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SCIENCE TEACHERS' ATTENDANCE OF PROFESSIONAL DEVELOPMENT PROGRAMMES AND THEIR USE OF COMPUTER SOFTWARE IN TEACHING

By

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Submitted in partial fulfilment of the requirements for the degree

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General

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Supervisor

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January 2015

Declaration of Originality

I **Meganathan Moodley** declare that the thesis, which I submit for the degree Masters in 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.

Signature: ______________________________

Date: 15 April 2015

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Abstract

Title	Science teachers' attendance of professional development programmes and their use of computer software in teaching
Student name	Meganathan Moodley
Supervisor name	Prof Dr J.G. Knoetze
Department	Department of Science, Mathematics and Technology Education
Degree for which the thesis is submitted	Master's in Education (M.Ed.)

The aim of this research is to investigate the relationship between Science teachers attending seven types of teacher professional development (TpD) programme and the influence these have on their use of computer software in the teaching of Science. This research focuses on five of the seven programmes that are essential for the improvement of Science performance and assessment results in South African schools. Teachers' mastery of Science is not exclusively dependent on their depth of understanding of the content, but also on their understanding of and expertise in pedagogy, the curriculum, assessment practices and Information Communication Technology (ICT).

The use and role of ICT in teaching have without a doubt become a non-negotiable aspect of education. However, integration of technology in education faces multiple hurdles. The greatest hurdle is the ability of the teacher to use ICT effectively. For teachers to use technology effectively they need to possess a range of skills and knowledge that allows them to achieve the objective of effective integration of ICT. Teachers need to be skilled to use computers in all aspects of their work. The focus in this research falls on the five TpD programmes that teachers attended; they include Science content, Science pedagogy, the Science curriculum, ICT and assessment in Science.

This is secondary data analysis research that makes use of data collected from the South African component of the TIMSS 2011 assessment. The data was derived from the Grade 9 Science teacher questionnaires and focuses on two key variables: (1) professional development programmes attended, and (2) the use of computer software to teach Science.

Data analysis was conducted at two levels: descriptive statistics to give the sample teachers a defined background and structure, and inferential statistics to surmise the relationship between teachers attending the various TpD programmes and their use of computer software to teach Science. The findings from this research show that attending academic TpD programmes is important to get teachers to use computers in the teaching of Science and that training to ensure mastery of basic ICT skills cannot be over-emphasised.

Key words: *Assessment in Science, content, curriculum, education transformation, ICT, pedagogy, professional development models, software, Teacher development, TIMSS 2011*

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I am the master of my faith

I am the captain of my soul.

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List of Acronyms

BECTA	British Educational Communities and Technology Agency
C2005	Curriculum 2005
CAT	Computer Applications Technology
DBE	Department of Basic Education
HSRC	Human Sciences Research Council
ICT	Information and Communications Technology
IEA	International Association for the Evaluation of Educational Achievement
ISI	Institute for Scientific Information
NRC	National Research Coordinator
OBE	Outcomes Based Education
PLC	Professional Learning Community
PRQlQt	Positivism Rationalism Qualitative Quantitative
QIRC	Questionnaire Item Review Committee
SITES	Second Information Technology in Education Study
SPSS	Statistical Package for Social Sciences
TAM	Technology Acceptance Model
TIMSS	Trends in International Mathematics and Science Study
TPACK	Technological Pedagogical Content Knowledge
TpD	Teacher professional Development
TpDCT	Teacher professional development programme in improving learners' critical thinking
TpDICT	Teacher professional development programme in integrating ICT into Science
TpDILN	Teacher professional development programme in addressing individual learner needs
TpDSA	Teacher professional development programme in Science assessment
TpDSC	Teacher professional development programme in Science content
TpDSC	Teacher professional development programme in Science curriculum
TpDSP	Teacher professional development programme in Science pedagogy
www	World Wide Web

CHAPTER 1
INTRODUCTION

1.1 Introduction

Education is the cornerstone of economic development and ultimately of human prosperity. Globalisation and the growing economic rivalry between countries and economic systems have resulted in education becoming an important stage in empowering citizens to solve regional and global problems (Pashby, 2011, p. 431). In order to prepare learners to face a world that revolves around information, communication and technology it has become vitally important that teachers are adequately trained and prepared to facilitate and transfer new and existing knowledge to learners by using technology (Friedrich & Hron, 2011, p. 282).

According to Steyn (2011, p. 43) and Moodley (2013, p. 1) change in learner performance in Science is dependent on the quality of the Science teacher's content knowledge and pedagogical knowledge that is ultimately measured by the performance of learners. The quality of Science instruction by teachers is dependent on their knowledge and level of expertise in subject content, pedagogy, assessment, the curriculum and the use of technology in the teaching of Science. The diffusion of technolgy into the classroom has brought an added responsibility to the Science teacher (Hennessy, Ruthven & Brindley, 2009, p. 2). However, technology should not be regarded by teachers as a forced burden on their teaching activities. The use of technology should rather be finely merged into a teacher's everyday duties so that its beneficial attributes can be recognised (Hennessy et al., 2009, p. 2; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur & Sendurur, 2012, p. 430; Ertmer & Ottenbreit-Leftwich, 2013, p. 9).

This research used secondary data collected from the South African module of the Trends in International Mathematics and Science Study (TIMSS) 2011 with the aim of investigating whether attending different teacher professional development programmes influences the use of computer software by the teacher to teach Science.

1.2 Background

1.2.1 Teacher professional development

Teacher professional development has become a priority in many countries with vast amounts of money and resources being spent on empowering teachers to ensure a quality teaching force (Mphale, 2014, p. 76). In South Africa the challenge has been to find teacher professional development programmes and practices that are contextually suited and have the potential to change teachers' knowledge and classroom practices for the better (Jita & Mokhele, 2014, p. 2). Even with the vast strides made in teacher professional development in South Africa, problematic areas still exist. Some of these problems stem directly from the perception and understanding of teachers and other role players of what teacher professional development entails (Steyn, 2011, p. 44). Professional development of teachers is not a simple process of training teachers in new or revised content but rather comprises of a set of programmes that will help empower teachers to carry out their duties effectively (Desimone, 2009, p. 181).

According to Steyn (2011, p. 44) the ultimate goal of professional development is not merely the mastery of content but rather mastery of professional self-efficacy, subject knowledge, skills, classroom management and the professional status of the teacher. He continues to accentuate that teachers should be guided and trained to identify professional development programmes that will help them to grow professionally. Taking this as a point of departure it is important to note that the development of a teacher is a holistic process (Panayiotis, Leonidas & Bert, 2011, p. 15). This entails that a teacher should not only have exceptional content knowledge but also an understanding of the curriculum, assessment practices and especially in the 21st century a pedagogic understanding of ICT applications and use (Kriek & Grayson, 2009, p. 186).

1.2.2 TIMSS 2011

The Trends in International Mathematics and Science Study (TIMSS) is an assessment of the Mathematics and Science knowledge of Grade 4 and Grade 8 learners, conducted by the International Association for the Evaluation of Educational Achievement (IEA) (Human

Sciences Research Council, 2012, p. 3). The relationship between the achievement scores of learners and contextual factors has been investigated and constructed around the results of learners gained from the achievement tests and auxiliary information gathered from questionnaires administered to principals, teachers and learners. Within the South African context a stratified sampling method was used with schools as the first tier of sampling, based on province, language of instruction and learning and the status (public or private) of each school. According to the Human Sciences Research Council (2012, p. 3), South Africa's participation in the TIMSS 2011 study allowed the country to benchmark its Mathematics and Science results against other countries. South Africa has participated in all TIMSS studies with the exception of 2007, due to its performance in TIMSS 2003.

1.3 Problem statement and research question

In order to ensure that South Africa improves its performance in Science, the focus needs to fall on factors that impede this objective. Various South African literature articles (Simkins, 2010, p. 5; Mayisela, 2013, p. 2; Moodley, 2013, p. 9; Mphale, 2014, p. 78; Jita & Mokhele, 2014, p. 3) identify a lack of resources, lack of funding, inadequate teacher content knowledge, poor pedagogic practices and an inability to use technology effectively as some key impeding factors that contribute to South Africa's poor performance in Science. Resources and funding have received considerable attention; however, the greatest contributor to poor learner performance in Science is the sub-standard quality of Science teachers in South African schools (Kriek & Grayson, 2009, p. 186). As is evident in Chapter 2 teacher professional developmental programmes have resulted in little if any change in the performance of learners in Science in South African schools (Makgato, 2007, p. 91). Literature also shows that professional development programmes for Science teachers tend to be one-dimensional with the focus falling predominately on Science content (Goldschmidt & Phelps, 2007, p. 4) with very little insight into how these programmes influence the use of ICT in the teaching of Science. This research investigated whether teachers attending various professional development programmes in Science influence their use of computer software in the teaching of Science. The main research question of this study is the following:

What is the relationship between teachers attending professional development programmes in Science and their use of computer software in the teaching of Science?

1.4 The purpose of the research and sub-research questions

The purpose of this research is to investigate the relationship between Science teachers attending teacher development programmes and their use of computer software to teach Science. The main research question is divided into seven sub-research questions that are outlined in Table 1.1.

Sub-research question	Description of sub-research question
1. What is the relationship between teachers attending professional development in ***Science content*** and their use of computer software in the teaching of Science?	Does attending professional development programmes in **Science content** empower and motivate teachers to use computer software in teaching Science?
2. What is the relationship between teachers attending professional development programmes in ***Science pedagogy*** and their use of computer software in the teaching of Science?	Does attending professional development programmes in **Science pedagogy** help prepare teachers to use computer software in teaching Science?
3. What is the relationship between teachers' attending professional development in ***the Science curriculum*** programmes and their use of computer software in the teaching of Science?	Does attending professional development programmes in the **Science curriculum** help prepare teachers to use computer software in teaching Science.
4. What is the relationship between teachers attending professional development programmes in ***integrating information communications technology*** in Science and their use of computers in the teaching of Science?	Does attending professional development programmes in **integrating information communications technology** into Science help prepare teachers to use computer software in teaching Science?
5. What is the relationship between teachers attending professional development programmes in ***improving learners' critical thinking or inquiry skills*** and their use of computer software in the teaching of Science?	Does attending professional development programmes in **improving learners' critical thinking or inquiry skills** help prepare teachers to use computer in teaching Science?

Table1.1: Sub-research questions and description

Sub-research question	Description of sub-research question
6. What is the relationship between teachers attending professional development programmes in ***Science assessment*** and their use of computer software in the teaching of Science?	Does attending professional development programmes in **Science assessment** help prepare teachers to use computer software in teaching Science?
7. What is the relationship between teachers attending professional development programmes in ***addressing individual learner needs*** and their use of computer software in the teaching of Science?	Does attending professional development programmes in **addressing individual learner needs** help prepare teachers to use computer software in teaching Science?

Table1.1: Sub-research questions and description (continued)

1.5 Rationale for the research

ICT has become an integral part of the teaching process, thus necessitating a review of teacher developmental programmes to ensure the promotion of the use of computers and computer software in the teaching of Science. Subsequently this research aims to draw attention to the different professional development programmes Science teachers attended and how attending these programmes influenced their use of computer software in the teaching of Science.

1.5.1 Significance of the research

It is anticipated that the findings of this research will be significant to patrons of education in making informed decisions regarding matters related to the use of ICT in schools and the planning of teacher professional development programmes in Science education. It is hoped that the findings from this research will inform strategies and policies that will bring about transformation in teacher professional development and information communications technology within the South African context.

1.6 Limitations of the research

The unit of analysis in this research is South African Grade 9 Science teachers. As is discussed later in Chapter 3 (p. 28) the teachers who took part in this research were not part of the sample design but formed part of the sampled schools. This does not allow for the findings from this research to be generalised to the wider South African population of Grade 9 Science teachers. However, these findings can be used by policy makers and patrons of education to guide and inform decisions concerning teacher professional development.

1.7 Outline of the research

The structure of the research will unfold over five chapters with each chapter focusing on a key element as shown in Table 1.2

Chapter	Title	Description
1	Introduction	A brief overview and background of the research.
2	Literature review	A review of literature related to the research.
3	Research design	The research design and methods used as well as the processes and procedures undertaken.
4	Data analysis	Detailed data analysis procedures undertaken in the research.
5	Recommendations and conclusion	A summary of the results with concluding remarks, recommendations and suggestions.

Table 1.2: Dissertation structure

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The essence of teaching has remained virtually unchanged over the past few decades. The traditional view of a teacher being the sole source of knowledge, leader and guide in the life of a learner has endured over time (Szűcs, 2010, p. 2). The spread of technology has seen a gradual transformation of the view of teachers transmitting knowledge to one where teachers are expected to facilitate the discovery and creation of new knowledge (Szűcs, 2010, p. 4; Mahruf, Shohel & Banks, 2012, p. 25). The emergence of technology in education has necessitated a transformation in the role of the teacher. Technology plays an increasingly vital role in the lives of teachers in the 21st century and subsequently technological literacy has become a fixed condition in the work expectations of a teacher (Danner & Pessu, 2013, p. 1).

To ensure that teachers have the necessary skills and knowledge to integrate technology into teaching it has become imperative that teachers be trained to use and integrate the available technologies efficiently (Klieger, Ben-Hur & Bar-Yossef, 2010, p. 190). According to Garcia (2012) a successful professional development programme in the 21st century should accommodate the following key processes: teachers learn collaboratively, teachers reflect on knowledge learnt, use technology to construct knowledge and receive coaching and mentoring from subject expert coaches.

The purpose of this chapter is to review articles that focus on teacher professional development and the use of ICT in the teaching of Science. The literature review was undertaken with a view to establishing common views and perceptions leading to an all-inclusive understanding of the topic and at the same time identifying gaps in the literature, thereby supporting and providing a purpose to undertake the research. The preliminary search for and selection of articles were based on set themes that included teacher professional development in general, teacher professional development in the integration of ICT in the teaching of Science, TIMSS assessments and the statistical analysis of secondary data.

2.2 The literature review process

The search for theme relevant articles and content took place across a range of *Institute for Scientific Information* (ISI) journals. This process resulted in a total of one hundred and fifty four (154) relevant articles being identified. Due to the high number of articles retrieved a stringent criteria selection process had to be put into place to select articles most pertinent to the proposed research. Specific selection criteria terms (Figure 2.1) were identified with the aim of guiding the filtering process.

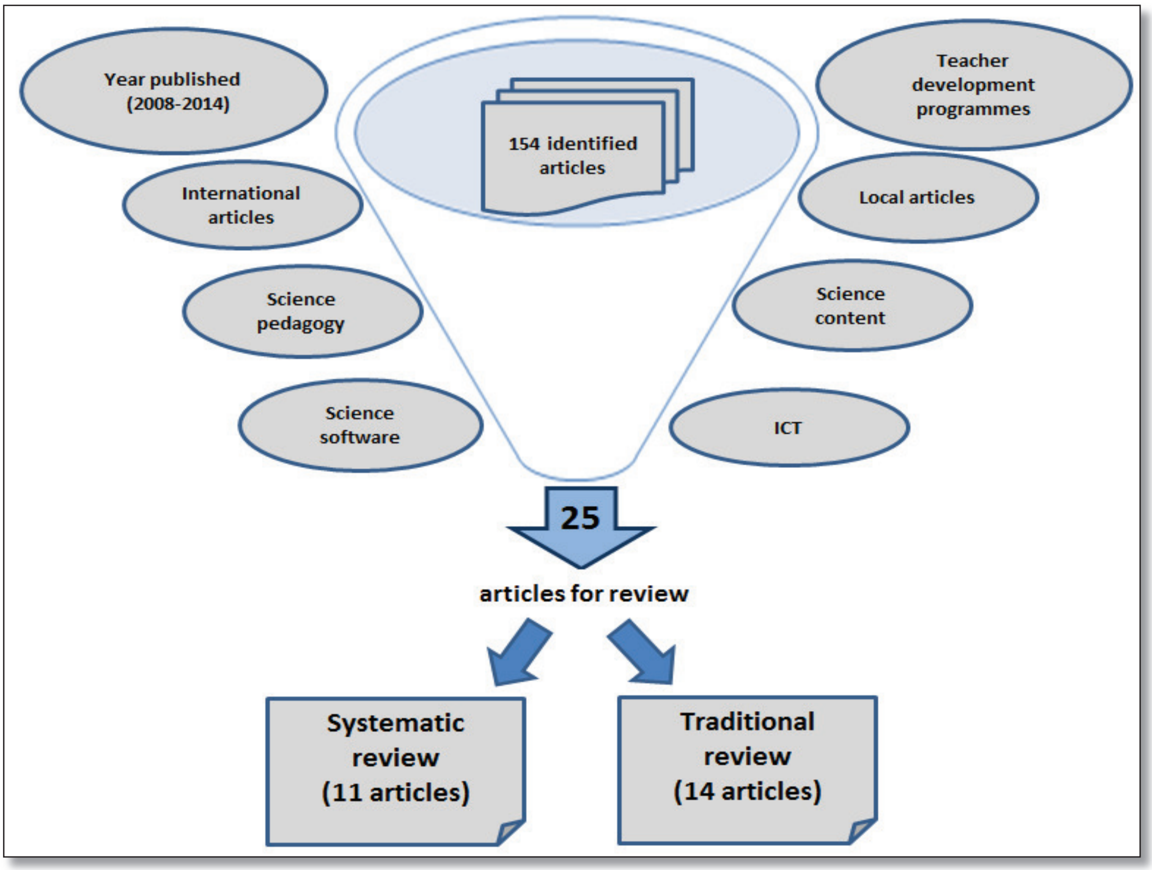

Figure 2.1: The journal article filtering process

Figure 2.1 displays the process in which the one hundred and fifty four (154) journal articles that broadly addressed the proposed research were refined, using a multiple criteria filtering method that consisted of eight filters. Upon completion of the filtering process a total of twenty five relevant articles were left. These articles were then taken through a second phase of filtering. This phase divided the articles into either a systematic review process or a traditional review process. The articles selected for the systematic review process had to be based on actual research on teacher development and/or the use of ICT in the teaching of Science. The articles selected for the traditional review process were articles that dealt with theory and policy relevant to teacher professional development, the use of ICT in the teaching of Science, the various TIMSS studies and finally articles that focused on statistical methods and secondary data studies. According to Khan, Kunz, Kleijnen and Antes (2003) and Jesson, Matheson and Lacey (2014) a literature review can be approached by using either the systematic or traditional approach. In this chapter the literature review started with a traditional approach and was followed by a systematic approach.

2.2.1 Traditional approach to the review of literature

2.2.1.1 Teacher professional development

The explanation of teacher professional development lends itself to a multitude of interpretations. The traditional view of professional development is teachers attending duration-specific Saturday workshops, holiday sessions, or after school seminars that focus on anything from increasing content knowledge to promoting the self-efficacy of the teacher (Buczynski & Hansen, 2010, p. 599).

This approach to teacher professional development has been the tried and tested method of professional development for many decades. Mushayikwa (2013, p. 277) identifies three core aspects of professional development: *experience, knowledge* and *skills* and positions them as the ultimate culmination of teacher professional development. Simon, Campbell, Johnson and Stylianidou (2011, p. 17) and Jones, Gardner, Robertson and Robert (2013, p. 1757) all suggest that teaching and teacher professional development are cultural activities that are embedded in specific social activity structures that form the backbone of the community. This view is consistent in the work of Soine and Lumpe (2014, p. 305) in which professional development is seen as a continuous process that allows the teacher to execute his or her professional and academic duties to contribute to an institution and the community at large.

