (2011 = 293; 2015 = 343) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 26 points by Limpopo learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school was not statistically significant. In Limpopo the increase in mathematics achievement between the years was higher for learners that indicated that they *frequently* used a computer or tablet for schoolwork at school.

The mathematics achievement of **Mpumalanga** learners who indicated that they *frequently* used a computer or tablet for schoolwork at school increased from an average of 303 points in 2011 to an average of 358 points in 2015. Since the p-value was less than 0.05, the difference of 55 points was statistically significant ($t = -3.66$; $p = 0.0002$). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at school increased by 4.27% from an average of 19.89% in 2011 to an average of 24.16% in 2015. The means (2011 = 303; 2015 = 358) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The mathematics achievement of Mpumalanga learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school increased from an average of 356 points in 2011 to an average of 378 points in 2015. Since the p-value was less than 0.05, the difference of 21 points was statistically significant ($t = -2.69$; $p = 0.0072$). The percentage of learners that indicated that they *infrequently* used a computer or tablet for schoolwork at school decreased by 4.27% from an average of 80.11% in 2011 to an average of 75.84% in 2015. The means (2011 = 356; 2015 = 378) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. In 2011, Mpumalanga learners who indicated that they *frequently* used a computer or tablet for schoolwork at school, scored an average of 53 points lower than learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school. In 2015 learners who indicated that they *frequently* used a computer or tablet for schoolwork at school, scored an average of 20 points lower than learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school. This difference of 33 points was statistically significant (t = 2.80, p = 0.0051). In Mpumalanga the increase in mathematics achievement between the years was higher for learners that indicated that they *frequently* used a computer or tablet for schoolwork at school.

An increase in mathematics achievement of 28 points by **Northern Cape** learners who indicated that they *frequently* used a computer or tablet for schoolwork at school was not statistically significant. An increase in mathematics achievement of 9 points by Northern Cape learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school was also not statistically significant. In 2011, Northern Cape learners who indicated that they *frequently* used a computer or tablet for schoolwork at school, scored an average of 12 points lower than learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school. In 2015 learners who indicated that they *frequently* used a computer or tablet for schoolwork at school, scored an average of 48 points lower than learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school. This difference of 36 points was statistically significant (t = 2.08, p = 0.0379). In the Northern Cape the increase in mathematics achievement between the years was higher for learners that indicated that they *infrequently* used a computer or tablet for schoolwork at school.

The mathematics achievement of **Western Cape** learners who indicated that they *frequently* used a computer or tablet for schoolwork at school decreased from an average of 437 points in 2011 to an average of 376 points in 2015. Since the p-value was less than 0.05, the difference of 61 points was statistically significant (t = -3.30; p = 0.0010). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at school decreased by 6.61% from an average of 39.06% in 2011 to an average of 32.44% in 2015. The means (2011 = 437; 2015 = 376) indicate a negative difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant decrease in achievement. An increase in mathematics achievement of 1 point by Western Cape learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school was not statistically significant. In 2011, Western Cape learners who indicated that they *frequently* used a computer or tablet for schoolwork at school, scored an average of 35 points higher than learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school. In 2015 learners who indicated that they *frequently* used a computer or tablet for schoolwork at school, scored an average of 27 points lower than learners who indicated that they *infrequently* used a computer or tablet for schoolwork at school. This difference of 62 points was statistically significant ($t = 3.81$, $p = 0.0001$). In the Western Cape the increase in mathematics achievement between the years was higher for learners that indicated that they *infrequently* used a computer or tablet for schoolwork at school.

The average mathematics achievement of South African learners in relation to the use of a computer or tablet for schoolwork at school, increased by 10 points from 358 points (2011) to 368 points (2015). Again, taking into account the relatively large jump in the average mathematics achievement of South African learners between 2011 and 2015, it was surprising how few of the increases in achievement were actually statistically significant. Out of 27 statistical calculations in Table 7.10, only nine were statistically significant. This may indicate that the availability of computers during mathematics lessons statistically had a small influence on the overall 20 point increase between 2011 and 2015.

It is interesting to note that in TIMSS 2011, only learners from the Western Cape achieved better results on the TIMSS achievement scale if they *frequently* used a computer or tablet for schoolwork at school. In 2015 learners from all six provinces achieved better results on the TIMSS achievement scale if they *infrequently* used a computer or tablet for schoolwork at school. This finding seems to be related to findings from the Eighth Grade *Mathematics Teacher* Questionnaires on computer use by mathematics educators that also indicated that learner achievement decreased with the use of computers in mathematics teaching. Again a possible explanation may be the choice of educational software available. Another explanation may be that the mathematical comprehension of the average learner in these provinces was so low, that they benefitted more from a structured, traditional face-to-face interaction with an educator who could explain concepts on a level that they understood. A solid mathematics pedagogical content knowledge is required in order to effectively teach mathematics (Plotz et al., 2012). It seems as if educators who feel confident in teaching mathematics shy away from using technology for teaching and learning. On the other hand, educators who do not feel confident in teaching mathematics may rely heavily on technology for teaching and learning and this does not seem to benefit the learners in these classes.

7.8. Computer use at any other place (BSBG10C and BSBG13C)

Variable BSBG10C from TIMSS 2011 dealt with the question of how often learners used a computer at any other place. In TIMSS 2015, variable BSBG13C was expanded and specifically asked learners how often they used a computer or tablet at any other place for schoolwork. The details of variables BSBG10C and BSBG13C are depicted in Table 7.11.

Table 7.11: Computer use at any other place (BSBG10C and BSBG13C)

Variable	Year	Question text	Original coding values	Recoded values
BSBG10C	2011	How often do you use a computer at some other place?	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid
BSBG13C	2015	How often do you use a computer or tablet in each of these places for schoolwork? • Some other place	1 = Every day or almost every day 2 = Once or twice a week	101 = Frequently
			3 = Once or twice a month 4 = Never or almost never	102 = Infrequently
			6 = Logically not applicable 9 = Omitted or invalid	6 = Logically not applicable 9 = Omitted or invalid

7.8.1. Descriptive statistics – Computer use at any other place (BSBG10C and BSBG13C)

Variable BTBG10C in TIMSS 2011 dealt with the question of how often the learners used a computer at a place other than at home or at school. In TIMSS 2015 the question of variable BTBG13C was expanded to refer to the use of a computer or tablet for schoolwork at any other place. Figure 7.6 depicts the descriptive statistical analysis of BTBG10C and BTBG13C.