According to Ono and Ferreira (2010, p. 59) professional development is a key element in educational reform and not an end point but rather an ongoing process built around the personal growth of the teacher. Teacher professional development can be regarded as a compilation of processes be they instinctive or deliberate, individual or communal that result in definite changes in a teacher's skills, knowledge, attitudes, actions or beliefs (Simon et al., 2011, p. 7). This view is elaborated on by Jones et al. (2013, p. 1758) who explain that teacher professional development should have an undeviating focus on improving learning and learning environments to support and realise each learner's potential achievement.

There are diverse approaches to and definitions of teacher professional development. While each of the approaches may differ in terms and procedure, they intrinsically have the same end goal, which is to prepare teachers adequately to teach subject content effectively to benefit the learners as well as to improve the efficiency and effectiveness of the school (Ono & Ferreira, 2010, p. 62). However, the view of Boaduo (2010, p. 2) differs from those of Ono and Ferreira (2010, p. 62). According to Boaduo (2010, p. 3) the professional development of teachers should cover both managerial and professional skills that not only prepare the teacher to improve the quality of teaching and standards at a school but also at the same time ensure that the teacher focuses on personal and professional growth and development. It is based on the argument that Boaduo (2010, p. 3) identifies four types of teacher development programmes as reflected in Figure 2.2.

Figure 2.2: Four parts of teacher development

The two programmes on the left in Figure 2.2 empower teachers to ensure learners and the school benefit from their attending professional development. The two on the right in the figure are teacher-centred in that they focus on the needs of the teacher as a professional and provide training to the teacher that result in the academic and career advancement of the teacher.

Valanides and Angeli (2008, p. 3) suggest that the use of computers in instruction and learning should not be seen as a bone of contention; the focus should be on how to deliver it effectively in the classroom. This sentiment resonates in the writing of Rogers and Twidle (2013, p. 239) who state that computers and appropriate subject-specific software are becoming an essential element in the 21^{st} century classroom and as a result teachers should possess the necessary skill set to use the technology effectively. Rogers and Twidle (2013, p. 239) point out that mastery of ICT technical skills is not the final solution to the problem; all teachers need to possess the necessary pedagogical and content knowledge to use the technology effectively to engage all learners. This perspective is echoed in the work of Ertmer and Ottenbreit-Leftwich (2013, p. 178) in which they remark that the primary focus of teachers who use technology should be facilitating learner-centred pedagogical approaches. This approach should allow learners to discover and construct their own knowledge.

Kim, Kim, Lee, Spector and De Meester (2013, p. 77) identify barriers to the integration of ICT in teaching. These barriers are then refined and identified as either first- or second-level barriers. First-level barriers are the easiest to overcome, and include ICT resources and teachers' technical skill set. However, second level barriers that include beliefs, pedagogic knowledge, content knowledge, knowledge of the curriculum and assessment practices of the teacher prove to be the most challenging. The acquisition of skills and knowledge by the teacher cannot serve as a predictor of effective technology integration (Kim, Kim, Lee, Spector & De Meester, 2013, p. 77). This view is sustained by Kreijns, Vermeulen, Kirschner, Van Buuren and Van Acker (2013, p. 56) with the proviso that there should be sufficient resources available to encourage teachers to integrate technology in their teaching. Kreijns, et al. (2013, p. 57) present two key constructs that may predict the use of ICT by a teacher. The first construct is *perceived usefulness* and the second is *perceived ease of use*. The first construct states that teachers must understand that technology is there to support their teaching and not an augmentation of the teaching process. The second construct looks at the user friendliness of technology; if the technology is difficult to use teachers will shy away from it. This concept is what Kreijns et al. (2013, p. 58) refer to as the *Technology Acceptance Model* (TAM). Using technology to teach is not a clear-cut process. There are certain instances where the use of technology to teach particular content is realistic and appropriate. Then there are instances where the content to be taught can definitely be taught more efficiently with the integration of technology (Koehler & Mishra, 2009, p. 61). It is at this juncture that the teacher needs to step in to determine the way forward. Teachers who have a solid grasp of content, pedagogy, assessment and information communications technology are able to plan the effective integration of technology in the lesson. Koehler and Mishra (2009, p. 63) put forward the TPACK model (Figure 2.3) that identifies the three main knowledge components required by a teacher in the 21st century.

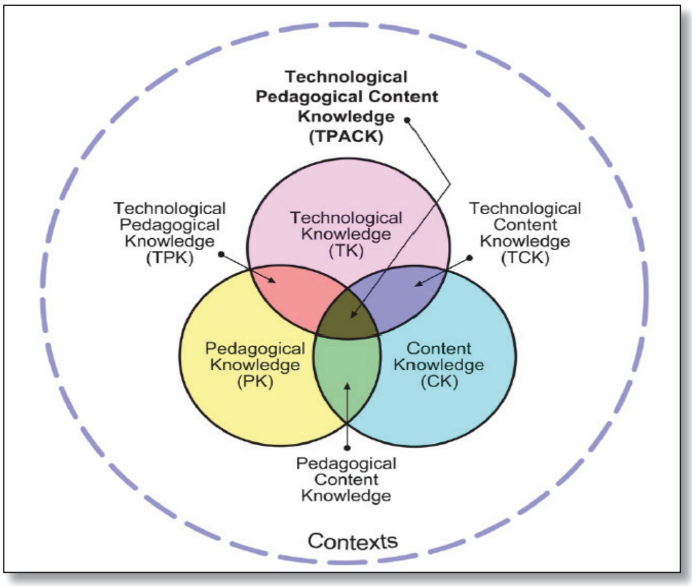

Figure 2.3: The TPACK model

This model identifies the three main knowledge components of a teacher: (1) *Content knowledge*, (2) *Pedagogical knowledge,* and (3) *Technological knowledge*. The ideal situation would be for a teacher to be at the *TPACK* overlap stage. At this overlap stage teachers have sufficient knowledge and understanding of the interactions between all three components (Koehler & Mishra, 2009, p. 66). Such teachers have a profound understanding of the subject content to be taught and are able to define the best pedagogic method, using technology to teach the subject content to learners.

It can be concluded from this model that in order for teaching with technology to be effective, teachers should be fluent in the three knowledge components propagated by the TPACK model. In order to achieve this teacher development needs to take on a more holistic approach with equal emphasis being placed on subject content, subject pedagogy, the subject curriculum, ICT and assessment practices.

2.2.1.2 TIMSS

The key goal of TIMSS is to provide participating countries with information to improve their standards of instruction and learning in Mathematics and Science. To procure this information both achievement and background information was collected with the administration of tests and background instruments respectively (Mullis, Martin, Ruddock, O'Sullivan & Preuschoff, 2009). South Africa took part in the 1995, 1999 and 2003 TIMSS studies; however, due to the dismal performance of South African schools in TIMSS 2003 it was decided by the Minister of Education and the Department to exclude South Africa from the 2007 study on the premise that the interventions put in place after TIMSS 2003 did not have time to mature (Long, 2007, p. 1). It is important that high stakes tests like TIMSS provide insight into how educational systems rather than individual schools can benefit from the findings of these studies (Long, 2007, p. 1). As the findings from TIMSS filter down through the education system, it should reach the level of the teacher at the point of identifying professional development interventions that would ultimately influence instruction (Long, 2007, p. 2). According to Nasser Abu-Alhija (2007) in Long (2007, p. 3) large scale tests such as the TIMSS have four key intentions: to monitor educational systems, assure quality control of the educational system, provide information to teachers about the state of instruction and learning, and identify needs and resources to ensure effective instruction and learning. TIMSS performed the function of monitoring educational systems with the aim of improving education systems; the research design focused on and compared the intended curriculum, the implemented curriculum and attained curricula of world education systems with special focus on Mathematics and Science (Long, 2007, p. 2).

As the focus is on Mathematics and Science it became important to determine the role ICT plays in the teaching of these two subjects especially now that South Africa no longer participates in the *Second Information Technology in Education Study* (SITES) that focused on the use and integration of ICT in teaching.

2.2.1.3 Analysis of secondary data

Secondary data analysis entails the re-analysis of existing data to either answer the original research question(s) with improved statistical techniques, or to answer new research question(s) using the existing data (Smith, 2008, p. 324). In this research data collected from the TIMSS 2011 component of the South African Grade 9[1], Science teachers were used to answer a new research question with seven sub-questions. According to Frederick, Barnard-Brak and Sulak (2012, p. 31) most secondary data sets are rich in information and potential. However, researchers need to be aware of possible drawbacks when using such secondary data sets. One of the main drawbacks of using secondary data to answer new research questions is that the data could have been collected for a totally different purpose (Smith, 2008, p. 328). As this research depends entirely on data collected from the South African TIMSS 2011 study, it was important to validate the data to be used. IEA studies have a very resilient empirical foundation that relies on both cross-sectional and longitudinal designs (International Association for the Evaluation of Educational Achievement, 2013). To ensure a genuine representation of the population at large, the sampling process was rigorous and followed strict IEA procedures (Nachmias, Mioduser & Forkosh-Baruch, 2008, p. 70).

The unit of analysis in this research was the South African Grade 9 Science teachers; however, in the TIMSS study the main sample unit was the school rather than teachers. The use of secondary data guarantees the researcher that the final datasets have been organised through a process high in proficiency and professionalism (Boslaugh, 2007, p. 4; Smith, 2008, p. 332). A major disadvantage identified by literature is that the secondary data to be used may not answer the researcher's specific research question(s) since the focus of the initial study might have had another research goal (Boslaugh, 2007, p. 4; Frederick, Barnard-Brak & Sulak, 2012, p. 31).

2.2.2 The systematic approach to the literature

Using the selection criteria filter (Figure 2.1) a total of eleven pure research-based articles were reviewed in this section. Three of the articles are based on studies conducted within

[1] In the case of South Africa, where it was expected that the Grade 8 tests would be too difficult for Grade 8 learners, the option existed that higher grade learners could be assessed. In this case Grade 9 learners would write the Grade 8 assessment (Mullis, Foy, Stanco & Martin, 2012).

South Africa and eight internationally. The articles selected for the systematic process comprise articles from both a Science subject context as well as a generic subject context. The systematic approach in reviewing the various articles started by grouping the articles into three focus areas: (1) Teacher perceptions and beliefs; (2) Teacher development models, and (3) ICT integration as reflected in Table 2.1. Each of the focus areas was then discussed under the following headings: (1) Purpose of the research; (2) Findings from the research, and (3) Limitations of the research. Table 2.2 on page 22 presents a composite review of both local and international articles that address the three focus areas.

	Focus Area	Author(s)	Contextual setting
1	**Perceptions and beliefs of teachers regarding teacher professional development**	Mestry, Hendricks & Bisschoff, 2009; Lustick, 2011.	South African (1) International (1)
2	**Teacher professional development models**	Ono & Ferreira, 2010; Moyer-Packenham, Bolyard, Oh & Cerar, 2011; Dichaba & Mokhele, 2012; Jones, Gardner, Robertson & Robert, 2013.	South African (2) International (2)
3	**Integration of ICT in teaching**	Lavonen, Juutia, Aksela, & Meisalo, 2006; Hermans, Tondeur, Van Braak, & Valcke, 2008; Inan & Lowther, 2010; Prestridge, 2012; Mushayikwa, 2013.	South African (0) International (5)

Table 2.1: Reviewed articles

2.2.2.1 Purpose of the studies under review

The purpose of the research described in the two articles in focus area 1 (*Teacher perceptions and beliefs*) *focuses on the need to understand teacher perceptions around teacher development programmes on offer*. According to Mestry et al. (2009, p. 477) professional development is a process that allows teachers to review, renew and extend their commitment as teachers to the ever-changing South African educational landscape and to maintain the moral purpose of teaching. The professional development programmes offered to teachers should not be static but fluid so that a cyclical process of evaluation, reflection and learning takes place with the aim of the improvement of development programmes. The discussion around reflection initiated in the work of Mestry et al. (2009) is continued by Lustik (2011) who attempts to explore and understand from the perspective of the Science teacher as to which teacher development opportunities are the most effective (Table 2.2).

The purpose of the research as described in the four articles in focus area two (*Professional development models*) *is to determine the need to understand which model of professional development for teachers is the most effective*. There are many models used in teacher professional development with one common aim, which is to prepare teachers adequately to teach subject content effectively to benefit the learners (Ono & Ferreira, 2010, p. 62). The roll-out of Curriculum 2005 (C2005) in South Africa witnessed the use of the cascade model for professional development that saw a high number of teachers being reached in the most cost-effective manner (Dichaba & Mokhele, 2012, p. 250). Due to the dismal failure of the cascade model Suzuki, (2008, p. 2) and Ono and Ferreira, (2010, p. 61) propose the use of the lesson study approach as an alternative model (See Table 2.2).

This model, during its pilot phase, faced severe challenges as the South African education system was undergoing another curriculum revamp. The work of Moyer-Packenham, Bolyard, Oh and Cerar (2011) proposes an approach that merges research strategies with teacher development with the hope of getting teachers to discover and construct their own knowledge, which links to a constructivist approach. Jones et al. (2013) sustain a constructivist approach in their work but add a community and social component to their model, like the lesson study model proposed earlier by Ono and Ferreira (2010) in which teachers observe, reflect and critically evaluate their lessons. So too the proposed model of Jones et al. (2013) allows for teachers to form a community of practice so that they may share ideas and resources (Table 2.2).

The purpose of the research described in the five articles in focus area three (*Integration of ICT in teaching*) *is examining the need to understand the influence ICT has on teaching in general and teaching Science in* particular (Lavonen, Juutia, Aksela & Meisalo, 2006). Both contributions by Hermans, Tondeur, Van Braak and Valcke (2008) and Prestridge (2012) attempt to understand the role and impact teacher beliefs have on the use and integration of ICT in teaching as shown in Table 2.2. Inan and Lowther (2010) attempt to understand the individual and environmental factors that could either promote or hinder the integration of ICT in teaching, which echoes the work of Prestridge (2012).

2.2.2.2 Findings from the studies under review

The findings of the two research articles from focus area one (*Teacher perceptions and beliefs*) reflect contradictory findings. According to Mestry et al. (2009, p. 477) teacher professional development can be successful at a school level on condition that the needs of the teacher are kept as high priority. However, the findings of Lustick (2011, p. 231) allude to the fact that less than 50% of teachers in the study indicated that school-level teacher development programmes were effective. A further finding by Mestry et al. (2009, p. 488) points to the fact that teacher professional development becomes successful when teachers recognise the need to improve their knowledge. This finding is validated in the study of Lustick (2011, p.230) in which 81% of teachers indicate that teacher professional development that focuses on reading of Science content improves their knowledge and thus allows them to be more effective in the transmission of content (See Table 2.2).

The findings around the second focus area (*Professional development models*) revolve around the four articles shown in Table 2.1. All four these articles attempt to propagate a particular model for conducting teacher professional development. Dichaba and Mokhele (2012, p. 250) put forward the cascade model that gained prominence during the introduction of Outcomes Based Education (OBE) in South Africa. Although alluding to the harsh criticism of the cascade model, they put forward a strong argument based on some of the benefits of the cascade model; they, like the earlier work of Mestry et al. (2009, p. 60) accept that the cascade model allowed for the misinterpretation and loss of information during the "cascade down" process (Dichaba & Mokhele, 2012, p. 250).

Further conflict in the research findings arose between the work of Ono and Ferreira (2010) and Moyer-Packenham, Bolyard, Oh and Cerar (2011). In the study conducted by Ono and Ferreira (2010) the focus is on the Lesson Study approach (See Table 2.2). The findings from this study show that teachers willingly participated in teacher professional development programmes during school holidays. However, Moyer-Packenham et al. (2011, p. 584) present findings that contradict those put forward by Ono and Ferreira (2011) in that the findings show that teachers preferred teacher professional development programmes to be conducted during school time. Ono and Ferreira (2010, p. 67) admit to the failure of the Lesson Study approach; however, a positive but unintentional consequence of this model was the adoption and sustaining of the teacher cluster or community method in the Lesson Study programme in the Mpumalanga province. This concept of a community of teachers or community of practice is further sustained in the work of Jones et al. (2013) who refer to their model as the Professional Learning Community (PLC) approach. As in the case of the Lesson Study approach, teachers felt comfortable interacting with peers and also alluded to the fact that such an interaction allowed for the improvement of teaching. The concept of a *teacher community of practice* as promulgated by Ono and Ferreira (2010) and Jones et al. (2013) is rejected in the findings of Moyer-Packenham et al. (2011), where it is stated that teachers were not open to peer observation and appraisal and regarded it more as a threat than a support structure.

The findings of the third focus area (*Integration of ICT in teaching Science*) revolved around the five articles as reflected in Table 2.1. As education has entered the digital age, it becomes imperative that all teachers possess the necessary skills, attitudes, beliefs, content and pedagogical knowledge to integrate the use of ICT in their teaching (Looi, Sun, Seow & Chia, 2014, p. 229). From the five research articles selected for this review a disturbing trend has evolved in that all five the articles were from international sources. One of the biggest gaps identified during this literature review is the lack of South African literature concerning professional development of teachers in the integration of ICT in teaching.

Teachers' acceptance and appreciation of the role ICT plays in instruction and learning depend largely on the attitude and belief of the individual teacher regarding the place of ICT. The findings from the work of Hermans, Tondeur, Van Braak and Valcke (2008, p. 1502) point to the fact that the beliefs and readiness of the teacher influence the ICT integration process (Table 2.2). This point of view is supported by the findings of Inan and Lowther (2010, p. 146) who show that teachers with a positive belief about ICT tend to influence their adoption and integration of ICT into teaching practice. This view is also sustained in the work of Lavonen et al. (2006, p. 162); Hermans et al. (2008, p. 1507) and Prestridge (2012, p.457) who elaborate that teachers that believe that ICT is not simply tools but rather a vehicle that can be used to promote self-directed learning tend to find innovative ways to use ICT in teaching.

Another key finding emanating from the five studies relates to the issue of resources. According to Lavonen et al. (2006, p.172) teachers are becoming more aware of the depth of Science resources that are available to them on the World Wide Web (www). This point is elaborated on in the work of Mushayikwa (2013, p. 277), in which one of the key findings from the study shows that Science teachers use the web to find resources to support their teaching. Lavonen et al. (2006, p.161) refer to the availability of resources and point out that access to technological resources have an impact on the use of ICT. This point of view is expanded in the work of Inan and Lowther (2010, p. 142) in which it has been found that teachers' access to ICT not only influences their readiness to use it but also affects their belief and readiness to use information communications technology.

According to Prestridge (2012, p. 457) even though the focus of teacher development in ICT is to ensure that technology enhances teaching, it is impossible to ignore or nullify the importance of teachers mastering ICT skills. However, this view is challenged in the work of Ertmer and Ottenbreit-Leftwich (2013, p. 428) in which it is clearly stated that the training of teachers in ICT should not be a technologically-based process but rather a process that uses ICT as a tool during content and pedagogic training. This view is also echoed in the early work of Inan and Lowther (2010, p. 142) and later work of Mushayikwa (2013, p. 276) in which the findings show that teachers' proficiency in ICT skills has a positive impact on their use and integration of ICT in practice.

2.2.2.3 Limitations of the studies under review

Looking at focus area 1 (*Teacher perceptions and beliefs*) with special attention on the work of Mestry et al. (2009, p. 477) it should be noted that although the study makes mention of teacher development programmes, the article does not go on to identify the types of development programme that teachers could attend. Similar to the work of Mestry et al. (2009), Lustik (2011) makes no mention of the role of ICT in the teaching of Science. Regarding focus area 2 (*Professional development models*) the limitations that arose from the four studies point to the small sample size of teachers in the study of Dichaba and

Mokhele (2012, p. 250) and Jones et al. (2013, p. 1769) where the geographical location of the sample was a single school district. As a result generalising the findings to a larger population can be risky. None of the teacher professional development models used in these studies was linked to ICT integration in teaching Science (See Table 2.2).