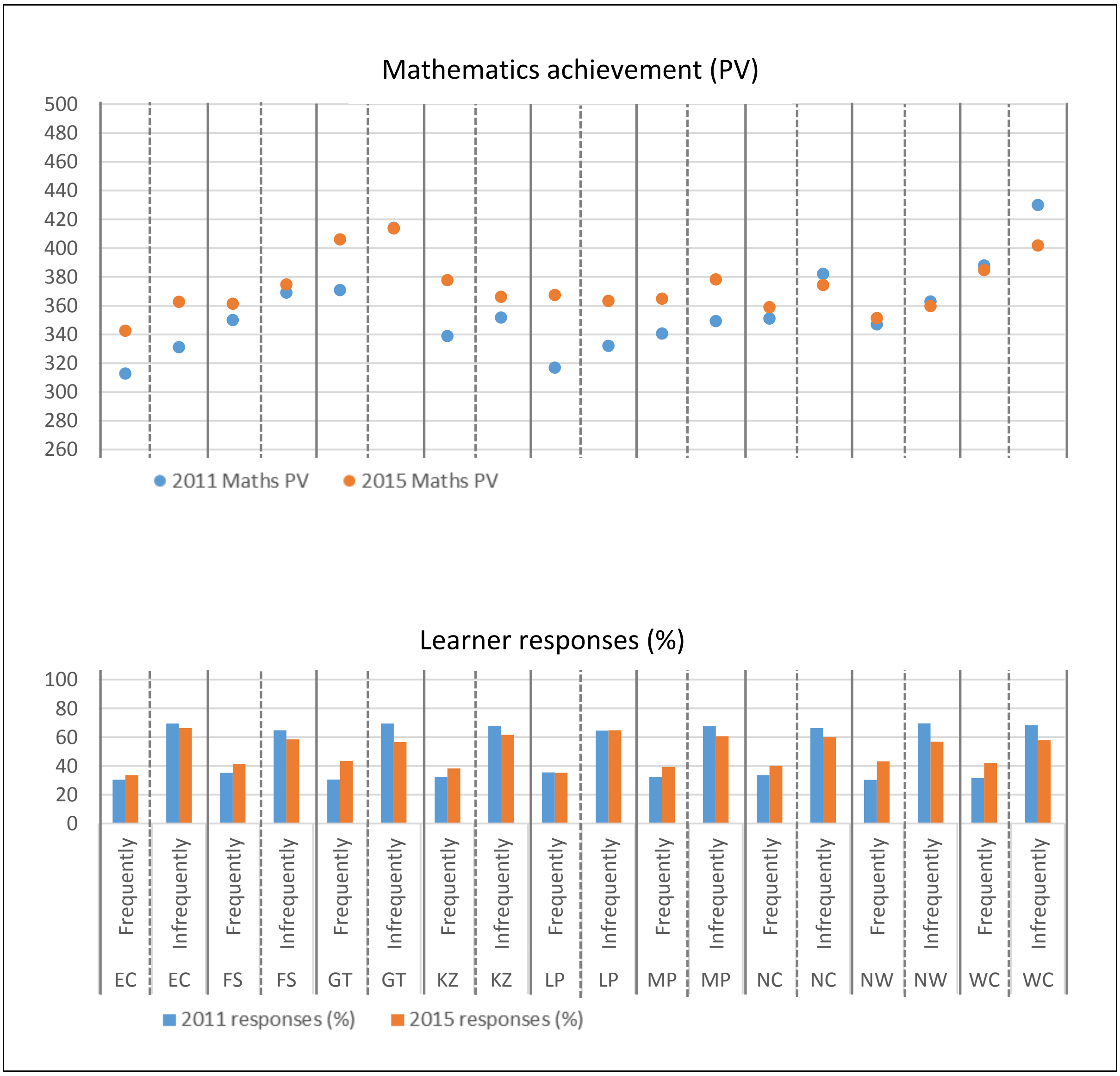

Figure 7.6: Computer use at any other place (BSBG10C and BSBG13C) – mathematics achievement and learner responses per province

Mathematics achievement in relation to computer use at any other place

In 2011 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, came from schools in Gauteng (PV = 414) and the Western Cape (PV = 430) where learners indicated that they *infrequently* used a computer at any other place. In 2015 the two groups of learners that achieved the two highest average scores on the TIMSS achievement scale, again both came from schools in Gauteng. Learners that *frequently* used a computer or tablet for schoolwork at any other place scored an average of 406 points on the TIMSS achievement scale, while learners that *infrequently* used computers at any other place for schoolwork scored an average of 414 points.

In TIMSS 2011 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in the Eastern Cape (PV = 313) and Limpopo (PV = 317) where learners indicated that they *frequently* used a computer at any other place. In TIMSS 2015 the two groups of learners that achieved the lowest average scores on the TIMSS achievement scale, came from schools in the Eastern Cape (PV = 343) and North West (PV = 351) where learners indicated that they *frequently* used a computer for schoolwork at any other place.

An interesting observation is that in the TIMSS 2011 descriptive data, learners from all nine provinces achieved better scores if they *infrequently* used computers or tablets at any other place. In the TIMSS 2015 descriptive data, learners from only two provinces (KZ, LP) achieved better scores if they *frequently* used computers or tablets for schoolwork at any other place. The interesting part is that learners from both Gauteng and the Western Cape who *infrequently* used computers at any other place were the top achievers of TIMSS 2011 and TIMSS 2015 – in 2011 learners from the Western Cape scored an average of 430 points, and in 2015 Gauteng learners came out tops with an average of 414 points. This finding seems to support the idea that the availability of a computer or tablet for schoolwork, does not necessarily translate into the optimal use of the computer or tablet for learning. In order to use a computer for their own benefit, learners need to acquire specific skills such as using ICT to aid knowledge construction and being able to use ICT to understand problems (ISTE, 2016). If learners do not acquire these skills, they tend to use ICT as a toy and not as a tool for learning (Anderson, 2008; Barrera-Osorio & Linden, 2009).

Learner responses in relation to computer use at any other place

In TIMSS 2011 the provinces where learners indicated the highest percentage of *frequently* using a computer at any other place were the Free State (35.19%) and Limpopo (35.47%). In TIMSS 2015 learners from Gauteng (43.40%) and North West (43.20%) recorded the highest percentage of *frequently* using a computer or tablet for schoolwork at any other place.

In 2011 the two provinces where learners indicated the highest percentage of *infrequently* using a computer at any other place were the Eastern Cape (69.50%) and North West (69.68%). In TIMSS 2015 learners from the Eastern Cape (66.37%) and Limpopo (64.80%) recorded the highest percentage of *infrequently* using a computer or tablet for schoolwork at any other place.

Another interesting observation is that the percentage of learners that indicated that they *frequently* used computers or tablets at any other place seem to have increased in eight of the nine provinces. In Limpopo the percentage of learners that indicated that they *frequently* used computers or tablets for schoolwork at any other place remained at around 35%. This finding seems to support findings by Statistics South Africa on the modest increase in the availability of computers in South African households from 2011 to 2015 (Statistics South Africa, 2013, 2017).

7.8.2. Inferential statistics – Computer use at any other place (BSBG10C and BSBG13C)

The IEA IDB Analyzer was used to explore the relationship between the frequency with which learners in the nine South African provinces used a computer at a place other than their home or school, and the mathematics achievement of these learners in both groups (*frequently* used a computer/tablet at another place; *infrequently* used a computer/tablet at another place) in both TIMSS 2011 and TIMSS 2015. The statistical significance of the difference in mathematical achievement in the two categories between 2011 and 2015, was examined by running t-tests of the differences and calculating the corresponding p-values. The inferential statistical analysis of BSBG10C and BSBG13C is depicted in Table 7.12.

Table 7.12: Computer use at any other place (BSBG10C and BSBG13C) – means, differences, t-tests and p-values

		TIMSS 2011 BSBG10C		TIMSS 2015 BSBG13C		Inferential statistics results			
Prov	**Code**	**Maths PV (mean)**	**Maths PV s.e.**	**Maths PV (mean)**	**Maths PV s.e.**	**Difference of diff**	**Error of Diff**	**t-test**	**p-value**
EC	Frequently	312.7924	10.5763	342.5809	15.3614	-29.7885	18.6502	-1.5972	0.1102
EC	Infrequently	331.0711	11.2420	362.6597	15.6078	-31.5886	19.2350	-1.6422	0.1005
EC	Difference	-18.2787	7.4964	-20.0788	6.7587	1.8001	10.0933	0.1783	0.8585
FS	Frequently	349.9756	7.6880	361.2763	11.4769	-11.3007	13.8139	-0.8181	0.4133
FS	Infrequently	369.0333	9.6543	374.6611	14.7577	-5.6278	17.6351	-0.3191	0.7496
FS	Difference	-19.0577	6.3917	-13.3848	9.4979	-5.6729	11.4483	-0.4955	0.6202
GT	**Frequently**	**370.7522**	**5.5778**	**406.0157**	**11.5853**	**-35.2636**	**12.8581**	**-2.7425**	**0.0061**
GT	Infrequently	414.0960	7.3840	413.6025	12.0371	0.4935	14.1214	0.0349	0.9721
GT	**Difference**	**-43.3438**	**7.0996**	**-7.5868**	**5.9851**	**-35.7571**	**9.2858**	**-3.8507**	**0.0001**
KZ	**Frequently**	**338.8462**	**5.8462**	**377.6632**	**14.3269**	**-38.8170**	**15.4738**	**-2.5086**	**0.0121**
KZ	Infrequently	351.6666	5.5027	366.1506	11.2012	-14.4840	12.4798	-1.1606	0.2458
KZ	**Difference**	**-12.8203**	**4.6475**	**11.5127**	**7.5153**	**-24.3330**	**8.8362**	**-2.7538**	**0.0059**
LP	**Frequently**	**316.8885**	**6.5638**	**367.3682**	**15.1964**	**-50.4798**	**16.5534**	**-3.0495**	**0.0023**
LP	**Infrequently**	**332.0637**	**7.5920**	**363.2725**	**13.5658**	**-31.2088**	**15.5457**	**-2.0076**	**0.0447**
LP	**Difference**	**-15.1752**	**8.2042**	**4.0957**	**5.1595**	**-19.2710**	**9.6917**	**-1.9884**	**0.0468**
MP	**Frequently**	**340.5719**	**6.1719**	**364.8177**	**6.1673**	**-24.2457**	**8.7251**	**-2.7789**	**0.0055**
MP	**Infrequently**	**349.2739**	**4.7178**	**378.1656**	**9.9183**	**-28.8916**	**10.9832**	**-2.6305**	**0.0085**
MP	Difference	-8.7020	5.5787	-13.3479	6.9398	4.6459	8.9041	0.5218	0.6018
NC	Frequently	350.9627	12.4991	358.8918	8.5021	-7.9291	15.1166	-0.5245	0.5999
NC	Infrequently	382.1135	19.5185	374.3159	7.1492	7.7976	20.7866	0.3751	0.7076
NC	Difference	-31.1508	11.1005	-15.4241	5.0779	-15.7267	12.2069	-1.2884	0.1976
NW	Frequently	346.9930	9.4577	351.3478	8.8910	-4.3548	12.9807	-0.3355	0.7373
NW	Infrequently	362.8399	11.2907	359.6596	8.2910	3.1803	14.0078	0.2270	0.8204
NW	Difference	-15.8470	6.9712	-8.3118	3.8640	-7.5351	7.9704	-0.9454	0.3445
WC	Frequently	387.8609	5.9289	384.6959	11.8828	3.1650	13.2797	0.2383	0.8116