Finally in focus area three (*The integration of ICT in teaching Science*) in the five articles reviewed certain common limitations started to appear. In these studies (Lavonen, et al., 2006; Hermans et al., (2008); Inan & Lowther, 2010; Mushayikwa, 2013) the focus is primarily on computer technical skills that teachers should master to use computer functions effectively.

2.3 Gaps identified

The various studies reviewed in this chapter all investigate a single teacher professional development programme. No study examines multiple teacher professional development programmes and their resultant impact on ICT integration. It is important to remember that the development of a teacher is not based on one programme only. In order to develop an effective teacher who is able to integrate ICT into teaching a holistic development programme has to be implemented that looks inter alia at Science content, Science pedagogy, the Science curriculum, ICT in Science and Science assessment. The TPACK model (Figure 2.3) proposed by Koehler and Mishra (2009, p. 66) bears witness to the fact that the three learning components cannot stand on their own; training in one component will never develop a holistic teacher. To conduct a full blown research in which all key knowledge components are studied with a large enough sample population can have major logistic and financial implications.

The gap identified in this literature review shows the inability of any one of the research articles to conduct a single study looking at the different knowledge components in totality with the same sample of teachers. The 2011 TIMSS study investigated both Mathematics and Science teachers and their response to attending different teacher professional development programmes and their resultant use of ICT in the teaching of Science. The TIMSS instrument used to collect the data used to answer the research questions underwent a stringent process to ensure validity and reliability (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2011, p. 7). The data garnered from the TIMSS 2011 Science teacher questionnaire served this research well as it represents teachers from schools from different provinces and quintile rankings.

	LOCAL ARTICLES			INTERNATIONAL ARTICLES							
Title	**Perceptions of teachers of the benefits of teacher development programmes in one province of South Africa**	**A case study of continuing teacher professional development through lesson study in South Africa**	**Does the Cascade Model Work for Teacher Training? Analysis of Teachers' Experiences**	**A professional development project for improving the use of information and communication technologies in Science teaching.**	**The impact of primary school teachers' educational beliefs on the classroom use of computers**	**Experienced secondary Science teachers' perceptions of effective professional development while pursuing National Board Certification**	**Common features of professional development activities for Mathematics and Science teachers.**	**Factors affecting technology integration in K-12 classrooms: a path model**	**The beliefs behind the teacher that influences their ICT practices**	**Science Professional Learning Communities: Beyond a singular view of teacher professional development**	**Teachers' Self-directed Professional Development: Science and Mathematics teachers' adoption of ICT as a professional development strategy**
Date published	2009	2010	2012	2008	2008	2010	2010	2010	2012	2013	2013
Author/s	**Raj Mestry, Ilona Hendricks and Tom Bisschoff**	**Yumiko Ono and Johanna Ferreira**	**Mpho M. Dichaba and Matseliso L. Mokhele**	**Jari Lavonen, Kalle Juuti, Maija Aksela and Veijo Meisalo**	**R. Hermans, J. Tondeur, J. van Braak, M. Valcke**	**David S. Lustick**	**Patricia S. Moyer-Packenham , Johnna J. Bolyard, Hana Oh & Nancy Irby Cerar**	**Fethi A. Inan. Deborah L. Lowther**	**Sarah Prestridge***	**M. Gail Jones, Grant E. Gardner, Laura Robertson & Sarah Robert**	**E. Mushayikwa**
Purpose of research	Examine the perceptions of teachers regarding the TPD they are offered.	Improving Mathematics and Science learning of secondary school learners using the lesson study approach in teacher development	Explore the effectiveness of information transmission using the cascade training model.	Examine how the use of ICT influenced teachers to use ICT in the teaching of Science.	Understand teachers' educational beliefs as a precursor of computer use, while controlling the impact of technology-related variables and demographical variables.	Explore Science teachers perceptions regarding the most effective TPD opportunities.	Examine the inclusion of research-based features in PD activities and the effects on teacher knowledge	Examine the effects of teachers' individual characteristics and environmental factors on teachers' technology integration.	Explores teacher beliefs that influence the ways Information and Communications Technology (ICT) are used in learning contexts.	Provide teachers with time to share ideas and resources for Science instructional improvement	Investigate the use of ICT in the Self-directed Professional Development (SDPD) of teachers in Mathematics and Science.
Subject	Generic	Mathematics and Science	ABET	Science	Generic	Science	Science and Mathematics	Generic	Generic	Science	Mathematics, Biology, Chemistry, Geography and Physics
Contextual setting	Gauteng, South Africa	Mpumulanga Province, RSA	Ngaka Modiri Molema District in North West Province, RSA	Finland	Flanders, Belguim	United States	N/A	Tennessee USA	Queensland, Australia	South Eastern USA	Zimbabwe
Socio-economic setting	Urban	Semi-urban	Rural and Urban	Urban	Urban	Urban	N/A	Urban	Urban	Urban	Rural
Research design	Quantitative	Qualitative	Quantitative	Quantitative	Quantitative	Quantitative	Quantitative	Quantitative	Mixed methods (Qty +Qua)	Mixed methods (Qty +Qua)	Mixed methods(Qty +Qua)
Participants	Primary and Secondary school teachers	Senior FET teachers	ABET teachers	Science teachers	Primary school teachers	Secondary school science teachers	Secondary analysis	School teacher	School teacher	Elementary school science teachers	Teachers in Zimbabwe
Number of participants	n= 500	n= 11	n= 103	n= 44	n= 525	n= 118	n= 34 004	n= 1382	n= 48	n= 65	n= 418
Statistical analysis	Bartlett's Test for Sphericity and Factor Analysis	Interviews followed thematic analysis	Descriptive statsitics, frequencies and percentages	Chi-square analysis	Descriptive statsitics and Multilevel modelling (MLwiN 2.02)	Chi-square and two tailed *t* -tests	Descriptive statsitics, frequencies and percentages	Regression and Coefficient of Determination	Factor analysis, Regression analysis and Interviews followed thematic analysis.	Qualitative: Interviews followed thematic analysis. Quantitative: test items were statistically analysed using frequencies and percentages.	Quantitative: Fisher's Exact Test and Qualitative: Interviews followed thematic analysis.
Results/ findings	TPD should be planned at a school level but keeping teachers needs as the focus	work needs to be done in the class to ensure meaningful change in learning.	(49%)& (43%) agreed that trainers knew their content knowledge	The percentage of teachers who realised that there are an abundance of Science resources on the web grew.	Teachers with constructivist teacher beliefs tended to use ICT more often in classroom.	According to teachers, attending education courses and in-service workshops was an ineffective approach to TPD.	Teachers appreciate and see the benefits of PD but due to demands at schools find it a challenge to implement.	Teachers' age and years teaching negatively affected their computer proficiency	Teachers came to a realisation that ICT is not just a tool but should be used to promote self-directed learning.	72% of teachers indicated that attending PLC motivated them to share ideas with other teachers.	4 of every 5 teachers who completed the questionnaire came from schools that had access to ICT.
	Schools and districts should synergise their TPD plans so that futile and repetitive work is not done.	initial adoption of lesson study was good but waned very quickly.	(54%)& (31%) agreed that trainers had the skills to transmit their training and encourage learning	Teachers found that computers/ICT was ideal for cooperative learning.	Teacher beliefs were found to be just as important as teachers attending training.	5% of teachers indicated an interest in writing for publications.	Most teachers felt that PD programmes should take place during teaching time as it is part of their job.	Teachers' computer proficiency positively affect their technology integration.	Even though the aim is to use ICT's as an enhancement to learning, one cannot run away from the fact that ICT skills are vitally important.	Teachers indicated that PLC did not focus on approaches to assess learners.	70% of teachers who had access to ICT did not use ICT in teaching the focus subjects during the study period.
	TPD only becomes successful when teachers have identified the need to learn and improve their knowledge.	Other workshops competed with Lesson Study model training that was conducted during the school holidays.	(55%)& (24%) agreed that cascade model allowed for misinterpretation and loss of information.	Teachers who adopted a way to use ICT in their class would stick to that way and explore other ways.	Teachers who work collaboratively tended to feel at ease when working on ICT in teaching.	98% of teachers indicated that involvement in developing Science curriculum is important to their development.	Peer appraisal is not welcomed as it is seen as judgemental.	Teachers' beliefs and readiness positively influence their technology integration.	Teachers also aware of the importance of the curriculum talking to the integration of ICT.	Attending PLC also changed the ways they planned their Science lessons.	45% of teachers who had access to ICT used ICT in their teaching during the study period.
		The lesson study workshops and the new NCS workshops did not complement each other.	(60%)agreed that they would not be able to train their peers at schools only 23% said they could train.	The Internet has numerous sources for Science teaching.		100% of teachers indicated that attaining some form of Science certification is important to their development.	Peer observation of lessons and/ or Principal visits to classes is not a common occurence.	School resources also affected teachers readiness and beliefs.	ICT should be used in all facets of a teachers work, not only in admin or or in teaching but across all these aspects.	Teachers indicated that workshops in Science were the most effective way for TPD and the least effective was research in labs an Science conferences.	Teachers from PRIVATE and MISSION schools tended to access ICT more often and use it more often.
		Although the lesson study was not successful it did initiate the cluster approach throughout the province	(32%) & (23%) agreed that they were not confident that they would be able to transmit the skills at their schools.			81% of teachers indicated that reading Science literature is important to their development.		The access to computers for teachers influenced their willingness to use computers.		Teachers felt that PLC were more useful to seasoned teachers as compared to new teachers.	39% of the teachers (n=254) could be categorised as ICT users.
		Teachers indicated that it was impossible to use the lesson study approach in their classes.				78% of teachers indicated that attending Science conferences or science workshops is important to their development.		The support that schools have for teachers strongly influenced teachers acceptance to use ICT in school.		Teachers also felt that during PLC sessions, school management used it to discuss school plans and activities.	Teachers used ICT to find resources to support their teaching conent rather than use ICT to teach content.
						Less than 50% of the teachers indciated that in-house school TPD was effective to their development.				63% of teachers felt that PLC was beneficial to improving Science teaching.	Many teachers sought to empower themselves with ICT skills.
										Teachers indicated that the main goal of PLC was to increase content knowledge, but this did not happen in this study.	
Focus or Theme	Teaching	Science content	Science content and Science pedagogy	ICT	ICT	Science curriculum	Science conent	ICT	ICT	Professional communities	Science content, ICT and Science pedagogy.
Discussion	All planning for TPD should be done with the ultimate goal that learners must benefit.	Change in teacher pratice will only occur over time and not overnight	Cascade model is cost effective	Does the integration of ICT in teaching require a change in attitudes, belief and pedagogical approach?	The factor of school culture and its possible conflict with individual culture can influence the use of ICT's at a school level.	TPD in Science curriculum came up as an important aspect in teachers view on their development	Unions not fully behind teacher observation.	Years' teaching experience plays a passive role when it comes to use of ICT in teaching.	The use of ICT in teaching should be fused so that ICT becomes an integral part of the pedagogy.	The use of PLC allows for the sharing of resources, ideas and collaborating with other teachers teaching Science.	Teachers found accessing ICT resources a challenge and a novel experience
	TPD programmes should not be generic programs but rather be designed to accommodate the varying contexts in South Africa.	Lesson study approach stopped by DBE in the district because of the poor matric results.	CM disseminates information in a short period of time.		A strong correlation between teachers having a traditional or constructive belief system and their acceptance of ICT in education.	Attending in-service workshops was seen by teachers as the least effective manner for TPD.	Teachers placed blame on the poor quality of district support together with quality of district officials.	New graduates more willing to use and accept technology.	Teachers can be found either in Foudational ICT practices or Developing ICT practices.	Lesson planning and sharing good practices also become an important aspect of PLC.	Teachers forced to learn how to use ICT as learners are more adept at using technology.
	There seems to be a level of competition between school initiated TPD and District initiated TPD.	Around the same time the introduction of the NCS moved attention away from lesson study approach.	Although trainers had the knowledge and skills, effective transmission was impossible.			TPD programmes at school allow teachers to select only what they want to attend.	The differences of the past (contextual factors) cannot be ignored when planning PD programmes.	Making resources (ICT) more readily available allows teachers to use ICT.	Foundational refers to teachers in the process of developing ICT skills and Developing when they attempt to integrate ICT into their teaching.	Teachers indicated that social differences at times cause PLC approach not to be effective.	Teachers felt more empowered attending ICT sessions.
	PD programmes should be initiated from a school level and supported from the district level	The project failed not because it was not well thought out, but rather a number of external factors also were to blame.	CM leads to dilution and misinterpretation of information.			Teachers had a postive feeling towards getting Science certification for courses attended.		As proficiency increases so to does willingness to integrate.	Teachers' ICT competence strongly correlated to their ICT competence and practice.	Time constraints became a major issue, as teachers needed to complete the mandated curriculum.	Need to move away from traditional approach to TPD and allow teachers to choose the type of support they need, when they need it, where they access it and how they use it.

Table 2.2: Condensed literature review

	LOCAL ARTICLES			INTERNATIONAL ARTICLES							
Title	**Perceptions of teachers on the benefits of teacher development programmes in one province of South Africa**	**A case study of continuing teacher professional development through lesson study in South Africa**	**Does the Cascade Model Work for Teacher Training? Analysis of Teachers' Experiences**	**A professional development project for improving the use of information and communication technologies in science teaching.**	**The impact of primary school teachers' educational beliefs on the classroom use of computers**	**Experienced secondary science teachers' perceptions of effective professional development while pursuing National Board certification**	**Common features of professional development activities for mathematicsand science teachers.**	**Factors affecting technology integration in K-12 classrooms: a path model**	**The beliefs behind the teacher that influences their ICT practices**	**Science Professional Learning Communities: Beyond a singular view of teacher professional development**	**Teachers' Self-directed Professional Development: Science and Mathematics teachers' adoption of ICT as a professional development strategy**
Date published	**2009**	**2010**	**2012**	**2008**	**2008**	**2010**	**2010**	**2010**	**2012**	**2013**	**2013**
Author/s	**Raj Mestry, Ilona Hendricks and**	**Yumiko Ono and Johanna Ferreira**	**Mpho M. Dichaba and Matseliso L.**	**Jari Lavonen, Kalle Juuti, Maija**	**R. Hermans, J. Tondeur, J. van**	**David S. Lustick**	**Patricia S. Moyer-Packenham ,**	**Fethi A. Inan. Deborah L. Lowther**	**Sarah Prestridge***	**M. Gail Jones, Grant E. Gardner, Laura**	**E. Mushayikwa**
	PD should be intrinsically driven rather than extrinsically	Lesson study approach is not a once off event there needs to be continous interaction and collaboration.							ICT competency cannot predict the level or complexity ICT is used by teachers for teaching.		ICT becomes that model for a new approach to TPD.
Implications to the study	This study could influence the plans of TPD at both a school and district level so that TPD programmes are designed so as to fit the needs of the teacher and also consider contextual factors.	In order to try and make the lesson study a success, it may be necessary to include discussion time and observation time into the school time table.	Although the cascade model is cost effective and reaches a high number of teachers, its use in any future TPD programmes needs to be well defined.	This study can form the backbone for future studies that can look at computers as the means for transfering Science content and pedagogic knowledge rather than a tool to be mastered.	The fact that a teachers beliefs influence their use of ICT in a teaching environment could influence future training or TPD programmes.	Policy makers and educational leaders might want to look at time and resources when planning future TPD programs.	To emphasise the role of school leadership to motivate teachers to attend PD and to advance themselves.	The use of age and years teaching can give insight into the make up of teachers who are willing to use computers in school for teaching.		As indicated in this study, TPD time was used for school administration work, so for future studies it will be important for school's SMT to ensure TPD is done exclusively for teacher development.	With the increase in technology platforms (tablet, PC, mobile phones) the technology TPD adoption model needs to be further studied.
Limitations to study	This study makes mention of developing skills and knowledge of the teacher, however does not go on further to specify which skills and which knowledge components.	Lesson study approach looks at the presentation lesson holistically, however in this study focus revolved around training teachers specifically in Science content with no focus on the use of ICT in Science.	The sample of teachers came from one specific rural district in the North West province with no reprentation of teachers from an urban centre.	In this study there is a limited focus on aspects of TPD that would promote the integration of ICT in teaching.	This study focused on teacher belief however lacked looking into the role of content and pedagogy.	This study had a very narrow focus and did not address learning objectives, collaboration and the role of ICT in Science teaching.	This study aimed to identify common features of TPD, this was achieved to an extent. However this study identified the cohesion needed between school level TPD and district level TPD. This study does not expand on the activites and these activities would also look at the cohesion between content, pedagogy, curriculum, assessment and ICT.	The study looked at the 12 variables having an impact the use of computers in teaching. However from all 12 the variables only 1 looked at ICT in relation to teaching and pedagogy.	In no way can a teacher's beliefs be used as a way to inform ICT practices by the teachers. The study could have provided more depth into the types of practices these teachers attempted.	Teachers within this sample were from a single school district, to make inferences beyond the district is not advisable.	Although ICT and the access to it was the basis of this study, no attention was given to developing ICT skills in teachers.
		The sample size is very small. As a result to interpret the findings and generalise them to the larger population is risky.	The study focused on TPD in Science content and Science pedagogy, the statsitical analysis used was purely frequencies. No mention of the curriculum or the use of ICT in TPD.	This study focused more on teachers' ICT technical skills rather than ICT pedagogical skills.							No mention is made of the level of teachers' ICT competency yet the same teachers were expected to teach Science using ICT.
Future research	This study could lay the foundation for a study that will look at those factors needed to ensure school leadership promotes TPD at a school level.	Include the use of ICT and see if the lesson study approach could shed light on ICT use and practice.			Future research could focus on certain specific school conditions and school culture variables.	Look at various Reform TPD approaches as well as Traditional TPD approaches and define a synergy between the two.	To identify measures to assess various TPD activities based on Science class room practice.	Future studies could look at adding more variables that could influence ICT integration.	Future research based on this study could try to look into teachers' beliefs and their impact on the various components invloved in TPD within a specific sibject.	Leading from the limitation future research could include more schools across a wider area with a greater time.	To determine what drives teachers towards self-directed professional development.
Conclusion	School management ultimately plays a pivotal role to ensure teachers are motivated to attend TPD programmes and for teachers to develop themselves.	Although the lesson study approach was unsuccesful in MP, teachers who were involved in some did improve their lessons.	Although CM is a widely used approach in this study it failed.	Science teachers can be guided towards the integration of ICT into Science teaching through the development of teaching methods based on the existing goals of Science education.	Teacher beliefs form the foundation for a succesful TPD programme. Understanding the beliefs of teachers will help introduce any new innovation into a class situation.	The perception that attending TPD programmes aims to foster improved learner gains is a dominant in teachers' views.	The learning gains of learners is the ultimate goal in any TPD programme and to document the effects on teacher knowledge and change in teaching practice.	Although there are multiple variables that can influence a teacher accepting or rejecting the use of technology in a class, the issue of skills empowerment still is of utmost importance.		Altough PLC is an effective form of TPD, there are many challenges that face its implementation.	As access to technology in the most remotest areas improves, so too has the thirst of teachers to access resources that will allow them to be involved in more flexible TPD programmes.