		TIMSS 2011 BSBG10C		TIMSS 2015 BSBG13C		Inferential statistics results			
Prov	Code	Maths PV (mean)	Maths PV s.e.	Maths PV (mean)	Maths PV s.e.	Difference of diff	Error of Diff	t-test	p-value
WC	Infrequently	429.8905	11.4038	401.8257	10.5424	28.0647	15.5302	1.8071	0.0707
WC	**Difference**	**-42.0295**	**11.5434**	**-17.1298**	**5.0249**	**-24.8997**	**12.5896**	**-1.9778**	**0.0480**

Note: **Red** formatting indicates a statistically significant t-test and p-value

Overall the South African Grade 9 mathematics achievement on the TIMSS achievement scale increased from an average of 352 points in TIMSS 2011 to an average of 372 points in TIMSS 2015 (Reddy, Visser, et al., 2016). When looking at the statistical significance of the changes in mathematics achievement in relation to the use of a computer or tablet at another place, five provinces (GT, KZ, LP, MP, WC) returned statistically significant t-tests and p-values. Accordingly only these five provinces will be discussed in this section.

The mathematics achievement of **Gauteng** learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place increased from an average of 371 points in 2011 to an average of 406 points in 2015. Since the p-value was less than 0.05, the difference of 35 points was statistically significant (t = -2.74; p = 0.0061). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at any other place, increased by 12.89% from an average of 30.51% in 2011 to an average of 43.40% in 2015. The means (2011 = 371; 2015 = 406) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 0.5 points by Gauteng learners who indicated that they *infrequently* used a computer or tablet for schoolwork at any other place, was not statistically significant. In 2011, Gauteng learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place, scored an average of 43 points lower than learners who *infrequently* used a computer or tablet for schoolwork at any other place. In 2015, learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place, scored an average of 8 points lower than learners who *infrequently* used a computer or tablet for schoolwork at any other place. This difference of 36 points was statistically significant (t = 3.85, p = 0.0001). In Gauteng the increase in mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place.

The mathematics achievement of **KwaZulu-Natal** learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place increased from an average of 339 points in 2011 to an average of 378 points in 2015. Since the p-value was less than 0.05, the difference of 39 points was statistically significant (t = -2.51; p = 0.0121). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at any other place, increased by 6.08% from an average of 32.22% in 2011 to an average of 38.30% in 2015. The means (2011 = 339; 2015 = 378) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. An increase in mathematics achievement of 14 points by KwaZulu-Natal learners who indicated that they *infrequently* used a computer or tablet for schoolwork at any other place was not statistically significant. In 2011, KwaZulu-Natal learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place, scored an average of 13 points lower than learners who *infrequently* used a computer or tablet for schoolwork at any other place. In 2015, learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place, scored an average of 12 points higher than learners who *infrequently* used a computer or tablet for schoolwork at any other place. The difference of 24 points was statistically significant (t = -2.75, p = 0.0059). In KwaZulu-Natal the increase in mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place.

The mathematics achievement of **Limpopo** learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place increased from an average of 317 points in 2011 to an average of 367 points in 2015. Since the p-value was less than 0.05, the difference of 50 points was statistically significant (t = -3.05; p = 0.0023). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at any other place, decreased by 0.26% from an average of 35.47% in 2011 to an average of

35.20% in 2015. The means (2011 = 317; 2015 = 367) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The mathematics achievement of Limpopo learners who indicated that they *infrequently* used a computer or tablet for schoolwork at any other place increased from an average of 332 points in 2011 to an average of 363 points in TIMSS 2015. Since the p-value was less than 0.05, the difference of 31 points was statistically significant ($t = -2.01$; $p = 0.0447$). The percentage of learners that indicated that they *infrequently* used a computer or tablet for schoolwork at any other place, increased by 0.26% from an average of 64.53% in 2011 to an average of 64.80% in 2015. The means (2011 = 332; 2015 = 363) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. In 2011, Limpopo learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place, scored an average of 15 points lower than learners who *infrequently* used a computer or tablet for schoolwork at any other place. In 2015, learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place, scored an average of 4 points higher than learners who *infrequently* used a computer or tablet for schoolwork at any other place. This difference of 19 points was statistically significant ($t = -1.99$, $p = 0.0468$). In Limpopo the increase in mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place.

The mathematics achievement of **Mpumalanga** learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place increased from an average of 341 points in 2011 to an average of 365 points in 2015. Since the p-value was less than 0.05, the difference of 24 points was statistically significant ($t = -2.78$; $p = 0.0055$). The percentage of learners that indicated that they *frequently* used a computer or tablet for schoolwork at any other place, increased by 7.12% from an average of 32.20% in 2011 to an average of 39.31% in 2015. The means (2011 = 341; 2015 = 365) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. The mathematics achievement of Mpumalanga learners who indicated that they *infrequently* used a computer or tablet for schoolwork at any other place increased from an average of 349 points in 2011 to an average of 378 points in 2015. Since the p-value was less than 0.05, the difference of 29 points was statistically significant (t = -2.63; p = 0.0085). The percentage of learners that indicated that they *infrequently* used a computer or tablet for schoolwork at any other place, decreased by 7.12% from an average of 67.80% in 2011 to an average of 60.69% in 2015. The means (2011 = 349; 2015 = 378) indicate a positive difference, therefore when combining this with the information of the t-test and corresponding p-value, the means show a statistically significant increase in achievement. In Mpumalanga the increase in mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *infrequently* used a computer or tablet for schoolwork at any other place.

A decrease in mathematics achievement of 3 points by **Western Cape** learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place was not statistically significant. A decrease in mathematics achievement of 28 points by Western Cape learners who indicated that they *infrequently* used a computer or tablet for schoolwork at any other place was also not statistically significant. In 2011, Western Cape learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place, scored an average of 42 points lower than learners who *infrequently* used a computer or tablet for schoolwork at any other place. In 2015, learners who indicated that they *frequently* used a computer or tablet for schoolwork at any other place, scored an average of 17 points lower than learners who *infrequently* used a computer or tablet for schoolwork at any other place. This difference of 25 points was statistically significant (t = -1.98, p = 0.0480). In the Western Cape the decrease in mathematics achievement between 2011 and 2015 was higher for learners who indicated that they *infrequently* used a computer or tablet for schoolwork at any other place.

The average mathematics achievement of South African learners in relation to the use of a computer or tablet for schoolwork at any other place, increased by 15 points from 358 points (2011) to 373 points (2015). Out of 27 statistical calculations in Table 7.12, only 10 were statistically significant. This may indicate that the use of a computer or tablet for schoolwork at any other place, statistically had a small influence on the overall 20 point increase between 2011 and 2015.

It is interesting to note that in TIMSS 2011, learners from all five provinces achieved better results on the TIMSS achievement scale if they indicated that they *infrequently* used a computer or tablet for schoolwork at any other place. In 2015 the situation changed completely whereby learners from two provinces (KZ; LP) achieved better results on the TIMSS achievement scale if they indicated that they *frequently* used a computer or tablet for schoolwork at any other place, and learners from three provinces (GT; MP; WC) achieved better results on the TIMSS achievement scale if they indicated that they *infrequently* used a computer or tablet for schoolwork at any other place. One would expect learners from Gauteng and the Western Cape to be able to optimally use computers to improve their learning, but it seems they struggle to apply the specific skills needed to optimally use computers to aid knowledge construction and being able to use computers to understand problems. This may indicate that though there is a higher percentage of computer use in these provinces, the use of computers in schools in these provinces do not translate in usable skills that learners can use when alone.

7.9. Findings from the statistical analysis of the Eighth Grade *Student* Questionnaires

This chapter focused on the secondary data analysis of nine ICT-related variables from the 2011 and 2015 Eighth Grade *Student* Questionnaires, four from 2011 and five from 2015. If one takes a global overview of the mathematics results of learners in relation to the use of computers and tablets for schoolwork, it seems as if learners that *infrequently* use computers or tablets for schoolwork achieve better results in the TIMSS assessments.

The percentage of learners that indicated that they *frequently* used computers or tablets at home or at any other place for schoolwork, seems to have increased in most provinces. A worrying observation is that during the same time the percentage of learners that indicated that they *frequently* used computers or tablets at school for schoolwork, seems to have decreased in most provinces. Even in the provinces where there was an increase in the *frequent* use of computers or tablets at school, these increases were very small. This finding corresponds with the findings from the Eighth Grade *Mathematics Teacher* Questionnaires where the vast majority of educators indicated that they do not use computers during mathematics lessons. Educators indicated that they do not use computers for teaching and learning mainly because computers are not available during mathematics lessons.

In both 2011 and 2015 learners who indicated that they had access to a computer, a tablet, a shared computer, or a shared tablet at home achieved higher scores on the TIMSS achievement scale; this holds for all provinces. Computer ownership is generally linked to a higher SES and this may explain the difference in achievement between learners who had access to a computer or tablet at home, and those that did not have access to a computer or tablet at home. Learners from higher SES households have access to better schools and better academic support at home than learners from lower SES households (Carnoy, 2015; Chiu & Khoo, 2005). Additionally, computer ownership seemed to be much more common in urban and metropolitan areas, such as Gauteng and the Western Cape, and much less common in rural areas, such as the Eastern Cape, KwaZulu-Natal, Mpumalanga and the Northern Cape.

In both 2011 and 2015, most learners achieved better results on the TIMSS achievement scale if they *infrequently* used a computer or tablet for schoolwork at home, school, or any other place. This finding seems to correspond with findings from the Eighth Grade *Mathematics Teacher* Questionnaires on computer use by mathematics educators that also indicated that learner achievement decreased with the increased use of computers in mathematics teaching. A possible explanation may be that the choice of educational software available for mathematics teaching and learning was inappropriate for the target audience. Another explanation may be that the mathematical comprehension of the average South African learner was so low that they benefitted more from a structured, traditional face-to-face interaction with an educator who could explain concepts on a level and in a language that they understood. Additionally, mathematics educators require solid mathematics pedagogical content knowledge in order to effectively teach mathematics. It seems as if educators who felt confident in teaching mathematics shied away from using technology to support mathematics teaching and learning. On the other hand, it seems as if educators who did not feel confident in teaching mathematics may have relied heavily on technology for teaching and learning and this did not seem to benefit the learners in these classes.

One would expect learners from Gauteng and the Western Cape where computers have been available at most schools for an extended period of time, to be able to use computers to enhance their learning. However, it seems as if they struggled to apply the specific skills needed to optimally use computers to aid knowledge construction outside of the school environment. This may indicate that though there was a higher percentage of computer use in these provinces, the use of computers in schools in these provinces did not necessarily translate in usable skills that learners could use when outside the school environment.

The mathematics achievement of South African Grade 9 learners increased by 20 points on the TIMSS achievement scale from 2011 to 2015 (Reddy, Visser, et al., 2016). The study also explored the relationship between ICT-related variables and the difference in mathematics achievement between 2011 and 2015. Table 7.13 depicts the number of statistically significant findings for the ICT-related variables identified from the Eighth Grade *Student* Questionnaires.

Table 7.13: Statistically significant findings for ICT-related variables from the Eighth Grade *Student* Questionnaires

TIMSS 2011 variables	TIMSS 2015 variables	Variable description	Number of statistically significant findings	Reference to statistics
BSBG05A	BSBG06A	GEN\HOME POSSESS**COMPUTER\ TABLET**	8 out of 27	See Table 7.4
	BSBG06B	GEN\HOME POSSESS**COMPUTER\ TABLET SHARED**	8 out of 27	See Table 7.6
BSBG10A	BSBG13A	GEN\HOW OFTEN**USE COMPUTER\ HOME**	6 out of 27	See Table 7.8
BSBG10B	BSBG13B	GEN\HOW OFTEN**USE COMPUTER\ SCHOOL**	9 out of 27	See Table 7.10
BSBG10C	BSBG13C	GEN\HOW OFTEN**USE COMPUTER\ OTHER**	10 out of 27	See Table 7.12

The ICT-related variables identified from the Eighth Grade *Student* Questionnaires returned by far the highest number of statistically significant calculations of the difference in mathematics achievement between 2011 and 2015. This finding may indicate that learner-related ICT factors had the greatest effect on mathematics achievement in TIMSS between 2011 and 2015.

It seems as if the use of a computer at school (BSBG10B and BSBG13B) and the use of a computer at any other place (BSBG10C and BSBG13C) had the greatest effect on the difference in mathematics achievement between 2011 and 2015. Close to 35% (19 out of 54) of the statistical calculations in Table 7.10 and Table 7.12 were statistically significant. This is a very important finding for schools and educators – even though very few educators used computers during school time, the difference in mathematics achievement in relation to these two variables between 2011 and 2015 were statistically significant. This may indicate that using computers in class benefits teaching and learning. Additionally, this finding seems to correspond with findings from the Eighth Grade *School* Questionnaires and the Eighth Grade *Mathematics Teacher* Questionnaires that learners from better resourced schools achieved better results in TIMSS. It looks as if learners are more tempted to use the computer as a toy or for social media when using it at home, than when they use it at other places.

The difference in achievement between learners who had access to a computer or tablet at home, and those that did not have access to a computer or tablet at home decreased between 2011 and 2015. If one looks at this finding in relation with the findings on computer use at schools from the Eighth Grade *Mathematics Teacher* Questionnaires, this may indicate that computer use in schools have diminished over the period between 2011 and 2015 and therefore learners did not have the skills to fully benefit from having a computer at home for schoolwork. This finding seems to support the idea that the availability of a computer or tablet for schoolwork, does not necessarily translate into computer use for learning. In order to use a computer for their own benefit, learners need to acquire specific skills, such as using ICT to aid knowledge construction and being able to use ICT to understand problems (ISTE, 2016). If learners do not acquire these skills, they tend to use ICT as a toy and not as a tool for learning (Anderson, 2008; Barrera-Osorio & Linden, 2009).

7.10. Summary

This chapter focused on the secondary data analysis of ICT-related variables from the 2011 and 2015 Eighth Grade *Student* Questionnaires. Nine ICT-related variables were identified from the Eighth Grade *Student* Questionnaires. These variables were recoded in SPSS into a dichotomous scale – those representing a low level of agreement with the variable statement and those representing a high level of agreement with the variable statement.

The data analysis of the 2011 and the 2015 Eighth Grade *School* Questionnaires were discussed in Chapter 5. Furthermore, the data analysis of the 2011 and the 2015 Eighth Grade *Mathematics Teacher* Questionnaires were discussed in Chapter 6. Chapter 8 will focus on the consolidated results and findings from the study as a whole.

8. CHAPTER 8 – CONCLUSION AND RECOMMENDATIONS

8.1. Introduction

The research project focused on the use of ICT in mathematics teaching and learning in relation to the mathematics achievement of South African Grade 9 learners as reported in the TIMSS assessments of 2011 and 2015. The purpose of the research project was therefore to explore the relationship between the investment in ICT in South African schools and the mathematics achievement of South African learners. In the context of this study, the term *Investment* was seen as the making available of ICT in schools without expecting returns in monetary terms (Krueger, 2013).

Although TIMSS provides an overview and comparison of the effectiveness of the education systems of participating countries by assessing learner achievement in mathematics and science every four years, it does not take the differences in education systems and the factors that may have an influence on the variations in achievement into account. This study attempted to examine the South African context in detail by comparing the relationship of identified ICT-related variables with the TIMSS 2011 and 2015 Grade 9 mathematics results across the nine South African provinces. The selection of variables was guided by their relation to ICT in schools and the theoretical framework of the study. The variables were explored by means of descriptive and inferential statistics to attempt to better understand the effect of integrating ICT in schools on learner achievement in mathematics.

This chapter provides a summary of the study and the research findings, an interpretation of the results, recommendations for further research, and a conclusion to the study. The chapter is organised into the following structure: a summary of the research project, the literature consulted, the conceptual framework of that guided the study, and the research methodology is presented (Section 8.2). This is followed by a discussion of the first research question and its sub-questions (Section 8.3) as well as the second research question (Section 8.4). The relationship between investment in ICT and mathematics achievement is also discussed (Section 8.5), and recommendations for further research, policy making and practice is given (Section 8.6). Finally conclusions are drawn as a result of the research project (Section 8.7).