Table 2.2: Condensed literature review (continued)

CHAPTER 3
RESEARCH METHODS

3.1 Introduction

The purpose of this research was to investigate the relationship between Science teachers attending various professional development programmes and their use of computer software in the teaching of Science. The inherent assumption underlying computer integration in the classroom is the belief that increased access to computers and computer software will effectively enhance learner performance (Gibson, Stringer, Cotten, Simoni, O'Neal & Howell-Moroney, 2014, p. 165). However, earlier literature (Blignaut, Hinostroza, Els & Brun, 2010, p. 1559) shows teacher professional development plays an equal if not greater role in effective integration of ICT in teaching. In this research attention is given to the two key variables, *Teachers attending teacher professional development programmes* and *Teachers using computer software in Science instruction* that were identified in the South African Grade 9 Science teacher questionnaires of TIMSS 2011. According to Thomson and McIntyre (2013, p. 410) understanding the beliefs, goals, motivations and values of teachers is a complex process; understanding these factors should help to improve teaching practices. Chapter 3 describes and elaborates on the appropriateness of the research method and provides information on the population, the sampling process, the study sample, data collection, the validity and reliability of the instrument used in the primary study, and the data preparation and analysis used in this secondary research.

3.2 Research design

3.2.1 Philosophical approach to research

The philosophical foundation of this research is guided by three key stances: epistemological, ontological and methodological. Epistemology is the theory of knowledge and the beliefs about the nature of knowledge; ontology is concerned with the assumptions and beliefs about the nature of being and existence; methodology deals with how knowledge about the world is gained through a theoretically informed process of data collection (Cohen & Crabtree, 2008). These three stances shaped and guided how this secondary research was conducted and the hypotheses were tested (Marsh & Furlong, 2002, p. 17).

Researchers inclined towards the positivist position believe that observing human experience through a scientific lens ensures the research is untainted by the values, political slant and ideology of the researcher (Heidtman, Wysienska & Szmatka, 2000, p. 1; Ryan, 2006, p. 12). This is further supported by Ryan (2006, p. 14) who states that an individual's worldviews influence the approach used in research. Within the positivist position measurements, tools and stringent procedures are important and make the research more objective and replicable and this is made possible by the use of statistical processes (Taber, 2011 p. 396). A positivist position in research places faith in quantification and on the idea that the use of correct statistical techniques provides correct answers. However, positivism has many critiques according to Heidtman et al. (2000, p. 2); many social scientists view human relations and social life as a fluid and dynamic process and subsequently a positivist position or using a scientific approach will negate the fluidity of a "real social experience". Podoksik (2004, p. 300) refers to positivism in social Science as a "defective" science. Ryan (2006, p. 18) challenges the critics of positivism by affirming that a positivist position on social research is a dominant approach and will always play a vital role ensuring that personal bias is minimised and research questions that slant towards a quantitative approach are accommodated. In this research the main research question attempts to understand the relationship between teachers attending teacher development programmes and their use of computer software to teach Science.

As alluded to by Ryan (2006, p. 20) there are research questions that always lend themselves to a quantitative approach. In this research the main research question is one of those quantitative types of question. In order to answer this question it is important that a link is drawn between the *number* of teachers who attend teacher development programmes and the *regularity* with which they use computer software to teach Science. Quantifying the number of teachers attending teacher professional development programmes and quantifying the use of computer software allow for a pattern to emanate from the data (Ryan, 2006, p. 21). From the pattern and the elaboration of the various relationships that emanated from this research, suggestions and concepts emerged that inform policy and planning (Taber, 2011, p. 396). Heidtman et al. (2000, p. 12), maintain that a "scientific approach is a clearly definable form of enquiry that can be used to examine any area of experience".

As this research is based on the use of secondary data the empiricists' stance that knowledge can only be acquired through experience (Dalile, 2014, p. 2) becomes somewhat debatable. The rationalist position sees knowledge as gained through pure and intense thinking which is independent of sensory experience. Knowledge attainment from the perspective of a rationalist is achieved through deduction, in which conclusions are based on intuitive premises and valid arguments rather than the sense experience of individuals (Bryant, 2010; Markie, 2013; Dalile, 2014). This research used data collected from the TIMSS 2011 study; the data represents the responses from teachers based on questions from the Grade 9 Science teacher questionnaire. These responses are not in a narrative form but rather valid and reliable numerical data. The TIMSS 2011 data is unchanging, eternal and certain (Dalile, 2014, p. 1; Wang, 2012, p. 2). The data used covers the seven professional development programmes that teachers may or may not have attended. The data is in a quantitative form and as a result does not espouse any opinion or thought of the responding teachers. Through a process of inference that includes the use of various statistical analysis methods, the seven identified hypotheses (See Table 3.3) were tested and conclusions drawn (Bryant, 2010). The process whereby human experience or practice, in this case attending teacher professional development programmes and the use of computer software to teach Science is reduced to a set of variables, exemplifies a classic approach of rationalism called reductionism. It must be noted that almost all statistical analyses are based on measures of central tendency and thus are reductionist in principle (Bryant, 2010). In this research the different phases of statistical analysis applied to the data led to the testing of the hypotheses that according to Dalile (2014, p. 1) allowed for informed judgments and conclusions to be drawn regarding the relationship between attending teacher professional development programmes and the use of computer software by teachers for teaching.

As alluded to earlier in Chapter 3, the data used in this research reflects the responses of the Grade 9 Science teachers and their attending teacher professional development programmes (See Appendix 3.2) and their use of computer software to teach Science (See Appendix 3.1). These two variables reflect human experience and practice (qualitative), which with the use of the Statistical Package for Social Sciences (SPSS) were converted into a numerical format (quantitative) that allowed statistical analysis to be administered to the variables (Guest, Namey & Mitchell, 2013, p. 1). The method used in this research is detached from the view of the purists as well as the situationalists who regard the integration of qualitative and quantitative approaches in one research project as unthinkable (Niglas, 2000, p. 2). Creswell (2005, p. 4) rejects the views of the purists and situationalists in that the advantage of a mixed method approach or integrated approach to research allows for data not only to be explained in a singular qualitative or quantitative perspective but rather to offer the best of both approaches. The use of an integrated approach compensates for the deficiencies of using a single approach (Molina-Azorín, López-Gamero, Pereira-Moliner & Pertusa-Ortega, 2012, p. 426). The proponents of an integrated approach or pragmatists are of the opinion that the focus should be on solving social problems using the widest array of conceptual or methodological approaches rather than debating the appropriateness and suitability of approaches (Niglas, 2000, p. 3).

This research utilises an integrated qualitative-quantitative approach. The purpose of the South African Grade 9 Science teacher questionnaires was to extract information that would reflect contemporary practices in teaching Science and the use of computers and computer software in its teaching (Mullis, Drucker, Preuschoff, Arora & Stanco, 2011, p. 16). The qualitative nature of the data collected through this questionnaire in TIMSS 2011 allowed for the why's and how's of human behaviour, opinion and experience to be answered (Guest, Namey & Mitchell, 2013, p. 1). The questionnaire is elaborated on later in this chapter. The original qualitative data obtained from the TIMSS 2011 dataset was transformed into numerical format to be used for quantitative analysis with the aim of deducing findings that inform policy and practice (Srnka & Koeszegi, 2007, p. 33). The numerical data then underwent several statistical analysis processes using SPSS (Briggs, Coleman & Morrison, 2012, p. 282) that are discussed in more detail later in this chapter.

The philosophical foundation of this research design was a PRQlQt (Positivism Rationalism Qualitative Quantitative) stance that guided the research and attempted to test the seven hypotheses postulated.

3.3 Population of the research

3.3.1 Population and process of sampling

TIMSS 2011 views the national population as all schools in South Africa that have learners who are in their ninth year of schooling (Grade 9) and take Science as a subject (Perše, Kozina & Leban, 2011, p. 5). In this research the national population refers to all Grade 9 Science teachers in South Africa. South Africa was one of three countries that included Botswana and Honduras that administered the assessments at a Grade 9 level. All three these countries demonstrated low performances at this level in both Mathematics and Science (Human Sciences Research Council, 2012). The TIMSS 2011 sampling framework utilised a two-stage random sample design (Joncas & Foy, 2011, p. 8). At the first level a national sample of schools was secured and at the second level an intact class from the sampled school was secured (Joncas & Foy, 2011, p. 5; Chong, 2012, p. 719). To ensure a proportionate representation of South Africa, the South African school population was then stratified into groups or strata. The stratification process followed a two level process: firstly explicit stratification based on province, language and school type, and secondly implicit stratification based on the poverty index and location was conducted. This process led to the final sample of schools to be used in TIMSS 2011 (Joncas & Foy, 2011, p. 88).

3.3.2 The sample

A total of 287 public schools and 29 independent schools from all nine provinces made up the eventual South African sample that took part in the TIMSS 2011 study (Human Sciences Research Council, 2012, p. 9). Based on the sampling framework, teachers at the sampled schools teaching Science to the sample of Grade 9 learners became the unit of analysis in this secondary study. The focus fell on the Grade 9 Science teacher who was not part of the sample framework but rather was responsible for teaching Science to Grade 9 learners within a sampled school (Joncas & Foy, 2011, p. 10).

3.4 Instruments

The TIMSS 2011 study consisted of multiple instruments comprising questionnaires and assessments. The instruments included the following:

- School level questionnaire

- Learner questionnaire
- Grade four Mathematics teacher questionnaire
- Grade four Science teacher questionnaire
- Grade eight Mathematics teacher questionnaire
- Grade eight Science teacher questionnaire
- Grade four Mathematics assessment booklet
- Grade four Science assessment booklet
- Grade eight Mathematics assessment booklet
- Grade eight Science assessment booklet

In this secondary research the focus was on the Grade 8 Science teacher questionnaire only.

3.4.1 Science teacher questionnaire

The Science teacher questionnaire consisted of ten key topics that generated a holistic picture of the Grade 9 Science teacher population in South Africa. Table 3.1 provides a breakdown of the configuration of the Science teacher questionnaire. For the purpose of this research and to answer the main research question attention was given to the three highlighted topics, viz. *biographical teacher details, resources in teaching Science* and *preparation to teach Science*.

Topic	Number of Questions	%
Biographical details	5	6
School	4	4
Being a teacher	2	2
Actual teaching	5	6
Teaching Science	3	3
Resources in teaching Science	4	4
Science topics taught	20	22
Science content coverage	5	6
Science homework	7	8
Science assessment	8	9
Preparation to teach Science	27	30

Table 3.1: Science teacher questionnaire

3.4.2 Reliability and validity of teacher questionnaire

Reliability and validity of research instruments are crucial aspects in quantitative research (Creswell, et al., 2010, p. 80). The issue of reliability and validity in all TIMSS studies is of utmost importance, especially as TIMSS provides all participating countries with an opportunity to measure progress (Mullis et al., 2011, p. 7). All instruments developed were field-tested in their respective countries to ensure contextualisation, reliability and validity (Johansone, 2011, p. 3 and 7). The results from the analysis of the questionnaire items were reviewed by the Questionnaire Item Review Committee (QIRC) and the TIMSS National Research Coordinators. The analysis guaranteed that the proposed contextual questions were likely to provide valid and reliable indicators of effective environments for learning for each participating country with the least possible response burden (Johansone, 2011, p. 6). Majority of the field test question items had good measurement properties and were reserved for the main data collection process.

To provide a gauge of the reliability of the chosen questions, Cronbach's Alpha was used to compute the internal consistency of each question that would be included in the Grade 9 Science teacher questionnaire. A question was considered adequately reliable if Cronbach's Alpha was at least 0.7. Most of the proposed questions in the TIMSS 2011 Science teacher instrument had Cronbach's Alpha coefficients that surpassed 0.7 (Johansone, 2011, p. 4). To ensure validity of the instruments in TIMSS 2011 there had to be a positive relationship between the indicators for effective learning environments as determined from the Science teacher instrument and learner achievement. This was achieved by attaching the Science teachers' responses to learner records, so that the questions describing learning environments could be related to learner achievement results (Mullis et al., 2011, p. 15).

3.5 The research variables

The emphasis of this research centres on the main research question, which has been formulated around the key variables (See Table 3.2). Knowing the complexity and relationships of each variable is important as this will guide all future analysis (Nenty, 2009, p. 26).

	Variable	Variable description	Variable	Variable type
1	BTBG02	Gender	Control	Nominal
2	BTBS20D	When you teach Science how do you use the following resources? *Computer software for Science instruction*	Dependent	Ordinal
3	BTBS28A	Teacher Development: Science content	Independent	Nominal, binary
4	BTBS28B	Teacher Development; Science pedagogy/instruction	Independent	Nominal, binary
5	BTBS28C	Teacher Development: The Science curriculum	Independent	Nominal, binary
6	BTBS28D	Teacher Development: Integrating information technology into Science	Independent	Nominal, binary
7	BTBS28E	Teacher Development: Improving learners' critical thinking or inquiry skills	Independent	Nominal, binary
8	BTBS28F	Teacher Development: Science assessment	Independent	Nominal, binary
9	BTBS28G	Teacher Development: Addressing individual learner needs	Independent	Nominal, binary

Table 3.2: Variables used in the research

3.5.1 Control variable

The control variable *Gender (**BTBG02**)* is described using a nominal scale grouped into two classes (See Appendix 3.3): ***1 (Female) and 2 (Male)***.

3.5.2 Dependent variable

The dependent variable *Use of computer software in Science instruction (**BTBS20D**)* is described by an ordinal scale grouped into classes (Creswell, et al., 2010, p. 148) and is built on a three-point scale (See Appendix 3.1): ***1 (Basis for instruction), 2 (Supplement) and 3 (Not used).***

3.5.3 Independent variables

The independent variable *Teachers attending teacher professional development (**BTBS28A - BTBS28G**)* describes the seven types of professional development programme teachers could attend and is described using a nominal scale grouped into a two-point scale (Creswell, et al., 2010, p. 148) (See Appendix 3.2), ***1 (Yes) and 2 (No):***

1. *Science content*
2. Science pedagogy/instruction

3. Science curriculum
4. Integrating information technology in Science
5. Improving learners' critical thinking or inquiry skills
6. Science assessment
7. Addressing individual learner needs

3.6 Research hypotheses

To formalise and narrow the scope of this research a hypothesis testing research (HTR) approach was used to test the seven hypotheses derived from the main research question. Each hypothesis is made up of a null hypothesis (H_o) and alternative hypothesis (H_a) that describe the relationship between the independent and dependent variable. The alternative hypothesis is what one tries to test or prove to be true, while the null hypothesis accepts that the alternative hypothesis is not true (Plano-Clark, Huddleston-Casaa, Churchill, Green & Garrett, 2008, p. 1546). Table 3.3 presents the seven hypotheses consisting of both the null hypothesis (H_o) and alternative hypotheses (H_a) that guided this research. The eventual aim of this research was to determine the relationship between teachers attending professional development programmes (independent variables) and their use of computer software in teaching Science (dependent variable).

To test the hypotheses (Table 3.3) and determine the type of relationship between the variables, a four-phase analysis approach was used. In the first phase descriptive analysis determined through the use of frequencies was used to provide a holistic background to the research; this was followed by inferential statistics, constituting the second phase that utilised Fisher's Exact Test to determine if the relationship between the two variables was statistically significant or not. The third phase of analysis was determining the strength of the relationship using Kendall's tau-c, and the fourth and final phase was to determine the type of association that exists between the two variables; this was achieved by adding a control variable to the original bivariate analysis and then re-running Kendall's tau-c analysis after which the value of the bivariate and the multivariate association was compared. These statistical approaches are discussed in more detail later on in this chapter. Once all analyses had been completed, the following conclusions could stand:

- Reject the null hypothesis (H_o) in favour of the alternate hypothesis (H_a).
- Do not reject the null hypothesis (H_o).

Hypothesis 1
$H_{o:}$ there is no significant relationship between ***teachers' attending professional development in Science content*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Tested against the alternative hypothesis
$H_{a:}$ there is a significant relationship between ***teachers' attending professional development in Science content*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Hypothesis 2
$H_{o:}$ there is no significant relationship between ***teachers' attending professional development in Science pedagogy*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Tested against the alternative hypothesis
$H_{a:}$ there is a significant relationship between ***teachers' attending professional development in Science pedagogy*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Hypothesis 3
$H_{o:}$ there is no significant relationship between ***teachers' attending professional development in Science curriculum*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Tested against the alternative hypothesis
$H_{a:}$ there is a significant relationship between ***teachers' attending professional development in Science curriculum*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Hypothesis 4
$H_{o:}$ there is no significant relationship between ***teachers' attending professional development in integrating information technology in Science*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Tested against the alternative hypothesis
$H_{a:}$ there is a significant relationship between ***teachers' attending professional development in integrating information technology in Science*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Hypothesis 5
$H_{o:}$ there is no relationship between ***teachers' attending professional development in improving learners' critical thinking or inquiry skills*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Tested against the alternative hypothesis
$H_{a:}$ there is a significant relationship between ***teachers' professional development in improving learners' critical thinking or inquiry skills*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)

Table 3.3: Research hypothesis

Hypothesis 6
H_o: there is no significant relationship between ***teachers' attending professional development in Science assessment*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Tested against the alternative hypothesis
H_a: there is a significant relationship between ***teachers' professional development in Science assessment*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Hypothesis 7
H_o: there is no significant relationship between ***teachers' attending professional development in addressing individual learner needs*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)
Tested against the alternative hypothesis
H_a: there is a significant relationship between ***teachers' professional development in addressing individual learner needs*** (independent variable) and their ***use of computer software in teaching Science*** (dependent variable)

Table 3.3: Research hypothesis (continued)

3.7 Data collection

This research is based on data collected from the South African component of the TIMSS 2011 Grade 9 Science teachers' instrument and mined from the IEA's online repository.

3.8 Data analysis plan

According to Chambliss and Schutt (2013, p. 155) statistics are a numerical description of a population specifically relevant to the identified sample. In this research the data retrieved from IEA online repository was analysed using the Statistical Package for the Social Sciences (SPSS) software. SPSS is able to handle simple as well as complex statistical procedures (Pallant, 2001, p. xiv). In this research multiple variables comprising a single dependent variable, seven independent variables and one control variable were analysed using descriptive statistics followed by inferential statistics that were used to investigate and understand possible relationships that might exist between the various variables. Table 3.2 reflects the different variables and their types. A description of the statistical techniques used in this research is provided in paragraphs 3.8.1 and 3.8.2.

3.8.1 Descriptive statistics

In this research descriptive statistics were used to add insight into the data and were sustained by the use of tables (Argyrous, 2011, p. 21). A descriptive analysis of each of the key variables in this research was conducted to bring to the fore important features and patterns that support and contribute to a deeper understanding of the relationship between the identified variables during the inferential statistical process (Hatch, 2003, p. 1).

3.8.1.1 Control Variable

3.8.1.1 (a) Gender

The sample population of Science teachers as per gender attached to the sample schools (See Appendix 3.3) is presented in tabular format. Both the categories of gender (female and male) were interpreted by a raw score and the corresponding valid percentage; the value of missing teachers was not included in the table. A one-way Chi Square was done to determine whether the variable is statistically significant (Garczynski, 2011).

3.8.1.2 Dependent variable

3.8.1.2 (a) Use of computer software to teach Science

This statement has five variables; however, in this research only variable BTBS20D, *Use of Computer software for Science instruction* (See Appendix 3.1) formed part of the data analysis process. The data is represented in tabular format comprising a single row identifying the use of computer software in Science instruction and three ordered columns reflecting the three levels of selection based on the use of computer software: *Basis for instruction, Supplement* and *Not used*. Each level is reflected by a raw score and a corresponding percentage. The value of missing teachers has not been included in the table. A one-way Chi Square was done to determine whether the variable is statistically significant.

3.8.1.3 Independent variables

3.8.1.3 (a) Attending teacher professional development programmes

The single independent variable consists of seven sub-variables, each representing a teacher professional development programme (TpD) that teachers may have attended over a two-year period (See Appendix 3.2). As this is one of the key variables in this research, it is imperative to understand the spread of teachers who responded to this question pertaining to their attendance of these programmes (Argyrous, 2011, p. 20; Briggs, Coleman &

Morrison, 2012, p. 282). The seven sub-variables outlining the different TpD programmes consist of the following:

i. Teacher professional development programme in Science content

This variable indicates the frequency of the sample population of Grade 9 Science teachers (male and female) who indicated either attending or not attending a professional development programme in Science content. The frequencies are represented in tabular format by means of a raw score and an associated valid percentage. A one-way Chi Square was done to determine whether the variable is statistically significant.

ii. Teacher professional development programme in Science pedagogy/instruction

The frequency of Grade 9 Science teachers (male and female) attending or not attending a professional development programme in Science pedagogy is displayed in tabular format. The frequencies are represented in the form of a raw score and an associated valid percentage. A one-way Chi Square was done to determine whether the variable is statistically significant.

iii. Teacher professional development programme in Science curriculum

This variable indicates the frequency of the sample population of Grade 9 Science teachers (male and female) who indicated either to have attended or not attended a professional development programme in Science curriculum. The frequencies are represented in tabular format by means of a raw score and an associated valid percentage. A one-way Chi Square was done to determine whether the variable is statistically significant.

iv. Teacher professional development programme in integrating information technology in Science

This variable represents the frequencies of Grade 9 Science teachers (male and female) who indicated having attended or not attended a professional development programme in the integration of information technology in teaching Science. The respective frequencies are represented in a table displaying both the raw score and valid percentage. A one-way Chi Square was done to determine whether the variable is statistically significant.

v. Teacher professional development programme in improving learners' critical thinking or inquiry skills

The frequency of Grade 9 Science teachers (male and female) attending or not attending a professional development programme in improving learners' critical thinking or inquiry skills is displayed in tabular format. The frequencies are represented by means of a raw score and a related valid percentage. A one-way Chi Square was done to determine whether the variable is statistically significant.

vi. Teacher professional development programme in Science assessment

This variable represents the frequencies of Grade 9 Science teachers (male and female) who indicated having attended or not attended a professional development programme in Science assessment. The respective frequencies are represented in a table displaying both the raw score and a valid percentage. A one-way Chi Square was completed to determine whether the variable is statistically significant.

vii. Teacher professional development in addressing individual learner needs

The frequency of Grade 9 Science teachers (male and female) who indicated attending a professional development programme in addressing individual learner needs is displayed in tabular format. The frequencies are represented by means of a raw score and an associated valid percentage. A one-way Chi Square was computed to determine whether the variable is statistically significant.

3.8.2 Inferential statistics

According to Gabrenya (2003, p. 1) inferential statistics involve mathematical procedures that allow researchers to use data collected from the sample population and then to generalise the outcome to the larger population. The inferential analysis portion of this research is made up of seven analyses. Each of the seven independent variables was matched and analysed against the one independent variable and the one dependent variable. Each of these analyses followed a common set of processes involving the *original table* comprising the total sample population of the Grade 9 Science teachers and the two *partial tables* that consist of the calculated values of the control variable (gender). Each of the gender categories (male and female) makes up one *partial table*. All calculations derived from the various analyses underwent a process referred to as a *decision-making process;* this process defines the type of relationship present between the respective variables.

3.8.2.1 Determining statistical significance using Fisher's Exact Test

Fisher's Exact Test was used to determine the statistical significance (See Table 4.15) in relationships that comprise *bivariate relationships* (1) between the independent and dependent variables and (2) the dependent and control variables as well as *multivariate relationships* between the independent, dependent and control variables (Freeman & Campbell, 2007, p. 2). If the p-value determined in the Fisher's Exact Test for each of these relationships is less than .05 it implies that a statistical significance exists between the variables. According to Schuyler (2004, p. 457) Fisher's Exact Test serves as an inferential tool to many researchers. The value derived was used in the decision-making process to determine the type of relationship that exists between the variables under analysis. Once the statistical significance had been determined the next step was to determine the strength of the relationship (Cohen, Manion, & Morrison, 2007, p. 515; StatPac, 2014).

3.8.2.2 Determining the strength of the relationship using Kendall's tau-c

The Kendall's tau-c measure of association was used to determine the strength of the series of *bivariate relationships:* (1) between the independent and dependent variables and (2) the dependent and control variables as well as the series of *multivariate relationships* between the independent, dependent and control variables. The values derived from Kendall's tau-c analysis were interpreted using the Kendall's tau-c scale of values reflected in Table 4.17. The value derived was used in the decision process to determine the type of relationship that exists between the variables for analysis (Gingrich, 2003).

3.8.2.3 Determining the degree of association using Phi

To determine the degree of association between the control variable and the dependent variable a Phi analysis was conducted. The value derived was used in the decision-making process to determine the type of relationship that exists between the variables under analysis.

3.8.2.4 Determining type of relationship

The values derived in the process as described in 3.8.2.1 and 3.8.2.2 led to the stage where according to Losh (2004) defines the type of relationship. A comparison of the values led to a *decision-making process* that defines the type of relationship that might exist:

- A direct relationship or extraneous relationship;
- A joint relationship;
- A statistical interaction;
- An Intervening or spurious relationship and
- A supressed relationship.

3.8.2.4 (a) Direct or extraneous relationship

In a direct relationship the Kendall's tau-c value for the original table as well as the values of the two partial tables were compared. The difference between these three values should be within the range of .10 for it to be classified a direct relationship.

3.8.2.4 (b) Joint relationship

In a joint relationship, if both the Fisher's Exact Test values (*p*-value) from the two *bivariate relationships* (1) between the independent and dependent variables and (2) the dependent and control variables are significant, then a joint relationship exists.

3.8.2.4 (c) Statistical interaction

To determine whether a statistical interaction exists between the variables, the Kendall's tau-c values of both *partial tables* (male and female were compared; if the differences are within the .10 range then a state of statistical interaction exists. Based on the outcomes of this process, a state of statistical interaction may be reached at which point no further analysis is required.

3.8.2.4 (d) Absence of statistical interaction

If a state of statistical interaction is not present in this relationship, then further analysis must be done, at which point it should be determined if an intervening relationship exists. In this instance the Kendall's tau-c value derived from the *original table* was compared to the Kendall's tau-c values of both the *partial tables*. The Kendall's tau-c value of each *partial* was compared to the value of the *original table* and subsequently the value of the *partial tables* must be less than the *original table*. If this condition exists in both instances, then the relationship is an intervening relationship.

3.8.2.3 (e) Spurious relationship

A spurious relationship is a false indication of causality between the two variables under discussion without taking into account the control variable and its effect on the two variables. In this instance the Kendall's tau-c value of each *partial* table was compared to the value of the *original table* and subsequently the value of the *partial tables* had to be less than the *original table*. If this condition exists in both instances then the relationship is spurious.

3.8.2.4 (f) Suppressed relationship

In a suppressed relationship the Kendall's tau-c value of the original table should be greater than the Kendall's tau-c value of each of the partial tables individually. When this situation exists then the relationship is said to be a suppressed relationship.

3.9 Ethical issues

The selection of the target sample group used in this the secondary study went through a rigorous process to ensure voluntary acceptance into the research (Joncas & Foy, 2011, p. 8). Within the South African context, the local TIMSS National Research Coordinator (NRC) was responsible for obtaining permission from Department of Basic Education and from schools. A sampled school could opt out from the study and would then be replaced by either of the two reserved schools identified. The Department of Basic Education (DBE) provided the Human Sciences Research Council (HSRC) with an official approval letter that sanctioned the study. Schools were contacted and were given the opportunity of accepting or rejecting participation in the study (Joncas & Foy, 2011, p. 12). As part of the TIMSS 2011 informed consent form, anonymity and confidentiality of participants were secured through the entire research sampling process. In this secondary study permission was requested from the HSRC and the convenors and administrators of the TIMSS 2011 study (See Appendix 3.4).

3.10 Limitations of the research

This research focuses primarily on teacher professional development within the South African context; one of the key limitations experienced in this research was that in the primary TIMSS 2011 study, the main sampling framework was conducted firstly at school level and then learner level (Joncas & Foy, 2011, p. 6). However, in this research the focus is on teachers who are the primary unit of analysis and as a result the findings of this research cannot be generalised to the Grade 9 South African Science teacher population at large.

Most primary studies have set objectives and another possible limitation to this research could be that the objective of the impact of teacher professional development on the use of computer software was not part of the design in the primary study. As a result, certain variables may not react naturally when attempts are made to define associations or relationships between them (Briggs, Coleman & Morrison, 2012, p. 282). In the South African context ICT is still an under-researched area. Schools and provincial departments are still finding their feet regarding ICT and ICT integration in teaching, whether it is in the physical resources or the development of teachers (Hennessy, Harrison & Wamakote, 2010, p. 43). As a result another limitation within the South African context could be the low response rate regarding teachers responding to any ICT-related question. This low response rate may result in a number of statistical analysis approaches not being further investigated.

3.11 Conclusion

This research is based on data collected from the South African component of the TIMSS 2011 study with special focus on the responses of questions in the TIMSS Science Teacher Questionnaire of South African Grade 9 Science teachers. The analysis tool used in this research was the SPSS statistical package.

The analysis process commenced with descriptive statistics: bivariate analysis comprising each of the seven independent variables matched against the single dependent variable resulting in values that identify the statistical significance (Fisher's Exact Test) and the strength of the relationship (Kendall's tau-c). A control variable (*gender*) was then added to the original bivariate relationship to determine new values for the statistical significance (Fisher's Exact Test) and the strength of the relationship (Kendall's tau-c). A series of comparisons led to a decision-making process that identified and defined the type of relationship that might exist within that specific interaction between the variables (Argyrous, 2011, p. 158).

Chapter 4 focuses on the process of analysis and presents the findings regarding teachers attending the different programmes of professional development and their resultant impact on their use of computer software in Science instruction.

CHAPTER 4
DATA ANALYSIS

4.1 Introduction

This research was driven by an interest in understanding the relationship between Grade 9 Science teachers attending programmes in professional development and their influence on the teachers' using computer software in the teaching of Science. This chapter outlines the analysis of the TIMSS 2011 data mined from IEA's online data repository as derived from the TIMSS 2011 Science Teacher Questionnaire. The analysis of the data started with descriptive statistics with the aim of identifying, describing and exploring the key variables pertinent to this research. Inferential statistics were then used to identify and explore the relationship between Science teachers attending each of the seven teacher developmental programmes and their subsequent use of computer software in Science instruction.

4.2 Descriptive statistics

4.2.1 Control variable

4.2.1.1 Gender of the Grade 9 Science teachers

Table 4.1 shows the breakdown of the TIMSS 2011 sample of South African teachers per gender. In respect to gender there were 13% more female Grade 9 Science teachers compared to male Grade 9 Science teachers in the study sample. There are 22 missing teacher records from the teacher population (n = 316).

	Frequency	Percentage
Female	166	56.5
Male	128	43.5
Total	294	100.0

Teacher Gender	
Chi-Square	4.912
df	1
Significance (*p*-value)	.027

Table 4.1 Gender of Science teachers

The frequencies of male and female teachers in Table 4.1 show a statistically significant difference: ($\chi 2$ (1, n = 294) = 4.912, $p < .05$).

4.2.2 Dependent variable

4.2.2.1 Use of computer software by Grade 9 teachers

Table 4.2 displays the spread of the TIMSS 2011 sample of South African Science teachers based on their use of computer software in Science instruction. The sample reflects a combined percentage of 34% (n = 14+86) teachers who used computer software as a ***basis for instruction*** or a ***supplement*** in teaching Science. However, a large percentage (66%) of teachers ***did not use*** software in the teaching of Science.

	Frequency	Percentage
Basis for instruction	14	4
Supplement	86	30
Not used	191	66
Total	291	100

Software use	
Chi-Square	163.361
df	2
Significance (*p*-value)	.000

Table 4.2: Use of computer software in Science instruction

The frequencies describing the use of computer software by Science teachers as shown in Table 4.2 show a statistically significant difference: ($\chi 2$ (2, n = 294) = 163.361, p < .05).

4.2.3 Independent variable

4.2.3.1 Teacher professional development in Science content

Table 4.3 denotes the sample of South African Grade 9 Science teachers (n = 291) who might or might not have attended a teacher professional development programme in Science content (TpDSC).

	Frequency	Percentage
Yes	177	61
No	114	39
Total	291	100.0

TpD Science Content	
Chi-Square	13.639
df	1
Significance (*p*-value)	.000

Table 4.3: Professional development in Science content

The frequencies in Table 4.3 show that a higher number of Science teachers attended a professional development programme in Science content and indicate a statistically significant difference ($\chi 2$ (1, n = 291) = 13.639, p < .05).

4.2.3.2 Teacher professional development in Science pedagogy

Table 4.4 shows the sample of South African Grade 9 Science teachers (n = 286) who might or might not have attended a teacher professional development programme in Science pedagogy (TpDSP).

	Frequency	Percentage
Yes	106	37
No	180	63
Total	286	100.0

TpD Science Pedagogy	
Chi-Square	19.147
df	1
Significance (*p*-value)	.000

Table 4.4: Professional development in Science pedagogy

Table 4.4 shows a higher number of Science teachers did not attend a professional development programme in Science pedagogy and indicates a statistically significant difference: ($\chi 2$ (1, n = 286) = 19.147, $p < .05$).

4.2.3.3 Teacher professional development programme in the Science curriculum

Table 4.5 shows the spread of the sample South African Grade 9 Science teachers (n = 291) who might or might not have attended a teacher professional development programme in the Science curriculum (TpDSC).

	Frequency	Percentage
Yes	203	70
No	88	30
Total	291	100

TpD Science Curriculum	
Chi-Square	45.447
df	1
Significance (*p*-value)	.000

Table 4.5: Professional development in Science curriculum

The frequencies in Table 4.5 show that a higher number of Science teachers attended a professional development programme in the Science curriculum and display a statistically significant difference: ($\chi 2$ (1, n = 291) = 45.447, $p < .05$).

4.2.3.4 Teacher professional development programme in integrating ICT

Table 4.6 represents the sample of South African Grade 9 Science teachers (n = 292) who might or might not have attended a teacher professional development programme in integrating ICT in Science (TpDICT).

	Frequency	Percentage	TpD in ICT integration in Science	
Yes	103	35	Chi-Square	25.329
No	189	65	df	1
Total	292	100.0	Significance (*p*-value)	.000

Table 4.6: Professional development in integrating ICT in Science

The frequencies reflected in Table 4.6 show a higher number of Science teachers who did not attend a professional development programme in integrating ICT in Science and indicate a statistically significant difference: ($\chi 2$ (1, n = 292) = 25.329, p < .05).

4.2.3.5 Teacher professional development programme in improving learner critical thinking

Table 4.7 shows the sample South African Grade 9 Science teachers (N = 291) who might or might not have attended a teacher professional development programme in improving learners' critical thinking (TpDCT).

	Frequency	Percentage	TpD in critical thinking	
Yes	122	42	Chi-Square	7.591
No	169	58	df	1
Total	291	100.0	Significance (*p*-value)	.006

Table 4.7: Professional development in improving learners' critical thinking

The frequencies reflected in Table 4.7 show that a slightly higher number of Science teachers did not attend a professional development programme to improve learner critical thinking and reflects a statistically significant difference: ($\chi 2$ (1, n = 291) = 7.591, p < .05).

4.2.3.6 Teacher professional development in Science assessment

Table 4.8 shows the sample South African Grade 9 Science teachers (n = 293) who might or might not have attended a teacher professional development programme in Science assessment (TpDSA).

	Frequency	Percentage	TpD in Science Assessment	
Yes	173	59	Chi-Square	9.587
No	120	41	df	1
Total	293	100.0	Significance (*p*-value)	.002

Table 4.8: Professional development in Science assessment

The frequencies in Table 4.8 show that a higher number of Science teachers had attended a professional development programme in Science assessment and display a statistically significant difference: ($\chi 2$ (1, n = 291) = 9.587, p < .05).

4.2.3.7 Teacher professional development programme in addressing individual learner needs

Table 4.9 shows the sample of South African Grade 9 Science teachers (n = 292) who might or might not have attended a teacher professional development programme in addressing individual learner needs (TpDILN).

	Frequency	Percent
Yes	114	39
No	178	61
Total	292	100.0

TpD in Addressing individual learner needs	
Chi-Square	14.027
df	1
Significance (*p*-value)	.000

Table 4.9: Professional development in addressing learner needs

The frequencies in Table 4.9 show that a higher number of Science teachers did not attend a professional development programme in Science assessment and indicate a statistically significant difference: ($\chi 2$ (1, n = 292) = 14.027, p < .05).

4.2.4 Summary of variables

4.2.4.1 Control variable

Table 4.10 focuses on the single control variable pertinent to this research and summarises the one way Chi-Square (χ^2) results and indicates a statistically significant difference.

Variable	Options	Frequency	Chi-Square	Significant difference
Gender	Female	166 (57%)	χ^2 (1, n = 294) = 4.912, $p < .05$	Yes
	Male	128 (44%)		

Table 4.10: Summary of control variable

4.2.4.2 Dependent variable

Table 4.11 summarises the single dependent variable based on the results of the one-way Chi-Square (χ^2). The options from the single dependent variable reflect a statistically significant difference.

Variable	Options	Frequency	Chi-Square	Significant difference
Use of computer software	Basis for instruction	10 (3%)	χ^2 (2, n = 294) = 225.423, $p < .05$	Yes
	Supplement	68 (23%)		
	Not used	213 (73%)		

Table 4.11: Summary of dependent variable

4.2.4.3 Independent variables

Table 4.12 displays the seven independent variables representing the seven Teacher Professional Development programmes and summarises each, looking at the one-way Chi-Square (χ^2) results.

Variable	Options	Frequency	Chi-Square	Significant difference
Professional development in Science content	Yes	177(61%)	χ^2 (1, N = 291) = 13.639 , $p < .05$	Yes
	No	114(39%)		
Professional development in Science pedagogy	Yes	106(37%)	χ^2 (1, N = 286) = 19.147 , $p < .05$	Yes
	No	180(63%)		
Professional development in the Science curriculum	Yes	181(62%)	χ^2 (1, N = 291) = 45.447 , $p < .05$	Yes
	No	110(38%)		
Professional development in integrating ICT in Science	Yes	103(35%)	χ^2 (1, N = 292) = 25.329 , $p < .05$	Yes
	No	189(65%)		
Professional development in improving learners' critical thinking	Yes	122(42%)	χ^2 (1, N = 291) = 7.591 , $p < .05$	Yes
	No	169(58%)		
Professional development in Science assessment	Yes	173(59%)	χ^2 (1, N = 291) = 9.587, $p < .05$	Yes
	No	120(41%)		
Professional development in addressing individual learner needs	Yes	114(39%)	χ^2 (1, N = 291) = 14.027, $p < .05$	Yes
	No	178(61%)		

Table 4.12: Summary of independent variables

For the seven independent variables, the frequencies of each reflect a statistically significant difference.

4.3 Inferential statistics

To gain a deeper understanding of the bivariate relationship between the independent and dependent variables a series of inferential statistical procedures was carried out with the inclusion of a third or control variable. This process where the original bivariate relationship is extended or elaborated upon is described in detail in Chapter 2. The inclusion of the control variable may result in a modification of our understanding of the bivariate relationship (Argyrous, 2011. p 157). This chapter expands on the series of relationships comprising the single dependent variable and each of the seven independent variables when attached to the control variable. The process used for elaboration followed a set path that is summarised in Table 4.13.