8.2. Summary of the research project

In an African context South Africa is seen as a middle-income country, that has attained high levels of compulsory school enrolment, and where the annual government expenditure on education is significantly higher compared to most other developing countries (Spaull & Kotze, 2015; Statistics South Africa, 2013, 2015, 2017). Despite this, the outcomes to education is extremely poor and many learners leave the schooling system with only a basic level of reading attainment and basic mathematics skills (DBE, 2016c; DBE, 2016e; Spaull, 2013; Spaull & Kotze, 2015). There is an expectation that integrating technology in teaching and learning will translate into better achievement of educational outcomes across the schooling system in South Africa (DOE, 2004; Mdlongwa, 2012; Stols et al., 2015).

The research questions that guided this study were a response to reports of large amounts of money spent on establishing ICT for teaching and learning in South African schools (DBE, 2015; GDE, 2013; National Treasury, 2017a; WCED, 2007a) and evidence that seems to suggest that establishing ICT in South African schools 'does not work' to improve learner achievement (Alfreds, 2015; Blignaut et al., 2010; MyBroadband staff writer, 2017; Vilakati, 2014).

Research question 1:

What is the relationship between the investment in ICT in South African schools, and the mathematics achievement of the Grade 9 learners who participated in TIMSS 2011 and TIMSS 2015 respectively?

In order to focus the study and align it to the theoretical framework, the first research question was expanded into the following two sub-questions:

a) To what extent was ICT available to South African learners as reported in TIMSS 2011 and 2015 in relation to the:

- School context,
- Classroom and educator context, and
- Learner context?

b) What was the relationship between the ICT-related variables and the mathematics achievement in TIMSS 2011 and TIMSS 2015 in relation to the:

- School context,
- Classroom and educator context, and
- Learner context?

Research question 2:

How can the integration of ICT in South African schools be improved to show an increased educational return on investment (ROI)?

8.2.1. Summary of the literature

The purpose of the research project was to explore the relationship between the investment in ICT in South African schools and the mathematics achievement of South African Grade 9 learners. When one looks at the literature as discussed in this thesis, it seems as if integrating

ICT in the teaching and learning in schools can have a positive impact on learner achievement, especially in developing countries where access to quality learning materials is limited.

The expectation exists that the integration of ICT in teaching and learning may assist with the improvement of educational outcomes in South Africa (DOE, 2004; National Planning Commission, 2012b; Plomp et al., 2007) and may improve education in dysfunctional schools (Bai et al., 2016; Rahimi & Yadollahi, 2011). Although several interventions aimed at improving education in South African schools have been introduced, concerns still remain about the quality of education in South Africa (DBE, 2016b; Howie & Hughes, 1998; Reddy, 2006; Spaull & Kotze, 2015). Government spending on education has been steadily increasing to around 20% of the total South African government budget (National Treasury, 2017a; Statistics South Africa, 2015).

The responsibility for creating a focused vision and strategy for ICT implementation and encouraging teaching staff to collaborate in the development of ICT-friendly materials lies to a large extent with the school itself (Ferrer et al., 2011; Lakkala & Ilomäki, 2015). However, the implementation of the vision and strategy for ICT implementation in the school remains the responsibility of the educator in the class (Bryderup et al., 2009). Previous studies identified educator behaviour as one of the main concerns associated with the unsuccessful integration of ICT into the curriculum (Drent & Meelissen, 2008; Kennisnet Foundation, 2015; Rahimi & Yadollahi, 2011). A big challenge identified seems to be that some educators use educational software without matching the software with the educational developmental levels of their learners (Bai et al., 2016; Condie & Munro, 2007; Krashen, 1987; Rahimi & Yadollahi, 2011). Rahimi and Yadollahi (2011) found that in such cases learner achievement could actually be detrimentally affected.

The availability of ICT infrastructure remains one of the biggest challenges to the successful implementation of ICT in schools (Hassan & Geys, 2016; Mdlongwa, 2012; Rahimi & Yadollahi, 2011). In South Africa, educators indicated physical challenges, such as unpredictable electricity supply and lack of access to ICT in their classrooms, as some of their main challenges that inhibit the integration of ICT in teaching and learning (Mdlongwa, 2012;

Mofokeng & Mji, 2010; Stols et al., 2015). Additionally, South African educators identified a lack of technical ICT support as a big challenge to the integration of ICT in teaching and learning (Stols et al., 2015; Vandeyar, 2013).

South African educators identified improved administration, such as better record keeping and lower administrative costs as some of the main benefits of integrating ICT in schools (Mdlongwa, 2012). Educators also felt that they were able to respond more effectively to frequent changes in the curriculum and that their learners had access to better quality learning materials when using ICT (Bonaveri et al., 2015; Mdlongwa, 2012). The use of data projectors allowed educators to show disadvantaged learners real-life situations that they would not normally be able to experience (Bonaveri et al., 2015; Mdlongwa, 2012). ICT therefore provide educators with opportunities for expanding teaching beyond the classroom (Bonaveri et al., 2015).

The positive impact of the use of ICT should not only be seen in relation to increasing academic achievement in school subjects (Anderson, 2008; Bonaveri et al., 2015; Chiles, 2012; Fuchs & Woessmann, 2004). Learners who use ICT develop new skills and thinking patterns and these may not directly reflect in their school marks, but in their application of creative problem solving strategies in their everyday life (Anderson, 2008; Bonaveri et al., 2015; Hansen et al., 2012).

Learners also need to be prepared to be able to acquire new knowledge and the requisite ICT skills to function in a knowledge society – this means that they need to be able to “access, analyse, evaluate, integrate, present and communicate” relevant information (DOE, 2004, p. 14). There is a belief that the use of ICT in teaching and learning can improve the skill levels of learners and thus prepare them for participation in the information and knowledge society (Gudmundsdottir, 2010; National Planning Commission, 2012a; United Nations, 2015).

However, merely adding ICT resources to classrooms, without a clear plan to integrate ICT in the teaching and learning in that classroom will not improve the quality of teaching and learning. Unfortunately, this seems to be the case in many South African classrooms surveyed by the TIMSS studies.

8.2.2. Summary of the conceptual framework

This study was customised for the South African context by using an adaptation of the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2010) as basis for the conceptual framework. The Dynamic Model was selected as basis for the conceptual framework of this study because the levels of educational effectiveness as described in the Dynamic Model, matches the categories of the TIMSS curriculum model (Mullis & Martin, 2013; Mullis et al., 2009). The conceptual framework guided the research process and allowed for the examination of ICT-related elements in a diverse set of South African schools and their relationship with mathematics achievement.

The Dynamic Model attempts to define the factors associated with educational effectiveness and consists of four distinct, but connected levels, namely context-related factors (e.g. national and regional educational departments and policies), school-related factors (e.g. school policies for teaching and learning), classroom and educator-related factors, and learner-related factors (Antoniou et al., 2011). The TIMSS studies are designed around a curriculum model that focuses on three aspects of teaching and learning, namely the intended curriculum, the implemented curriculum and the attained curriculum (Mullis & Martin, 2013).

This study focused on ICT-related variables on school-level (taken from the Eighth Grade *School* Questionnaires), classroom-level (taken from Eighth Grade *Mathematics Teacher* Questionnaires) and learner-level (taken from Eighth Grade *Student* Questionnaires). The ICT-related variables were explored in relation to the mathematics achievement attained by South African Grade 9 learners sampled for the TIMSS assessments.

8.2.3. Summary of the methodology

The study followed a quantitative research approach utilising data collected by the IEA during the TIMSS 2011 and TIMSS 2015 assessments in South Africa. Secondary data analysis has become an increasingly popular research method among researchers because it allows access to data that would otherwise be difficult for individual researchers to collect and use (Cheng & Phillips, 2014; Goodwin, 2012).

In the case of this study, secondary data related to South Africa was extracted from the TIMSS 2011 and TIMSS 2015 databases, respectively. The study focused on all South African Grade 9 learners sampled for TIMSS 2011 and 2015. Context information about their schools and their educators were also included in the TIMSS databases. Purposive sampling was used since the original TIMSS sampling design already ensured a representative sample of South African learners. The TIMSS databases included rich information about learners, educators, classrooms and schools in South Africa that could be used to examine the relationship between ICT-related variables and learner achievement in mathematics within the country.