	Analysis method	Purpose
Stage 1	*Run a bivariate analysis of the dependent and independent variables:* 1.1 Compute the *p*-value using Fisher's Exact Test. 1.2 Compute the value of Kendall tau-c.	1.1 Determine the statistical significance of the relationship between the two variables ***(dependent and independent)*** 1.2 Determine the strength of the relationship between the two variables ***original table = (dependent and independent)***
Stage 2	*Add a control variable (age) to the bivariate analysis as per Stage 1:* 2.1 Compute the p-value using Fisher's Exact Test. 2.2 Compute the value of Kendall tau-c.	2.1 Determine the statistical significance of the relationship between the three variables ***(dependent, independent and control)*** 2.2 Determine the strength of the relationship between the between the three variables ***partial tables = (dependent, independent and control)***
Stage 3	*Test for a direct relationship* 3.1 Compare the Kendall's tau-c values of the original and partial tables. 3.2 Compute the p-value using Fisher's Exact Test. 3.3 Define the level of association between the identified variables. 3.4 Define the relationship as an extraneous relationship.	3.1 Determine if there is a direct relationship between the Original Table and Partial Tables by comparing the difference in the values. 3.2 Determine the statistical significance of the relationship between the two variables ***(dependent and control)*** 3.3 Determine the level of association between the two variables with the Phi value ***(dependent and control)*** 3.4 Compare the difference between the Kendall's tau-c values of the two partial tables and the Kendall tau-c value of the original table.
Stage 4	*Test for a joint relationship* 4.1 Determine the existence of a joint relationship between the variables.	4.1 Determine a joint relationship; a statistical significance must exist between ***(independent and dependent)*** ***(control and dependent)***

Table 4.13: Process of elaboration

	Analysis method	Purpose
Stage 5	*Test for statistical interaction* 5.1 Detect the presence a statistical interaction between the partial tables.	5.1 Determine if there is statistical interaction by comparing the Kendall's tau-c values of the two partial tables. ***If it is determined that there is a statistical interaction then the analysis process should stop at this point.***
Continue with these stages of analysis only if NO statistical interactions are noted		
Stage 6	*Test for an intervening relationship* 6.1 Define the relationship as an intervening relationship.	6.1 Determine if the Kendall tau-c values of the two partial tables are larger than the original table.
Stage 7	*Test for a spurious relationship* 7.1 Define the relationship as a spurious relationship.	7.1 Determine if the Kendall's tau-c value of the original relationship is lower than the two partial relationships.
Stage 8	*Test for a suppressed relationship* 8.1 Define the relationship as a suppressed relationship.	8.1 Determine if the Kendall tau-c values of the two partial tables are smaller than the original relationship.

Table 4.13: Process of elaboration (continued)

4.3.1 Teachers attending professional development programmes in Science content and their use of computer software to teach Science

4.3.1.1 Stage 1: Bivariate analysis of dependent and independent variables

4.3.1.1 (a) Frequency of teachers using software to teach Science

From the total sample of Grade 9 Science teachers (N = 316), a total of 90% (n = 284) of the teachers responded to this question and 10% (n = 32) did not respond. Table 4.14 displays the frequencies of all Science teachers who attended Teacher Professional Development (TpD) in Science content and their subsequent use of software in teaching Science. A total of 172 teachers indicated that they attended TpD in Science content, and from these 39% (n = 9+59) indicated that they used computer software in their teaching of Science compared to 61% (n = 104) of the teachers who did not use computer software.

		Professional development in Science content				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	9	5	4	3	13
	Supplement	59	34	29	26	88
	Not used	104	61	79	71	183
Total		172	100	112	100	284

Table 4.14: Frequency of teachers' use of computer software regarding Science content

4.3.1.1 (b) Statistical significance of teachers using software to teach Science

The relationship between teachers attending TpD in Science content and their use of computer software in teaching Science reflects a relationship that is not statistically significant (Fisher's Exact Test: p = .227, n = 284) as shown in Table 4.15.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.025	2	.220	.222	
Likelihood ratio	3.063	2	.216	.223	
Fisher's Exact Test	2.952			.227	
Linear-by-Linear Association	2.804	1	.094	.114	.057
N of valid cases	284				

Table 4.15: Fisher's Exact Test of teachers' use of computer software in teaching-Science content

4.3.1.1 (c) Strength of the relationship of teachers using software to teach Science

The Kendall's tau-c value (τ = .097, n = 284) as reflected in Table 4.16 defines the strength of the relationship between teachers attending TpD in Science content and their use of computer software in teaching it. By matching this value to the Kendall's table of values (Table 4.17) it can be established that the Kendall's tau-c value (τ = .097) is less than 0.10, thus showing that this relationship is a very weak one.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.097	.055	1.772	.076	.084
N of valid cases		284				

Table 4.16: Kendall tau-c of teachers' use of computer software in teaching Science content

Kendall tau-c	Strength
Less than + or - 0.10	Very weak
+ or – 0.11 to 0.18	Weak
+ or – 0.19 to 0.29	Moderate
+ or – 0.30 or above	Strong

Table 4.17: Kendall tau-c reading scale

4.3.1.2 Stage 2: Bivariate analysis of dependent and independent variables with a control variable

4.3.1.2 (a) Frequency of female teachers using software to teach Science

Two separate tables were generated, for each of the categories of the control variable (male and female). These are referred to as partial tables. Each underwent statistical analysis procedures. Table 4.18 represents the first partial table with the control variable (female gender) included in the analysis. The table displays the frequencies of female Science teachers who attended TpD in Science content and their use of software in teaching of Science. A total of 99 female teachers indicated that they had attended TpD in Science content, and from this a cumulative of 29% (n = 4+25) indicated that they used computer software in their Science teaching compared to 71% (n = 70) of the female teachers who indicated not having used computer software. Deeper analysis of Table 4.18 shows that of all female teachers who attended and did not attend TpD 25% (n = 6+33) used computer software in teaching Science and 75% (n = 120) did not use computer software in teaching Science.

		Professional development in Science content of female teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	4	4	2	3	6
	Supplement	25	25	8	13	33
	Not used	70	71	50	84	120
Total		99	100	60	100	159

Table 4.18: Frequency of computer software use by female teachers for teaching Science content

4.3.1.2 (b) Statistical significance of the relationship of female teachers using software to teach Science

The relationship between female teachers attending TpD in Science content and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: $p = .193$, $n = 159$) as shown in Table 4.19 (Kelly, 2005, p. 20).

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.396	2	.183	.204	
Likelihood ratio	3.557	2	.169	.195	
Fisher's Exact Test	3.409			.193	
Linear-by-Linear Association	2.371	1	.124	.164	.081
N of valid cases	159				

Table 4.19: Fisher's Exact Test of female teachers' use of computer software regarding Science content

4.3.1.2 (c) Strength of the relationship of female teachers using software to teach Science

The Kendall's tau-c value ($\tau = .116$, $n = 159$) is presented in Table 4.20 was derived from the analysis of the relationship between female teachers attending TpD in Science content and their use of computer software in teaching Science. Comparing this value to the Kendall's table of values (Table 4.17) it can be noted that the Kendall's tau-c value is greater than 0.10, thus showing a weak relationship.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.116	.063	1.833	.067	.086
N of valid cases		159				

Table 4.20: Kendall tau-c of female teachers' use of computer software regarding Science content

4.3.1.2 (d) Frequency of male teachers using software to teach Science

Table 4.21 is the second partial table in which the control variable (male gender) is included in the analysis. The table shows the frequencies of male Science teachers who attended TpD in Science content and their use of computer software in teaching Science. Looking at the male teachers who attended TpD in Science content, a total of 73 male teachers indicated attending such a programme. From this a cumulative of 53% (n = 5+34) of the male teachers indicated that they used computer software in their Science teaching compared to 47% (n = 34) of the teachers who indicated not having used any computer software when teaching Science.

		Professional development in Science content of male teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	5	6	2	4	7
	Supplement	34	47	21	40	55
	Not used	34	47	29	56	63
Total		73	100	52	100	125

Table 4.21: Frequency of computer software use by male teachers regarding Science content

4.3.1.2 (e) Statistical significance of male teachers using software to teach Science

The relationship between male teachers attending TpD in Science content and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: $p = .553$, $n = 125$) as presented in Table 4.22.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.263	2	.532	.527	
Likelihood ratio	1.283	2	.527	.527	
Fisher's Exact Test	1.208			.553	
Linear-by-Linear Association	1.247	1	.264	.293	.167
N of valid cases	125				

Table 4.22: Fisher's Exact Test of male teachers' use of computer software for teaching Science content

4.3.1.2 (f) Strength of the relationship of male teachers using software to teach Science

The Kendall's tau-c value ($\tau = .099$, $n = 125$) shown in Table 4.23 was derived from the analysis of the relationship between male teachers attending TpD in Science content and their use of computer software in teaching Science. When the calculated Kendall's tau-c value is equated to Kendall's table of values (See Table 4.17) it is noted that the value is less than 0.10, showing that the relationship is a very weak one.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.099	.089	1.107	.268	.282
N of valid cases		125				

Table 4.23: Kendall tau-c of male teachers' use of computer software for teaching Science content

4.3.1.3 Stage 3: Determining a direct relationship

4.3.1.3 (a) Testing for a direct relationship

Table 4.24 tabulates and draws a comparison between the three Kendall's tau-c values. The first value (τ = .097) represents the whole sample of Grade 9 Science teachers; the second (τ = .116) and third (τ = .099) set of values represent the Kendall's tau-c value for the female and male Science teachers respectively. The second and third values were derived from the two partial tables (Tables 4.20 and 4.23).

Group	Kendall's tau-c values
All Science teachers	.097
Female Science teachers	.116
Male Science teachers	.099

Table 4.24: Kendall tau-c values of Science teachers' use of computer software for teaching Science content

To determine if this is a direct relationship all three the Kendall's tau-c values should be equal to one another with no difference greater than a .10 point between them. From Table 4.24 it can be seen that the difference between all three the groups is within the .10 value range, thus making this relationship a direct relationship.

4.3.1.3 (b) Frequency of control and dependent variable

Table 4.25 tabulates the use of computer software to teach Science based on the gender of the Science teachers. Again it is noted that the percentage of female and male Science teachers is low when it comes to the use of computer software in the teaching of Science. The cumulative percentage of both genders that use software for teaching Science sits at 35% (n = 13 + 88) and 65% (n = 188) of the teachers who do not use computer software.

		Gender of teacher				Total
		Female	%	Male	%	
Use of computer software in Science instruction	Basis for instruction	6	4	7	6	13
	Supplement	33	20	55	44	88
	Not used	125	76	63	50	188
Total		164	100	125	100	289

Table 4.25: Frequency of female and male teachers' use of computer software for teaching Science content

4.3.1.3 (c) Statistical significance of the relationship between the control and dependent variable

The relationship between Science teachers (male and female) and their use of computer software in teaching Science is statistically significant (Fisher's Exact Test: p = .000, n = 289) as shown in Table 4.26.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	21.146	2	.000	.000	
Likelihood ratio	21.191	2	.000	.000	
Fisher's Exact Test	21.107			.000	
Linear-by-Linear Association	16.567	1	.000	.000	.000
N of valid cases	289				

Table 4.26: Fisher's Exact Test of female and male teacher's use of computer software for teaching Science content

4.3.1.3 (d) Level of association of the control and dependent variable

Running the Phi analysis and determining its value (Table 4.28) within the context of this research helped determine the degree of association of the control variable (*Gender*) and the dependent variable (*Use of computer software in teaching Science*).

Phi	Degree of association
-1.0 to -0.7	Strong negative association
-0.7 to -0.3	Weak negative association
-0.3 to +0.3	Little or no association
+0.3 to +0.7	Weak positive association
+0.7 to +1.0	Strong positive association

Table 4.27 Phi coefficient value table (Steve, 2011).

The relationship between the control variable and the dependent variable reflects little or no association: χ^2 (n = 289) p = 0.00, ϕ =.270 as derived from Table 4.26 and Table 4.28 (Neill, 2011).

	Value	Asymp. Std.	Exact Sig.
Nominal by Nominal Phi	.270	.000	.000
N of valid cases	289		

Table 4.28: Phi value of male and female Science teachers' use of computer software

4.3.1.3 (e) Testing for an extraneous relationship

To describe the relationship between the variables as extraneous, the Kendall's tau-c value between male and female should be equal and not have a difference larger than .10 and the Phi value should be small (between -0.3 and +0.3) as shown in Table 4.27.

In this case the differential value (.017) between the female and male Kendall's tau-c value is within the .10 figure, and the Phi value (.270) is small (Table 4.28). Based on these findings it can be concluded that this is an extraneous relationship.

4.3.1.4 Stage 4: Determining a joint relationship

4.3.1.4 (a) Testing for a joint relationship

To determine if this relationship is a joint relationship, the Fisher's exact test was conducted on two interactions: (1) the independent variable and the dependent variable, and (2) the control variable and the dependent variable as reflected in Table 4.29. In this instance the dependent variable is only affected by the control variable and results in a significant relationship; the relationship between the independent variable and dependent variable is not significant, thus indicating that this is not a joint relationship (Wicherts, Bakker, & Molenaar, 2011, p. 9).

	Relationship	Fisher Exact Test Value	Significant
(1)	Independent and dependent variable (Table 4.15)	Fisher's Exact Test: p = .227 (2-tailed)	No
(2)	Control variable and dependent variable (Table 4.26)	Fisher's Exact Test: p = .000 (2-tailed)	Yes

Table 4.29: Significance of the relationship regarding Science content

4.3.1.5 Stage 5: Determining a statistical interaction

4.3.1.5 (a) Testing for a statistical interaction

Table 4.24 defines whether a statistical interaction between the two partial table values exists. The difference between the Kendall's tau-c value for female Science teachers (.116) and male Science teachers (.099) reflects a difference of .017, which is within the .10 range, thus showing that there is a statistical interaction between the two partial tables.

Table 4.30 reflects the composite results of all statistical analyses carried out in the sequence to define and explain the relationships that exist between teachers attending TpD in Science content and their use of computer software in teaching Science. The results that populate Table 4.30 were derived from a range of statistical techniques defined in Table 4.31.

[1] = 2.952	[3] = .116	[5] = 21.107	[7] = No
[2] = .097	[4] = .099	[6] = .270	[8] = Yes

Table 4.30: Composite statistical results regarding Science content

Code	Analysis
[1]	Fisher's Exact Test (Table 4.18)
[2]	Kendall's tau-c (Table 4.19)
[3]	Kendall's tau-c (Table 4.23)
[4]	Kendall's tau-c (Table 4.26)
[5]	Fisher's Exact Test (Table 4.29)
[6]	Phi value (Table 4.31)
[7]	Test for statistical significance (Table 4.29)
[8]	Test for statistical significance (Table 4.29)

Table 4.31: Summary of statistical analyses used regarding Science content

Table 4.32 shows the decision process undertaken to determine and define the type of relationship(s) that best describe the interaction between teachers attending TpD in Science content and their use of computer software in teaching Science.

[2] = [3] = [4]	Direct relationship	■ True □ False
[3] = [4] and [6] = small	Extraneous relationship	■ True □ False
[7] = significant and [8] = significant	Joint relationship	□ True ■ False
[3] <> [4]	Statistical interaction	■ True □ False
[4] < [2] and [3] < [2]	Intervening/spurious relationship	□ True □ False
[3] >[2] and [4] > [2]	Suppressed relationship	□ True □ False

Table 4.32: Decision process to determine the type of relationship regarding Science content

From Table 4.32 it is evident that a statistical interaction does exist between the two variables under analysis (*Teachers attending TpD in Science content* and *The use of computer software in teaching Science*) and as a result no further analysis was necessary to supplement the explanation of the relationship.

4.3.2 Teachers attending professional development programmes in Science pedagogy and their use of computer software to teach Science

4.3.2.1 Stage 1: Bivariate analysis of dependent and independent variables

4.3.2.1 (a) Frequency of teachers using software to teach Science

From the total sample of Grade 9 Science teachers (n = 316), a total of 89% (n = 280) responded to this question and 11% (n = 36) of the teachers did not respond. Table 4.33 displays the frequencies of all Science teachers who attended Teacher Professional Development (TpD) in Science pedagogy and their subsequent use of software in teaching Science. A total of 104 teachers indicated that they had attended TpD in Science pedagogy, and from these 42% (n = 7+36) indicated that they did use computer software in their Science teaching compared to 58% (n = 61) of the teachers who indicated not using computer software.

		Professional development in Science pedagogy				**Total**
		YES	**%**	**NO**	**%**	
Use of computer software for Science instruction	Basis for instruction	7	8	6	3	13
	Supplement	36	34	50	28	86
	Not used	61	58	120	69	181
Total		104	100	176	100	280

Table 4.33: Frequency of teachers' use of computer software regarding Science pedagogy

4.3.2.1 (b) Statistical significance of teachers using software to teach Science

The relationship between teachers attending TpD in Science pedagogy and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .195, n = 280) as shown in Table 4.34 (Kelly, 2005, p 20).

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.291	2	.193	.210	
Likelihood ratio	3.230	2	.199	.228	
Fisher's Exact Test	3.336			.195	
Linear-by-Linear Association	3.231	1	.072	.086	.046
N of valid cases	280				

Table 4.34: Fisher's Exact Test of teachers' use of computer software regarding Science pedagogy

4.3.2.1 (c) Strength of the relationship of teachers using software to teach Science

The Kendall's tau-c value (τ = .096, n = 280) as reflected in Table 4.35 defines the strength of the relationship between teachers attending TpD in Science pedagogy and their use of computer software in teaching Science. By matching this value with the Kendall's table of values (Table 4.17) it can be established that the Kendall's tau-c value (τ = .096) is less than 0.10, thus showing that this relationship is a very weak relationship.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.096	.057	1.690	.091	.091
N of valid cases		280				

Table 4.35: Kendall tau-c of teachers' use of computer software regarding Science pedagogy

4.3.2.2 Stage 2: Bivariate analysis of dependent and independent variables with a control variable

4.3.2.2 (a) Frequency of female teachers using software to teach Science

Two partial tables were generated, one for each of the categories of the control variable (male and female). Each underwent statistical analysis procedures.

Table 4.36 represents the first partial table with the control variable (female gender) included in the analysis. The table displays the frequencies of female Science teachers who attended TpD in Science pedagogy and their use of computer software in teaching Science. A total of 59 female teachers indicated that they had attended TpD in Science pedagogy, and from these a cumulative of 28% (n = 2+15) indicated that they used computer software in their Science teaching compared to 72% (n = 42) of the teachers who indicated that they did not use computer software. Deeper analysis of Table 4.36 shows that of all female teachers (having attended and not having attended TpD) 25% (n = 6+33) used computer software in teaching Science and 75% (n = 119) did not use computer software in teaching Science.

		Professional development in Science pedagogy of female teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	2	3	4	4	6
	Supplement	15	25	18	17	33
	Not used	42	72	77	79	119
Total		59	100	99	100	158

Table 4.36: Frequency of computer software use by female teachers regarding Science pedagogy

4.3.2.2 (b) Statistical significance of the relationship of female teachers using software to teach Science

The relationship between female teachers attending TpD in Science pedagogy and their use of computer software in teaching Science reflects a non-statistically significant relationship (Fisher's Exact Test: $p = .557$, $n = 158$) as shown in Table 4.37.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.183	2	.554	.591	
Likelihood ratio	1.163	2	.559	.624	
Fisher's Exact Test	1.258			.557	
Linear-by-Linear Association	.464	1	.496	.537	.297
N of valid cases	158				

Table 4.37: Fisher's Exact Test of female teachers' use of computer software regarding Science pedagogy

4.3.2.2 (c) Strength of the relationship of female teachers using software to teach Science

The Kendall's tau-c value ($\tau = .058$, $n = 158$) is presented in Table 4.38 and was derived from the analysis of the relationship between female teachers attending TpD in Science pedagogy and their use of computer software in teaching Science. Comparing this value to the Kendall's table of values (Table 4.17) it can be noted that the Kendall's tau-c value is less than 0.10, showing that the relationship is very weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.058	.068	.853	.394	.406
N of valid cases		158				

Table 4.38: Kendall tau-c of female teachers' use of computer software regarding Science pedagogy

4.3.2.2 (d) Frequency of male teachers using computer software to teach Science

Table 4.39 is the second partial table in which the control variable (male gender) is included in the analysis. The table shows the frequencies of male Science teachers who attended TpD in Science pedagogy and their use of computer software in teaching Science. From the male teachers who attended TpD in Science pedagogy, a total of 45 indicated attending such a programme. A cumulative of 58% (n = 5+21) of the male teachers indicated that they used computer software in their Science teaching compared to 42% (n = 19) of the teachers who indicated not using computer software.

		Professional development in Science pedagogy of male teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	5	11	2	3	7
	Supplement	21	47	32	41	53
	Not used	19	42	43	56	62
Total		45	100	77	100	122

Table 4.39: Frequency of computer software use by male teachers regarding Science pedagogy

4.3.2.2 (e) Statistical significance of male teachers using computer software to teach Science

The relationship between male teachers attending TpD in Science pedagogy and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .099, n = 122) as presented in Table 4.40.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.796	2	.091	.089	
Likelihood ratio	4.673	2	.097	.109	
Fisher's Exact Test	4.585			.099	
Linear-by-Linear Association	3.809	1	.051	.062	.036
N of valid cases	122				

Table 4.40: Fisher's Exact Test of male teachers' use of computer software- regarding Science pedagogy

4.3.2.2 (f) Strength of the relationship of male teachers using computer software to teach Science

The Kendall's tau-c value (τ = .159, n = 122) shown in Table 4.41 was derived from the analysis of the relationship between male teachers attending TpD in Science pedagogy and their use of computer software in teaching Science. When this value is compared to Kendall's table of values (Table 4.17) it should be noted that the Kendall's tau-c value is greater than 0.10, showing that the relationship is a weak relationship.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.159	.090	1.759	.079	.074
N of Valid Cases		122				

Table 4.41: Kendall tau-c of male teachers' use of computer software regarding Science pedagogy

4.3.2.3 Stage 3: Determining a direct relationship

4.3.2.3 (a) Testing for a direct relationship

Table 4.42 tabulates and draws a comparison between the three Kendall's tau-c values. The first value (τ = .096) represents the whole sample of Grade 9 Science teachers, the second (τ = .058) and third (τ = .159) set of values represent the Kendall's tau-c value for the female and male Science teachers respectively. The second and third values were derived from the two partial tables (Tables 4.38 & 4.41).

Group	Kendall's tau-c values
All Science teachers	.096
Female Science teachers	.058
Male Science teachers	.159

Table 4.42: Kendall tau-c values of Science teachers' use of computer software regarding Science pedagogy

To determine if this is a direct relationship, all three the Kendall's tau-c values should be equal to one another with no greater than a .10 difference between them. From Table 4.42 it can be seen that the difference between all three the groups is within the .10 value range, thus making this relationship a direct one.

4.3.2.3 (b) Frequency of control and dependent variable

Table 4.25 tabulates the use of computer software to teach Science based on the gender of the Science teachers. It should be noted that the percentage of both female and male

Science teachers regarding the use of computer software in teaching Science is low. The cumulative percentage of both genders that use computer software for teaching Science is 35% (n = 13 + 88) and 65% (n = 188) for the teachers who did not use computer software.

4.3.2.3 (c) Statistical significance of the relationship between control and dependent variable

The relationship between Science teachers (female and male) and their use of computer software in teaching Science is statistically significant (Fisher's Exact Test: p = .000, n = 289) as shown in Table 4.26.

4.3.2.3 (d) Level of association of control and dependent variable

Running the Phi analysis and determining its value within the context of this research helped determine the degree of association shown in Table 4.28 of the control variable (*Gender*) and the dependent variable (*Use of computer software in teaching Science*).

The relationship between the control variable and the dependent variable reflects a strong positive association: χ^2 (n = 289) p = 0.00, ϕ = .270 derived from Table 4.26 and Table 4.28 (Neill, 2011).

4.3.2.3 (e) Testing for an extraneous relationship

To describe the relationship between the variables as extraneous, the Kendall's tau-c value between female and male should be equal and not have a difference larger than .10, and the Phi value should be small (between -0.3 and +0.3) as shown in Table 4.27.

In this case the differential value (-.10) between the female and male Kendall's tau-c value is within the .10 figure, and the Phi value (.270) is small (See Table 4.28). From these findings it can be concluded that this is an extraneous relationship.

4.3.2.4 Stage 4: Determining a joint relationship

4.3.2.4 (a) Testing for a joint relationship

To determine if this relationship is a joint relationship, the Fisher's Exact Test was conducted on two interactions: (1) the independent variable and the dependent variable, and (2) the control variable and the dependent variable. In this instance the dependent variable is affected only by the control variable and resulted in a significant relationship and the relationship between the independent and dependent variable is not significant, thus indicating that this is not a joint relationship, as shown in Table 4.43 (Wicherts, et al. 2011, p. 9).

	Relationship	Fisher's Exact Test Value	Significant
(1)	Independent and dependent variable (Table 4.34)	Fisher's Exact Test: p = .195 (2-tailed)	No
(2)	Control variable and dependent variable (Table 4.26)	Fisher's Exact Test: p = .000 (2-tailed)	Yes

Table 4.43: Significance of the relationship regarding Science pedagogy

4.3.2.5 Stage 5: Determining a statistical interaction

4.3.2.5 (a) Testing for a statistical interaction

From Table 4.42 it can be determined whether a statistical interaction between the two partial table values exists. The difference between the Kendall's tau-c value for female Science teachers (.058) and male Science teachers (.159) reflects a difference of -.10, which is within the .10 range, showing that there is a statistical interaction between the two partial tables.

Table 4.44 reflects the composite results of all statistical analyses carried out in the sequence to define and explain the relationship that exists between teachers attending TpD in Science pedagogy and their use of computer software in teaching Science.

[1] = 1.252	[3] = .052	[5] = 4.609	[7] = No
[2] = .055	[4] = .061	[6] = .270	[8] = Yes

Table 4.44: Composite statistical results regarding Science pedagogy

The values that populate Table 4.44 were derived from the range of statistical techniques defined in Table 4.45.

Code	Analysis
[1]	Fisher's Exact Test (Table 4.34)
[2]	Kendall's tau-c (Table 4.35)
[3]	Kendall's tau-c (Table 4.37)
[4]	Kendall's tau-c (Table 4.41)
[5]	Fisher's Exact Test (Table 4.26)
[6]	Phi value (Table 4.28)
[7]	Fisher's Exact test for statistical significance (Table 4.43)
[8]	Fisher's Exact test for statistical significance (Table 4.43)

Table 4.45: Summary of statistical analyses used regarding Science pedagogy

Table 4.46 represents the decision process undertaken to determine and define the type of relationship(s) that best describes the interaction between teachers attending TpD in Science pedagogy and their use of computer software in teaching Science.

[2] = [3] = [4]	Direct relationship	■ True □ False
[3] = [4] and [6] = small	Extraneous relationship	■ True □ False
[7] = significant and [8] = significant	Joint relationship	□ True ■ False
[3] <> [4]	Statistical interaction	■ True □ False
[4] < [2] and [3] < [2]	Intervening/spurious relationship	□ True □ False
[3] >[2] and [4] > [2]	Suppressed relationship	□ True □ False

Table 4.46: Decision process to determine the type of relationship regarding Science pedagogy

From Table 4.46 it is evident that a statistical interaction does exist between the two variables under analysis (*Teachers attending TpD in Science pedagogy* and *The use of computer software in teaching Science*) and as a result no further analysis is necessary to supplement the explanation of the relationship.

4.3.3 Teachers attending professional development programmes in the Science curriculum and their use of computer software to teach Science

4.3.3.1 Stage 1: Bivariate analysis of the dependent and independent variables

4.3.3.1 (a) Frequency of teachers using software to teach Science

From the total sample of Grade 9 Science teachers (n = 316), a total of 91% (n = 286) responded to this question and 10% (n = 30) of the teachers did not respond. Table 4.47

displays the frequencies of all Science teachers who attended Teacher Professional Development (TpD) in the Science curriculum and their subsequent use of software in teaching Science. A total of 199 teachers indicated that they had attended TpD in the Science curriculum, and from these 37% (n = 9+65) indicated that they did use computer software in their Science teaching compared to 63% (n = 125) of the teachers who indicated not having used computer software.

		Professional development in the Science curriculum				**Total**
		YES	**%**	**NO**	**%**	
Use of computer software for Science instruction	Basis for instruction	9	5	4	5	13
	Supplement	65	32	21	24	86
	Not used	125	63	62	71	187
Total		199	100	87	100	286

Table 4.47: Frequency of teachers' use of computer software regarding the Science curriculum

4.3.3.1 (b) Statistical significance of teachers using software to teach Science

The relationship between teachers attending TpD in the Science curriculum and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .332, n = 286) as shown in Table 4.48.

	Value	**df**	**Asymp. Sig. (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson Chi-Square	2.125	2	.346	.322	
Likelihood ratio	2.177	2	.337	.333	
Fisher's Exact Test	2.149			.332	
Linear-by-Linear Association	1.285	1	.257	.266	.153
N of valid cases	286				

Table 4.48: Fisher's Exact Test of teachers' use of computer software regarding the Science curriculum

4.3.3.1 (c) Strength of the relationship of teachers using software to teach Science

The Kendall's tau-c value (τ = .068, n = 286) reflected in Table 4.49 defines the strength of the relationship between teachers attending TpD in the Science curriculum and their use of computer software in teaching Science. By matching this value with the Kendall's table of values (Table 4.17) it can be established that the Kendall's tau-c value (τ = .068) is less than 0.10, thus showing that this relationship is very weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.068	.051	1.328	.184	.200
N of valid cases		286				

Table 4.49: Kendall tau-c of teachers' use of computer software regarding the Science curriculum

4.3.3.2 Stage 2: Bivariate analysis of dependent and independent variables with a control variable

4.3.3.2 (a) Frequency of female teachers using software to teach Science

Two partial tables were generated, one for each of the categories of the control variable (female and male). Each underwent statistical analysis procedures.

Table 4.50 represents the first partial table with the control variable (female gender) included in the analysis. The table displays the frequencies of female Science teachers who attended TpD in the Science curriculum and their use of computer software in teaching Science. A total of 105 female teachers indicated that they had attended TpD in the Science curriculum, and from these a cumulative of 26% (n = 4+23) indicated that they used computer software in their Science teaching as compared to 74% (n = 78) of the teachers who indicated not having used computer software. From Table 4.50 it can be established that of all female teachers (those that attended and did not attend TpD), 23% (n = 6+31) used computer software in teaching Science and 77% (n = 124) did not use computer software in teaching Science.

		Professional development in the Science curriculum of female teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	4	4	2	4	6
	Supplement	23	22	8	14	31
	Not used	78	74	46	82	124
Total		105	100	56	100	161

Table 4.50: Frequency of computer software use by female teachers regarding the Science curriculum

4.3.3.2 (b) Statistical significance of the relationship of female teachers using software to teach Science

The relationship between female teachers attending TpD in the Science curriculum and their use of computer software in teaching Science is a non-statistically significant relationship (Fisher's Exact Test: p = .477, n = 161) as shown in Table 4.51.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.399	2	.497	.506	
Likelihood ratio	1.451	2	.484	.506	
Fisher's Exact Test	1.410			.477	
Linear-by-Linear Association	.880	1	.348	.429	.220
N of valid cases	161				

Table 4.51: Fisher's Exact Test of female use of computer software regarding the Science curriculum

4.3.3.2 (c) Strength of the relationship of female teachers using software to teach Science

The Kendall's tau-c value (τ = .069, n = 161) is presented in Table 4.52 and was derived from the analysis of the relationship between female teachers attending TpD in Science curriculum and their use of computer software in teaching Science. Comparing this value to the Kendall's table of values (Table 4.17) it can be noted that the Kendall's tau-c value is slightly less than 0.10, showing that the relationship is a very weak one.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.069	.061	1.132	.258	.299
N of valid cases		.161				

Table 4.52: Kendall tau-c of female teachers' use of computer software regarding the Science curriculum

4.3.3.2 (d) Frequency of male teachers using computer software to teach Science

Table 4.53 is the second partial table in which the control variable (male gender) is included in the analysis. The table shows the frequencies of male Science teachers who attended TpD in the Science curriculum and their use of computer software in teaching Science. From the male teachers who attended TpD in the Science curriculum it is clear that a total of 94 male teachers indicated attending such a programme. From this a cumulative of 50% (n = 5+42) indicated that they used computer software in their Science teaching compared to 50% (n = 47) of the teachers who indicated not having used computer software.

		Professional development in the Science curriculum of male teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	5	5	2	7	7
	Supplement	42	45	13	41	37
	Not used	47	50	16	52	85
Total		94	100	31	100	125

Table 4.53: Frequency of computer software use by male teachers regarding the Science curriculum

4.3.3.2 (e) Statistical significance of male teachers using computer software to teach Science

The relationship between male teachers attending TpD in the Science curriculum and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test, $p = 1.000$, $n = 125$) as presented in Table 4.54.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.105	2	.949	.947	
Likelihood ratio	.104	2	.949	.947	
Fisher's Exact Test	.289			1.000	
Linear-by-Linear Association	.001	1	.969	1.000	.557
N of valid cases	125				

Table 4.54: Fisher's Exact Test of male teachers' use of computer software regarding the Science curriculum

4.3.3.2 (f) Strength of the relationship of male teachers using computer software to teach Science

The Kendall's tau-c value ($\tau = .007$, $n = 125$) shown in Table 4.55 was derived from the analysis of the relationship between male teachers attending TpD in Science curriculum and their use of computer software in teaching Science. When this value is compared to Kendall's table of values (Table 4.17) it should be noted that the Kendall's tau-c value is less than 0.10, showing that the relationship is very weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.007	.080	.090	.928	.995
N of valid cases		125				

Table 4.55: Kendall tau-c of male teachers' use of computer software regarding the Science curriculum

4.3.3.3 Stage 3: Determining a direct relationship

4.3.3.3 (a) Testing for a direct relationship

Table 4.56 tabulates and draws a comparison between the three Kendall's tau-c values. The first value (τ = .068) represents the whole sample of Grade 9 Science teachers; the second (τ = .069) and third (τ = .007) set of values represent the Kendall's tau-c value for the female and male Science teachers respectively. The second and third values were derived from the two partial tables (Tables 4.52 & 4.55).

Group	Kendall's tau-c values
All Science teachers	.068
Female Science teachers	.069
Male Science teachers	.007

Table 4.56: Kendall tau-c values of Science teachers' use of computer software regarding the Science curriculum

To determine if this is a direct relationship, all three the Kendall's tau-c values should be equal to one another with no greater than a .10 difference between them. From Table 4.56 it can be seen that the difference between all three the groups is within the .10 value range, thus making this relationship a direct relationship

4.3.3.3 (b) Frequency of control and dependent variable

Table 4.25 tabulates the use of computer software to teach Science, based on the gender of the Science teachers. It should be noted that the percentage of both female and male Science teachers regarding the use of computer software in teaching Science is low. The cumulative percentage of both genders that used computer software for teaching Science is 35% (n = 13 + 88) and 65% (n =188) of the teachers who did not use computer software.

4.3.3.3 (c) Statistical significance of the relationship between control and dependent variable

The relationship between Science teachers (female and male) and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .000, n = 289) as shown in Table 4.26.

4.3.3.3 (d) Level of association of control and dependent variable

Running the Phi analysis and determining its value within the context of this research helped determine the degree of association shown in Table 4.28 of the control variable (*Gender*) and the dependent variable (*Use of computer software in teaching Science*).

The relationship between the control variable and the dependent variable reflects a strong positive association: χ^2 (n = 289) P = 0.00, ϕ =.270 as derived from Table 4.26 and Table 4.28 (Neill, 2011).

4.3.3.3 (e) Testing for an extraneous relationship

To describe the relationship between the variables as extraneous, the Kendall's tau-c value between female and male should be equal and not have a difference larger than .10, and the Phi value should be small (between -0.3 and +0.3) as shown in Table 4.27.

In this case the differential value (.062) between the female and male Kendall's tau-c value is within the .10 figure, and the Phi value (.270) is small (Table 4.28). From these findings it can be concluded that this is an extraneous relationship.

4.3.3.4 Stage 4: Determining a joint relationship

4.3.3.4 (a) Testing for a joint relationship

To determine if this relationship is a joint relationship, the Fisher's Exact Test was conducted on two interactions: (1) the independent variable and the dependent variable, and (2) the control variable and the dependent variable. In this instance the dependent variable was affected by the control variable only and resulted in a significant relationship and the relationship between the independent variable and dependent variable is not significant, thus inferring that this is not a joint relationship as shown in Table 4.57.

	Relationship	Fisher's Exact Test Value	Significant
(1)	Independent and dependent variable (Table 4.48)	Fisher's Exact Test: p = .332 (2-tailed)	No
(2)	Control variable and dependent variable (Table 4.26)	Fisher's Exact Test: p = .000 (2-tailed)	Yes

Table 4.57: Significance of the relationship regarding the Science curriculum

4.3.3.5 Stage 5: Determining a statistical interaction

4.3.3.5(a) Testing for a statistical interaction

From Table 4.56 it can be determined whether a statistical interaction between the two partial table values exists. The difference between the Kendall's tau-c value for female Science teachers (.069) and male Science teachers (.007) reflects a difference of .062, which is within the .10 range, showing that there is a statistical interaction between the two partial tables. Table 4.58 shows the composite results of all statistical analyses carried out in the sequence to define and explain the relationship that exists between teachers attending TpD in the Science curriculum and their use of computer software in teaching Science.

[1] = 2.149	[3] = .069	[5] = 4.609	[7] = No
[2] = .068	[4] = .007	[6] = .270	[8] = Yes

Table 4.58: Composite statistical results regarding the Science curriculum

The values that populate Table 4.58 were derived from a range of statistical techniques as defined in Table 4.59.

Code	Analysis
[1]	Fisher's Exact Test (Table 4.48)
[2]	Kendall's tau-c (Table 4.49)
[3]	Kendall's tau-c (Table 4.52)
[4]	Kendall's tau-c (Table 4.55)
[5]	Fisher's Exact Test (Table 4.26)
[6]	Phi value (Table 4.28)
[7]	Fisher's Exact test for statistical significance (Table 4.57)
[8]	Fisher's Exact test for statistical significance (Table 4.57)

Table 4.59: Summary of statistical analyses used regarding the Science curriculum

Table 4.60 represents the decision process undertaken to determine and define the type of relationship(s) that best describes the interaction between teachers attending TpD in the Science curriculum and their use of computer software in teaching Science.

[2] = [3] = [4]	Direct relationship	■ True	□ False
[3] = [4] and [6] = small	Extraneous relationship	■ True	□ False
[7] = significant and [8] = significant	Joint relationship	□ True	■ False
[3] <> [4]	Statistical interaction	■ True	□ False
[4] < [2] and [3] < [2]	Intervening/spurious relationship	□ True	□ False
[3] >[2] and [4] > [2]	Suppressed relationship	□ True	□ False

Table 4.60: Decision process to determine the type of relationship regarding the Science curriculum

From Table 4.60 it is evident that a statistical interaction does exist between the two variables under analysis (*Teachers attending TpD in the Science curriculum* and *The use of computer software in teaching Science*) and as a result no further analysis was conducted to elaborate on any further relationships.