Copies of the TIMSS context questionnaires are packaged with the TIMSS databases (IEA, 2017d) and are available in the TIMSS 2011 User Guide for the International Database (Foy et al., 2013a) and the TIMSS 2015 User Guide for the International Database (Foy, 2017a). The following questionnaires from TIMSS 2011 and TIMSS 2015 were used during this study:

a. School context – TIMSS Eighth Grade *School* Questionnaires
b. Classroom and educator context – TIMSS Eighth Grade *Mathematics Teacher* Questionnaires
c. Learner context and background – TIMSS Eighth Grade *Student* Questionnaires

The quasi-longitudinal design of TIMSS ensures that related variables can be compared across years (IEA, 2017h). It was therefore possible to explore data from both TIMSS 2011 and TIMSS 2015 in order to attempt to identify relationships and report on the research questions.

Variables for this study were selected based on the theoretical framework of the study, a review of existing literature on the integration of ICT in education (see Chapter 2) and the implication the variables have on ICT integration in South African schools and learner achievement in mathematics. The dependent variable in the study was the mathematics achievement of the learner, expressed as a plausible value (PV) in the TIMSS databases. The independent ICT-related variables were grouped in three areas of study, corresponding with the three TIMSS context questionnaires identified for the study. The independent variables were grouped as ICT-related variables in the school context, ICT-related variables in the classroom and educator context, and ICT-related variables in the learner context. Each group of variables consisted of a number of existing variables in the TIMSS databases. The selection of variables was guided by the theoretical framework of the study and the relevance of the variable to ICT in schools.

8.3. Research question 1: *What is the relationship between the investment in ICT in South African schools, and the mathematics achievement of the Grade 9 learners who participated in TIMSS 2011 and TIMSS 2015 respectively?*

The statistical analysis and results emanating from this study will be summarised using the main research question as guideline. This section will therefore be divided as follows:

Research question 1: What is the relationship between the investment in ICT in South African schools, and the mathematics achievement of the Grade 9 learners who participated in TIMSS 2011 and TIMSS 2015 respectively?

- To what extent was ICT available to South African learners as reported in TIMSS 2011 and 2015 in relation to:
  - Results from the Eighth Grade *School* Questionnaires
  - Results from the Eighth Grade *Mathematics Teacher* Questionnaires
  - Results from the Eighth Grade *Student* Questionnaires?
- What was the relationship between the ICT-related variables and the mathematics achievement in TIMSS 2011 and TIMSS 2015 in relation to the:

- Results from the Eighth Grade *School* Questionnaires
- Results from the Eighth Grade *Mathematics Teacher* Questionnaires
- Results from the Eighth Grade *Student* Questionnaires?

The discussion of the two sub-questions will assist in providing insight into the first main research question.

8.3.1. Sub-question A: *To what extent were ICT available to South African learners as reported in TIMSS 2011 and TIMSS 2015?*

Fewer principals reported a *considerable effect* on teaching and learning due to a shortage of computers and computer software in 2015 than in 2011. It is also interesting to note that fewer principals reported a shortage of both computers and computer software in their schools. This seems to suggest that an increased number of principals did not perceive a shortage of computers and computer software as an impediment to effective teaching and learning in their schools.

However, according to the educators there was a general decrease in the availability of computers and computer software during mathematics lessons from 2011 to 2015. What is of concern is that the responses from the educators to questions on the availability of ICT for teaching and learning in the Eighth Grade *Mathematics Teacher* Questionnaires, did not seem to correspond with the responses of school principals to similar questions on shortages of ICT in schools in the Eighth Grade *School* Questionnaires. Again it seemed as if many school principals did not perceive a shortage of ICT as a challenge in their school, and therefore did not report on it as such.

At the same time the percentage of learners that indicated that they *frequently* used computers or tablets at home or at any other place for schoolwork, seemed to have increased in most provinces from 2011 to 2015. However, the percentage of learners that indicated that they *frequently* used computers or tablets at school for schoolwork, appears to have decreased in most provinces from 2011 to 2015. This finding corresponds with the findings from the Eighth Grade *Mathematics Teacher* Questionnaires where the vast majority of educators indicated that they did not use computers during mathematics lessons. This finding also contradicts the optimism of the principals regarding the availability of computers for teaching and learning in schools.

The percentage of educators countrywide that stated that they received professional development in the integration of ICT in mathematics in the previous two years, increased between 2011 and 2015 in all nine provinces. Additionally, there seems to have been an increase in support for the integration of technology available to Gauteng and Western Cape educators between 2011 and 2015. Although support for the integration of ICT in mathematics increased, it is a concern that the actual use of ICT in South African classrooms decreased.

8.3.2. Sub-question B: *What was the relationship between the ICT-related variables and the mathematics achievement in TIMSS 2011 and TIMSS 2015?*

In both 2011 and 2015 learners from all provinces achieved higher scores on the TIMSS achievement scale if they indicated that they had access to a computer, a tablet, a shared computer, or a shared tablet at home. Additionally, computer ownership seemed to be much more common in urban and metropolitan areas, such as Gauteng and the Western Cape, and much less common in rural areas, such as the Eastern Cape, Kwa-Zulu Natal, Mpumalanga and the Northern Cape. Computers and tablets are an indication of a household’s SES and this finding supports earlier research that found that learners from higher SES backgrounds generally achieve better academic results in schools.

In 2011 learners in most provinces achieved higher scores if their principals indicated that a shortage of computers, computer software and relevant audio-visual materials had a *considerable effect* on teaching and learning in the school. In 2015 the picture changed completely, whereby learners in most provinces achieved higher scores if their principals indicated that a shortage of computers, computer software and relevant audio-visual materials had a *minimal effect* on teaching and learning in the school. This finding seems to support the idea that school principals who were able to identify a *considerable effect* on teaching and learning in their schools, were more involved in the daily running of their schools, and were therefore able to identify challenges in the school and were able to provide more effective leadership to the educators in the school. This finding therefore appears to support the notion that effective school leadership may lead to improved teaching and learning, but further investigation is required to conclude unequivocally whether a relationship exists.

In both 2011 and 2015, the Gauteng and Western Cape learners that achieved the highest scores on the TIMSS achievement scale, came from schools where the majority of educators indicated that they *infrequently* allowed learners to explore mathematics principles and concepts on the computer, practise mathematics skills and procedures on the computer, look up ideas and information on the computer, and process and analyse data on the computer. Additionally, in both 2011 and 2015, most learners achieved better results on the TIMSS achievement scale if they *infrequently* used a computer or tablet for schoolwork at home, at school, or at any other place. This finding seems to correspond with findings from the Eighth Grade *Mathematics Teacher* Questionnaires on computer use by mathematics educators that also indicated that learner achievement decreased with the increased use of computers in mathematics teaching. The educational software available during mathematics lessons may have had a detrimental effect on learner achievement. Educational software need to be aligned with the needs and developmental stage of the learner and if the software was unsuitable optimal learning could not take place. A danger of large-scale computer integration projects could be to be the delivery of a ‘one-size-fits-all’ solution to all schools in a province, without taking the individual context of the end users into consideration. Another possible explanation may be that the mathematical comprehension of the average South African learner was so low, that they benefitted more from a structured, traditional face-to-face interaction with an educator who could explain concepts on a level that they could comprehend.

Support for the integration of technology in teaching and learning relies on the identification of this type of support as important by school management. It seems as if learners achieved higher mathematics achievement if they came from schools where the school management was able to identify support for the integration of technology as important, and acted upon this information to arrange such support for the educators. This seems to endorse findings from the Eighth Grade *School* Questionnaires where a principal's ability to accurately identify strengths and weaknesses in their school seemed to have a positive impact on teaching and learning in the school.

8.4. Research question 2: *How can the integration of ICT in South African schools be improved to show an increased educational return on investment?*

The research results from previous studies into the use of ICT for teaching and learning in South Africa, suggested that while ICT for teaching and learning may have been available in some South African schools, it did not get used in the classroom for teaching and learning purposes (Blignaut et al., 2010; DBE, 2017c). The discrepancies in the reporting of the availability and use of ICT for teaching and learning between school principals in the Eighth Grade *School* Questionnaires, mathematics educators in the Eighth Grade *Mathematics Teacher* Questionnaires, and learners in the Eighth Grade *Student* Questionnaires, as revealed by this study, seem to support the earlier findings made by SITES 2006 and SACMEQ IV that while ICT was available in some schools, it was rarely used for teaching and learning. A leading cause for this decrease in the use of ICT for teaching and learning seems to be the inability of schools to make the ICT that they receive available to educators for use in teaching and learning. It seems as if many of the different role-players in the integration of ICT for teaching and learning in schools do not have a clear understanding of their roles and responsibilities to ensure successful integration.

After consideration of the research results from this study in relation to the conceptual framework for the study, a new model for the integration of ICT in schools is proposed. The new model is based on an adaptation of the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2010) and the TIMSS curriculum model (Mullis & Martin, 2013; Mullis et al., 2009). The proposed IIIA-Model aims to direct the implementation of ICT for teaching and learning in schools by identifying the different zones of impact, the different role-players involved, as well as the curriculum expectations during the ICT implementation process. The proposed *IIIA-Model for the integration of ICT in Schools (IIIA-Model)* is depicted in Figure 8.1.

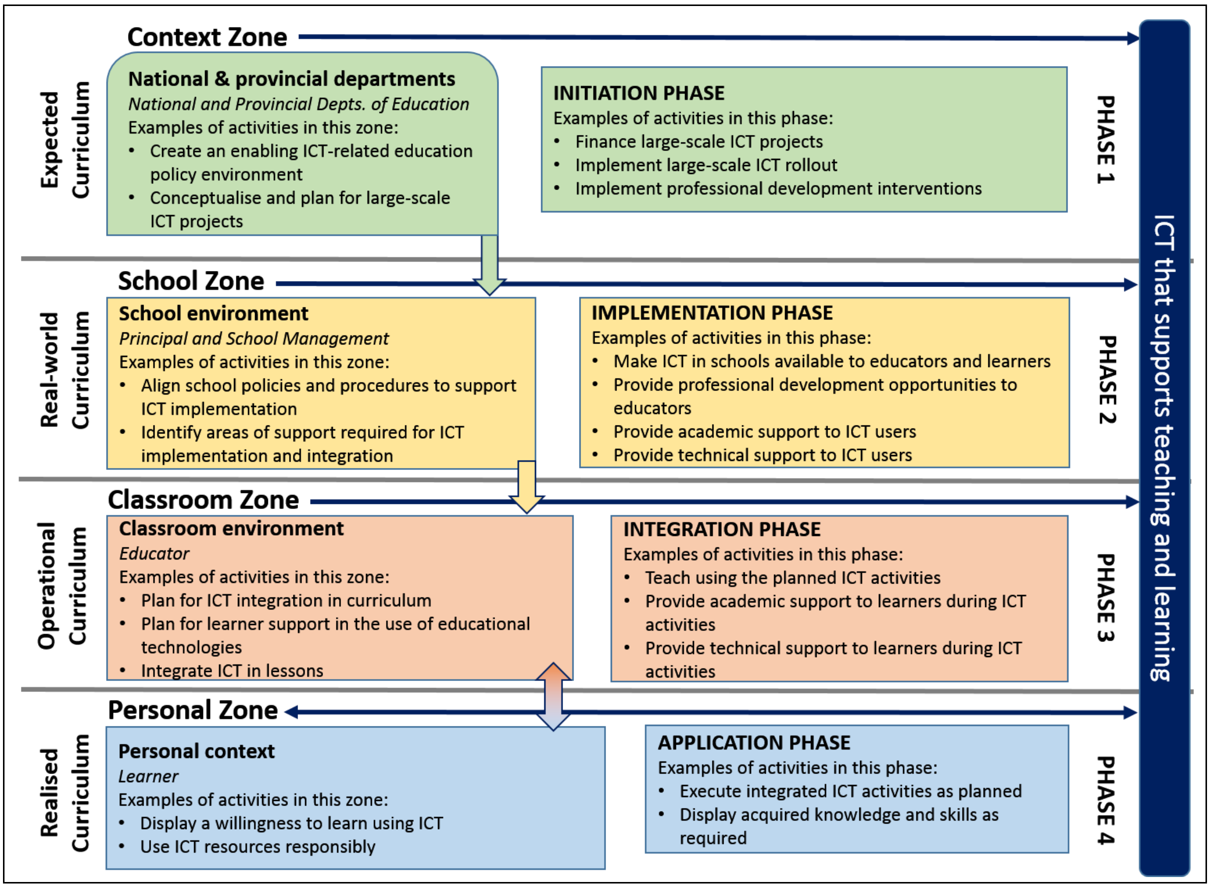

Figure 8.1: The IIIA-Model for the integration of ICT in Schools

The IIIA-Model was designed around four zones of impact, similar to those identified by Creemers and Kyriakides (2007). The zones of impact are defined in the IIIA-Model as the Context Zone, the School Zone, the Classroom Zone and the Personal Zone. Each zone carries specific curriculum expectations, similar to the TIMSS curriculum expectations identified by the IEA (Mullis & Martin, 2013).

The curriculum expectations are defined in the IIIA-Model as the Expected Curriculum, the Real-world Curriculum, the Operational Curriculum and the Realised Curriculum. The Expected Curriculum represents the official curriculum prescribed by the relevant education authority. The Real-world Curriculum represents the curriculum as influenced by the unique school-based policies, procedures, and support structures available. The Operational Curriculum represents the curriculum as taught by educators in the specific school. The Realised Curriculum represents the curriculum outcomes as achieved by learners in the schools and can be seen as the final outcome of the Expected Curriculum

The phases identified for successful integration of ICT for teaching and learning in schools were identified by examining the roles and responsibilities of the role-players in the different zones of impact. The phases of integration are defined in the IIIA-Model as the Initiation Phase, the Implementation Phase, the Integration Phase and the Application Phase.

The first phase of the IIIA-Model is the **Initiation Phase**. The Initiation Phase resides in the Context Zone and represents the roles and responsibilities of national and provincial departments of education. Departments of education are responsible for creating an enabling policy and legislative environment that enables the implementation of ICT in schools. Very few schools have the financial capability to procure ICT for teaching and learning and this study identified the rollout of ICT to schools as a responsibility of departments of education. It is also in the Context Zone that the Expected Curriculum is defined. The Expected Curriculum represents the official curriculum as approved by the departments of education.

The second phase of the IIIA-Model is the **Implementation Phase**. The Implementation Phase resides in the School Zone and represents the roles and responsibilities of school principals and school management. School management is responsible for creating a conducive environment for the implementation of ICT in schools through school policies and procedures that enables the implementation of ICT in that school. Results from this study seem to suggest that in some cases where ICT was available in a school, it was not made available for teaching and learning. Many educators did not seem to have the opportunity to apply what they have learned during professional development interventions in practice. The creation of an enabling environment for ICT integration may be as simple as equitable timetabling where every class in a school gets time allocated in a computer centre. School management is also responsible for arranging support for the users of the ICT. Again, this may be as simple as assigning the responsibility of ICT support to an enthusiastic staff member. Lastly, an often overlooked requirement is that educators need extra time in order to plan for, and implement the integration of ICT in their lessons. School management could assist educators with extra time by recognising the planning for, and implementation of ICT as a recognised extramural activity for a specified time. It is in the School Zone that the Real-world Curriculum is defined. The Real-world Curriculum represents the curriculum as guided by school-based policies, procedures, and support structures in the school.

The third phase of the IIIA-Model is the **Integration Phase**. The Integration Phase is critical as this is where the operationalisation of ICT integration takes place. The Integration Phase resides in the Classroom Zone and represents the roles and responsibilities of educators in the classroom. The integration of ICT in the school curriculum is a new endeavour in most schools and educators are therefore required to rework their existing lesson plans in order to integrate ICT in the lessons. Once the planning is done, it is also the responsibility of the educator to teach using the new, planned ICT activities. Additionally, educators are also responsible to support learners with technical queries while using the ICT to complete the activities. Results from this study seemed to suggest that while many educators are positive about the integration of ICT in teaching and learning and attended professional development interventions, these interventions do not adequately prepare educators for the reality of integrating ICT in teaching and learning. The Operational Curriculum is defined in the Classroom Zone. The Operational Curriculum represents the curriculum as taught by educators in the school.

The fourth phase of the IIIA-Model is the **Application Phase**. The Application Phase resides in the Personal Zone and represents the roles and responsibilities of learners in the classroom. ICT integration inherently changes teaching and learning activities from educator-centred activities to learner-centred activities and learners therefore have to take responsibility for their own learning. The Realised Curriculum is defined in the Personal Zone. The Realised Curriculum represents the curriculum as achieved by learners and can be seen as the final outcome of the Expected Curriculum.

The IIIA-Model attempts to address the concern raised that many role-players in the integration of ICT in schools do not know what their roles and responsibilities are in order to ensure successful integration. Although the IIIA-Model represents the picture of education in South Africa, the model is sufficiently generic to be applied in other education contexts as well. It is therefore suggested that the IIIA-Model be considered as guideline in future ICT integration in schools projects.

8.5. The relationship between investment in ICT and mathematics achievement

The main purpose of the study was to explore the relationship between the investment in information and communications technologies in South African schools and the mathematics achievement of the Grade 9 learners that participated in TIMSS 2011 and TIMSS 2015. Based on the research findings, the following conclusions regarding the availability of ICT for teaching and learning were drawn:

- There seems to have been an increase in awareness regarding the importance of integrating ICT in teaching and learning among school principals.
- There appears to have been a discrepancy between the perceptions of principals and educators regarding the availability of ICT for teaching and learning in schools.
- It looks as if there was a decrease in the availability of ICT specifically earmarked for teaching and learning in schools from 2011 to 2015. Coupled with the decrease in the availability of ICT for teaching and learning, there also seems to have been a decrease in the availability of educational software for mathematics teaching and learning in schools from 2011 to 2015.

- Support to educators for the integration of ICT in the mathematics curriculum increased from 2011 to 2015.
- Educator use of ICT in school to support teaching and learning decreased from 2011 to 2015.
- Learner use of ICT in school for schoolwork decreased from 2011 to 2015.
- Learner use of ICT outside of school for schoolwork increased from 2011 to 2015.
- In both 2011 and 2015 computer ownership at home appears to be much more common in urban and metropolitan areas than in rural areas.

Based on the research findings, the following conclusions regarding the relationship between the availability of ICT for teaching and learning and the mathematics achievement of the Grade 9 learners that participated in TIMSS, were drawn:

- Learners achieved higher scores if they had access to a computer or tablet at home.
- An overwhelming majority of learners achieved higher scores if their educators indicated that they *infrequently* allowed learners to explore mathematics principles and concepts on the computer, practise mathematics skills and procedures on the computer, look up ideas and information on the computer, and process and analyse data on the computer.
- The majority of learners achieved higher scores if they *infrequently* used a computer or tablet for schoolwork at home, at school, or at any other place.
- Learners achieved higher scores if they came from schools where the school management identified support for educators in the integration of ICT as important, and acted upon this information to arrange such support for the educators.

The main research question, namely "What is the relationship between the investment in ICT in South African schools, and the mathematics achievement of the Grade 9 learners who participated in TIMSS 2011 and TIMSS 2015 respectively?" was therefore convincingly answered through the research findings as revealed by this study.

8.6. Recommendations

This section will disseminate recommendations made based on the research findings of this study on the relationship between the investment in ICT in South African schools and the mathematics achievement of the Grade 9 learners who participated in TIMSS 2011 and TIMSS 2015. Recommendations for policy and practice in South Africa will be made, along with recommendations for further study.

8.6.1. Recommendations for policy and practice in South Africa

Recommendations for improved policy and practice in South Africa are organised according to the four zones of impact as identified in the proposed IIIA-Model for the integration of ICT in Schools. The zones identified are the Context Zone, the School Zone, the Classroom Zone and the Personal Zone.

The Context Zone (National and Provincial departments of education)

It is clear that schools need support from national and provincial departments of education in the implementation of ICT hardware and software in the school. Educational software needs to be selected on the basis of the educational needs of learners in a specific school, and not distributed as a one-size-fits-all solution to all schools in a province. Additionally, all educational software should be contextualised so that learners can identify with the scenarios, the language used, and the type of assessment and feedback required. Large-scale ICT in education projects should include ongoing technical and academic support to schools and educators with regard to the integration of the educational software into their normal class practices.

The School Zone (Principals and School Management)

Based on the findings of this study, it appears that school principals need different professional development activities on the integration of ICT in the school curriculum than educators. Many principals were not able to identify what is needed from them as school management to implement the integration of ICT in the school curriculum. They also seem to fail in identifying the positive impact that ICT can have on teaching and learning in their schools. Additionally, principals did not give adequate leadership regarding the integration and use of ICT in teaching and learning if they did not themselves have a clear idea of what ICT integration entails.

As the implementation of ICT is a costly endeavour, school management need to take responsibility for the proper use of the equipment. The school management is responsible to manage the school’s ICT resources in such a manner that every educator and class in the school gets equitable access to the ICT resources. A good idea may be to schedule a weekly slot in the formal school timetable to allow each class equitable access to the school’s ICT equipment.

The Classroom Zone (Educators)

Professional development interventions on the integration of ICT in the school curriculum need to start with basic computer literacies and skills for educators. If educators do not feel comfortable with the use of computers for personal matters, they will in all likelihood not have the confidence to implement ICT integration in their classes.

Opportunities for professional development for educators on the integration of ICT in the school curriculum need to be increased. The number of educators who indicated that they did not attend professional development activities in the previous two years, increased from

2011 to 2015. These professional development interventions could be managed centrally from the national or provincial departments of education to ensure that all educators have an opportunity to attend.

Professional development interventions for educators need to focus on the practical aspects of the integration of ICT in the school curriculum and need to include an element of workplace-based support. Based on the findings of this study, it appears as if many educators simply did not have the confidence to implement ICT in their classrooms. The danger with short, one-off interventions is that although they are mostly perceived as positive training experiences by educators, they are bound to fail as educators do not receive adequate in-depth training to enable them to take the plunge into the reality of teaching and learning with ICT.

Many educators in this study indicated that ICT for teaching and learning was not available to them during class time. Educators need to be given easy access to computers and computer software in order to plan for the integration of ICT in their lessons, and once their planning is complete, they need the opportunity to implement what they have planned.

The Personal Zone (Learners)

Learners need to use ICT on a regular basis in order to gain non-academic skills for them to participate in the knowledge society they will enter once they leave school. Many learners do not have computers at home and departments of education and schools have the responsibility to enable access to computers and computer software during school time.

Educational software needs to be applicable to the educational level of learners in a specific school. Additionally, learners need to spend adequate time on high quality educational software. The more time learners spend on high quality educational software, the greater the possibility that they will learn something and that their academic achievement will improve. The responsibility lies with the school management to ensure equitable access for all learners to the ICT in the school.

8.6.2. Recommendations for further research

One of the disadvantages of using secondary data is that it becomes difficult to answer any 'why?' questions. The recommendations for further research aim to broaden the understanding gained by this study on the use and usefulness of ICT in education in South Africa.

The study identified a discrepancy between school principals' reporting on the availability of ICT in schools and that of the educators in the schools. This discrepancy seems to be supported by the decrease in use of ICT in schools reported by learners. A recommendation for further research is therefore to explore the perceptions of school principals, educators and learners with regard to the availability of ICT in a sample of schools that participated in TIMSS 2011 and TIMSS 2015.

The study identified a downward trend in the use of ICT for teaching and learning in schools, but it cannot satisfactorily explain why there was a decrease in the use of ICT in schools. A recommendation for further research is therefore to do a focused qualitative study in a sample of schools, focusing on the reasons why there is a decrease in the use of ICT for teaching and learning despite the vast amounts that was spent on establishing ICT for teaching and learning in schools.

There was a large, statistically significant decrease in the mathematics achievement of Western Cape learners on the TIMSS achievement scale from 2011 to 2015. Although this decrease in achievement may be due to the influx of learners from other provinces, Gauteng experienced a similar influx of learners from other provinces and the mathematics achievement of Gauteng learners increased. A recommendation for further research is therefore to explore why the mathematics achievement in Western Cape schools decreased, while the mathematics achievement increased in all other South African provinces.

8.7. Conclusion

> *All South Africans should be able to acquire and use knowledge effectively. To this end, the institutional arrangements to manage the information, communications and technology (ICT) environment need to be better structured to ensure that South Africa does not fall victim to a 'digital divide'.* (National Planning Commission, 2012a, p. 23)

The decrease in the use of ICT in South African schools from 2011 to 2015 is a matter of concern. South African schools stand the risk of becoming irrelevant in the preparation of learners for tertiary education and the job market in general if ICT skills are not acquired during the schooling years of South African children. A huge danger is to try and quantify the return on the investment in ICT in terms of simple test achievement scores – it has not worked in other countries and it will most probably not work in South Africa. As can be seen from this study, the need for ICT in schools goes beyond the simple improvement of teaching, learning and test achievement.

Most South African schools do not have the financial resources to roll out ICT in the school. Ironically, the majority of learners from these schools are the ones who most desperately need to be skilled in the use of ICT during school time because they do not have access to ICT outside of the school environment. The onus therefore rests on the national Department of Basic Education and the Provincial Education Departments to initiate and manage the rollout of ICT in schools and the subsequent empowerment of educators to optimally use ICT for teaching and learning.

I trust that this thesis will serve as an enabler for an expanded rollout of ICT for teaching and learning in South African schools. May South African citizens in future be able to take charge of their own destinies through the knowledge, information and services afforded by the availability of ICT.

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