4.3.4 Teachers attending professional development programmes in information communications technology and their use of computer software to teach Science

4.3.4.1 Stage 1: Bivariate analysis of dependent and independent variables

4.3.4.1 (a) Frequency of teachers using software to teach Science

From the total sample of Grade 9 Science teachers (n = 316) 90% (n = 285) responded to this question and 10% (n = 31) did not respond. Table 4.61 displays the frequencies of all Science teachers who attended Teacher Professional Development (TpD) in information communications technology and their subsequent use of computer software in teaching Science. A total of 100 teachers indicated that they had attended TpD in information communications technology, and from these 45% (n = 6+39) indicated that they did use computer software in their Science teaching compared to 55% (n = 55) of the teachers who indicated not having used computer software.

		Professional development in information communications technology				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	6	6	7	3	13
	Supplement	39	39	49	27	88
	Not used	55	55	129	70	184
Total		100	100	185	100	285

Table 4.61: Frequency of teachers' use of computer software regarding ICT

4.3.4.1 (b) Statistical significance of teachers using software to teach Science

The relationship between teachers attending TpD in information communications technology and their use of computer software in teaching Science is statistically significant (Fisher's Exact Test: p = .042, n = 285) as shown in Table 4.65.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.172	2	.046	.045	
Likelihood ratio	6.095	2	.047	.054	
Fisher's Exact Test	6.225			.042	
Linear-by-Linear Association	5.608	1	.018	.023	.012
N of valid cases	285				

Table 4.62: Fisher's Exact Test of teachers' use of computer software regarding ICT

4.3.4.1 (c) Strength of the relationship of teachers using software to teach Science

The Kendall's tau-c value (τ = .135, n = 285) reflected in Table 4.63 defines the strength of the relationship between teachers attending TpD in information communications technology and their use of computer software in teaching Science. Matching this value with the Kendall's table of values (Table 4.17) it can be established that the Kendall's tau-c value (τ = .135) is greater than 0.10, thus showing that the relationship is weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.135	.056	2.429	.015	.014
N of valid cases		285				

Table 4.63: Kendall tau-c of teachers' use of computer software regarding ICT

4.3.4.2 Stage 2: Bivariate analysis of dependent and independent variables with a control variable

4.3.4.2 (a) Frequency of female teachers using software to teach Science

Two partial tables were generated, one for each of the categories of the control variable (female and male). Each underwent statistical analysis procedures.

Table 4.64 represents the first partial table with the control variable (female gender) included in the analysis. The table displays the frequencies of female Science teachers who attended TpD in information communications technology and their use of computer software in teaching Science. A total of 57 female teachers indicated that they had attended TpD in information communications technology, and from these a cumulative of 38% (n = 3+19) indicated that they used computer software in their Science teaching as compared to 62% (n = 35) who indicated not having used computer software. Further analysis of Table 4.64 shows that of all female teachers (having attended and not having attended TpD) 24% (n = 6+33) used computer software in teaching Science and 76% (n = 121) did not use computer software in teaching Science.

		Professional development in information communications technology of female teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	3	5	3	3	6
	Supplement	19	33	14	13	33
	Not used	35	61	86	84	121
Total		57	100	103	100	160

Table 4.64: Frequency of computer software use by female teachers regarding ICT

4.3.4.2 (b) Statistical significance of the relationship of female teachers using software to teach Science

The relationship between female teachers attending TpD in information communications technology and their use of computer software in teaching Science reflects a statistically significant relationship (Fisher's Exact Test: p = .007, n = 160) as shown in Table 4.65.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	9.842	2	.007	.007	
Likelihood ratio	9.529	2	.009	.009	
Fisher's Exact Test	9.670			.007	
Linear-by-Linear Association	7.860	1	.005	.007	.005
N of valid cases	160				

Table 4.65: Fisher's Exact Test of female teachers' use of computer software regarding ICT

4.3.4.2 (c) Strength of the relationship of female teachers using software to teach Science

The Kendall's tau-c value (τ = .064, n = 160) presented in Table 4.66 and was derived from the analysis of the relationship between female teachers attending TpD in information communications technology and their use of computer software in teaching Science. When comparing this value with the Kendall's table of values (Table 4.17) it can be noted that the Kendall's tau-c value is less than 0.10, showing that the relationship is a very weak one.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.064	.069	2.906	.004	.002
N of valid cases		160				

Table 4.66: Kendall tau-c of female teachers' use of computer software regarding ICT

4.3.4.2 (d) Frequency of male teachers using computer software to teach Science

Table 4.67 is the second partial table in which the control variable (male gender) was included in the analysis. The table shows the frequencies of male Science teachers who attended TpD in information communications technology and their use of computer software in teaching Science. The data of the male teachers who attended TpD in information communications technology shows that a total of 43 male teachers indicated attending such a programme. From these a cumulative of 44% (n = 3+20) indicated that they used computer software in their Science teaching compared to 56% (n = 20) who indicated not using computer software.

		Professional development in information communications technology of male teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	3	5	4	1	7
	Supplement	20	39	35	24	55
	Not used	20	56	43	75	63
Total		43	100	82	100	125

Table 4.67: Frequency of computer software use by male teachers regarding ICT

4.3.4.2 (e) Statistical significance of male teachers using computer software to teach Science

The relationship between male teachers attending TpD in information communications technology and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .783, n = 125) as presented in Table 4.68.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.512	2	.774	.783	
Likelihood ratio	.507	2	.776	.783	
Fisher's Exact Test	.662			.783	
Linear-by-Linear Association	.502	1	.479	.532	.289
N of valid cases	125				

Table 4.68: Fisher's Exact Test of male teachers' use of computer software regarding ICT

4.3.4.2 (f) Strength of the relationship of male teachers using computer software to teach Science

The Kendall's tau-c value (τ = .060, n = 125) as shown in Table 4.69 was derived from the analysis of the relationship between male teachers attending TpD in information communications technology and their use of computer software in teaching Science. When this value is compared to Kendall's table of values (Table 4.17) it should be noted that the Kendall's tau-c value is less than 0.10, showing that the relationship is very weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.060	.087	.685	.493	.531
N of valid cases		125				

Table 4.69: Kendall tau-c of male teachers' use of computer software regarding ICT

4.3.4.3 Stage 3: Determining a direct relationship

4.3.4.3 (a) Testing for a direct relationship

Table 4.70 tabulates and draws a comparison between the three Kendall's tau-c values. The first value (τ = .135) represents the whole sample of Grade 9 Science teachers; the second (τ = .064) and third (τ = .060) set of values represent the Kendall's tau-c value for the female and male Science teachers respectively. The second and third values were derived from the two partial tables (Tables 4.66 and 4.69).

Group	Kendall's tau-c values
All Science teachers	.135
Female Science teachers	.064
Male Science teachers	.060

Table 4.70: Kendall tau-c values of Science teachers' use of computer software regarding ICT

To determine if this is a direct relationship, all three the Kendall's tau-c values should be equal to one another with no one greater than a .10 difference between them. From Table 4.70 it can be seen that the difference between all three the groups is within the .10 value range, thus making it a direct relationship.

4.3.4.3 (b) Frequency of control and dependent variable

Table 4.25 tabulates the use of computer software to teach Science based on the gender of the Science teachers. It should be noted that the percentage of both female and male Science teachers regarding the use of computer software in teaching Science is low. The cumulative percentage of both genders that used computer software for teaching Science is 35% (n = 13 + 88) and 65% (n = 188) for the teachers who did not use computer software.

4.3.4.3 (c) Statistical significance of the relationship between the control and dependent variable

The relationship between Science teachers (female and male) and their use of computer software in teaching Science reflects a relationship that is not statistically significant (Fisher's Exact Test: p = .00, n = 289) as shown in Table 4.26.

4.3.4.3 (d) Level of association of the control and dependent variable

Running the Phi analysis and determining its value within the context of this research helped determine the degree of association shown in Table 4.27 of the control variable (*Gender*) and the dependent variable (*Use of computer software in teaching Science*).

The relationship between the control variable and the dependent variable reflects a strong positive association: χ^2 (n = 289) P = 0.93, ϕ =.270 derived from Table 4.26 and Table 4.28 (Neill, 2011).

4.3.4.3 (e) Testing for an extraneous relationship

To describe the relationship between the variables as extraneous, the Kendall's tau-c value of female and male should be equal and not have a difference larger than .10, and the Phi value should be small (between -0.3 and +0.3) as shown in Table 4.27.

In this case the differential value (.004) between the female and male Kendall's tau-c value is within the .10 figure, and the Phi value (.270) is small (Table 4.28). From these findings it can be concluded that this is an extraneous relationship.

4.3.4.4 Stage 4: Determining a joint relationship

4.3.4.4 (a) Testing for a joint relationship

To determine if this relationship is a joint relationship, the Fisher's Exact Test was conducted on two interactions: (1) the independent variable and the dependent variable, and (2) the control variable and the dependent variable. In this instance the dependent variable was affected by both the control variable and the independent variable, thus indicating that this is a joint relationship as shown in Table 4.71 (Wicherts, et al. 2011, p. 9).

	Relationship	Fisher's Exact Test Value	Significant
(1)	Independent and dependent variable (Table 4.65)	Fisher's Exact Test: p = .007 (2-tailed)	Yes
(2)	Control variable and dependent variable (Table 4.26)	Fisher's Exact Test: p = .000 (2-tailed)	Yes

Table 4.71: Significance of the relationship regarding ICT

4.3.4.5 Stage 5: Determining a statistical interaction

4.3.4.5 (a) Testing for a statistical interaction

From Table 4.70 it can be determined whether a statistical interaction between the two partial table values exists. The difference between the Kendall's tau-c value for female Science teachers (.064) and male Science teachers (.060) reflects a difference of .004, which is within the .10 range, thus showing that there is a statistical interaction between the two partial tables. Table 4.72 reflects the composite results of all statistical analyses carried out in the sequence to define and explain the relationship that exists between teachers attending TpD in information communications technology and their use of computer software in teaching Science.

[1] = 6.225	[3] = .064	[5] = 4.609	[7] = Yes
[2] = .315	[4] = .060	[6] = .270	[8] = Yes

Table 4.72: Composite statistical results regarding ICT

The values that populate Table 4.72 were derived from a range of statistical techniques as defined in Table 4.73.

Code	Analysis
[1]	Fisher's Exact Test (Table 4.65)
[2]	Kendall's tau-c (Table 4.63)
[3]	Kendall's tau-c (Table 4.66)
[4]	Kendall's tau-c (Table 4.69)
[5]	Fisher's Exact Test (Table 4.26)
[6]	Phi value (Table 4.28)
[7]	Fisher's Exact test for statistical significance (Table 4.71)
[8]	Fisher's Exact test for statistical significance (Table 4.71)

Table 4.73: Summary of statistical analyses used regarding ICT

Table 4.74 represents the decision process undertaken to determine and define the type of relationship(s) that best describes the interaction between teachers attending TpD in information communications technology and their use of computer software in teaching Science.

[2] = [3] = [4]	Direct relationship	■ True □ False
[3] = [4] and [6] = small	Extraneous relationship	■ True □ False
[7] = significant and [8] = significant	Joint relationship	■ True □ False
[3] <> [4]	Statistical interaction	■ True □ False
[4] < [2] and [3] < [2]	Intervening/spurious relationship	□ True □ False
[3] >[2] and [4] > [2]	Suppressed relationship	□ True □ False

Table 4.74: Decision process to determine the type of relationship regarding ICT

From Table 4.74 it is evident that a statistical interaction does exist between the two variables under analysis T*eachers attending TpD in information communications technology* and *The use of computer software in teaching Science*) and as a result no further analysis was necessary to supplement the explanation of the relationship.

4.3.5 Teachers attending professional development in improving learners' critical thinking or inquiry skills and their use of computer software to teach Science

4.3.5.1 Stage 1: Bivariate analysis of dependent and independent variables

4.3.5.1 (a) Frequency of teachers using software to teach Science

From the total sample of Grade 9 Science teachers (n = 316) 90% (n = 284) responded to this question and 10% (n = 32) did not. Table 4.75 displays the frequencies of all Science teachers who attended Teacher Professional Development (TpD) in improving learners' critical thinking or inquiry skills and their subsequent use of computer software in teaching Science. A total of 119 teachers indicated that they had attended TpD in improving learners' critical thinking or inquiry skills, and from these 39% (n = 7+39) indicated that they did use computer software in their Science teaching compared to 61% (n = 73) of the teachers who indicated not having used computer software.

		Professional development in improving learners' critical thinking or inquiry skills				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	7	6	6	4	13
	Supplement	39	33	48	29	87
	Not used	73	61	111	67	184
Total		119	100	165	100	284

Table 4.75: Frequency of teachers' use of computer software regarding critical thinking

4.3.5.1 (b) Statistical significance of teachers using software to teach Science

The relationship between teachers attending TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science reflects a relationship that is not statistically significant (Fisher's Exact Test: $p = .477$, $n = 284$) as shown in Table 4.76.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.443	2	.486	.477	
Likelihood ratio	1.431	2	.489	.477	
Fisher's Exact Test	1.496			.477	
Linear-by-Linear Association	1.390	1	.238	.252	.141
N of valid cases	284				

Table 4.76: Fisher's Exact Test of teachers' use of computer software regarding critical thinking

4.3.5.1 (c) Strength of the relationship of teachers using software to teach Science

The Kendall's tau-c value ($\tau = .063$, $n = 284$) reflected in Table 4.77 defines the strength of the relationship between teachers attending TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science. By matching this value with the Kendall's table of values (Table 4.17) it can be established that the Kendall's tau-c value ($\tau = .063$) is less than 0.10, thus showing that this relationship is very weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.063	.057	1.103	.270	.278
N of valid cases		284				

Table 4.77: Kendall tau-c of teachers' use of computer software- regarding critical thinking

4.3.5.2 Stage 2: Bivariate analysis of dependent and independent variables with a control variable

4.3.5.2 (a) Frequency of female teachers using software to teach Science

Two partial tables were generated, one for each of the categories of the control variable (female and male). Each underwent statistical analysis procedures.

Table 4.78 represents the first partial table with the control variable (female gender) included in the analysis. The table displays the frequencies of female Science teachers who attended TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science. A total of 64 female teachers indicated that they had attended TpD in improving learners' critical thinking or inquiry skills, and from this a cumulative of 27% (n = 3+14) indicated that they had used computer software in their Science teaching compared to 73% (n = 47) who indicated not having used computer software. Additional analysis of Table 4.78 shows that of all female teachers (those who attended and those who had not attend TpD) 24% (n = 6+33) used computer software in teaching Science and 76% (n = 121) did not use computer software in teaching Science.

		Professional development in improving learners' critical thinking or inquiry skills of female teachers				**Total**
		YES	**%**	**NO**	**%**	
Use of computer software for Science instruction	Basis for instruction	3	5	3	3	6
	Supplement	14	22	19	20	33
	Not used	47	73	74	77	121
Total		64	100	96	100	160

Table 4.78: Frequency of computer software use by female teachers regarding critical thinking

4.3.5.2 (b) Statistical significance of the relationship of female teachers using software to teach Science

The relationship between female teachers attending TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science reflects a non-statistically significant relationship (Fisher's Exact Test: d p = .813, n = 160) as shown in Table 4.79.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.398	2	.819	.813	
Likelihood ratio	.393	2	.822	.813	
Fisher's Exact Test	.541			.813	
Linear-by-Linear Association	.374	1	.541	.648	.321
N of valid cases	160				

Table 4.79: Fisher's Exact Test of female teachers' use of computer software regarding critical thinking

4.3.5.2(c) Strength of the relationship of female teachers using software to teach Science

The Kendall's tau-c value (τ = .037, n = 160) presented in Table 4.80 was derived from the analysis of the relationship between female teachers attending TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science. Comparing this value to the Kendall's table of values (Table 4.17) it can be noted that the Kendall's tau-c value is less than 0.10, showing that the relationship is a very weak one.

	Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal Kendall's tau-c	.037	.068	.552	.581	.601
N of valid cases	.160				

Table 4.80: Kendall tau-c of female teachers' use of computer software regarding critical thinking

4.3.5.2 (d) Frequency of male teachers using computer software to teach Science

Table 4.81 is the second partial table in which the control variable (male gender) is included in the analysis. The table shows the frequencies of male Science teachers who attended TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science. From the male teachers who attended TpD in improving learners' critical thinking or inquiry skills, a total of 55 indicated attending such a programme. From these a cumulative of 52% (n = 4+25) of the male teachers indicated that they used computer software in their Science teaching compared to 48% (n = 26) of the teachers who indicated not having used computer software.

		Professional development in improving learners' critical thinking or inquiry skills of male teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	4	7	3	4	7
	Supplement	25	45	29	42	54
	Not used	26	48	37	54	63
Total		55	100	69	100	124

Table 4.81: Frequency of computer software use by male teachers regarding critical thinking

4.3.5.2 (e) Statistical significance of male teachers using computer software to teach Science

The relationship between male teachers attending TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science reflects a relationship that is not statistically significant (Fisher's Exact Test: p = .671, n = 124) as presented in Table 4.82.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.789	2	.674	.703	
Likelihood ratio	.786	2	.675	.735	
Fisher's Exact Test	.854			.671	
Linear-by-Linear Association	.724	1	.395	.454	.241
N of valid cases	124				

Table 4.82: Fisher's Exact Test of male teachers' use of computer software regarding critical thinking

4.3.5.2 (f) Strength of the relationship of male teachers using computer software to teach Science

The Kendall's tau-c value (τ = .073, n = 124) shown in Table 4.83 was derived from the analysis of the relationship between male teachers attending TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science. When this value is compared to Kendall's table of values (See Table 4.17) it should be noted that the Kendall's tau-c value is less than 0.10, showing that the relationship is very weak.

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.073	.091	.803	.422	.440
N of valid cases		124				

Table 4.83: Kendall tau-c of male teachers' use of computer software regarding critical thinking

4.3.5.3 Stage 3: Determining a direct relationship

4.3.5.3 (a) Testing for a direct relationship

Table 4.84 tabulates and draws a comparison between the three Kendall's tau-c values. The first value (τ = .063) represents the whole sample of Grade 9 Science teachers; the second (τ = .037) and third (τ = .073) set out values represented the Kendall's tau-c value for the female and male Science teachers respectively. The second and third values were derived from the two partial tables (Tables 4.80 and 4.83).

Group	Kendall's tau-c values
All Science teachers	.063
Female Science teachers	.037
Male Science teachers	.073

Table 4.84: Kendall tau-c values of Science teachers' use of computer software

To determine whether this is a direct relationship, all three the Kendall's tau-c values should be equal to one another with no one greater than a .10 difference between them. From Table 4.84 it can be seen that the difference between all three the groups is within the .10 value range, thus making this relationship a direct relationship.

4.3.5.3 (b) Frequency of the control and dependent variable

Table 4.25 tabulates the use of computer software to teach Science based on the gender of the Science teachers. It should be noted that the percentage of both female and male Science teachers regarding the use of computer software in teaching Science is low. The cumulative percentage of both genders that used computer software for teaching Science is 35% (n = 13 + 88) and 65% (n =188) for the teachers who did not use computer software.

4.3.5.3 (c) Statistical significance of the relationship between the control and dependent variable

The relationship between Science teachers (female and male) and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .000, n = 289) as shown in Table 4.26.

4.3.5.3 (d) Level of association of the control and dependent variable

Running the Phi analysis and determining its value within the context of this research helped determine the degree of association shown in Table 4.27 between the control variable and the dependent variable. The relationship between the control variable and the dependent variable reflects a strong positive association: χ^2 (n = 289) p = 0.00, ϕ =.270 as derived from Table 4.26 and Table 4.28 (Neill, 2011).

4.3.5.3 (e) Testing for an extraneous relationship

To describe the relationship between the variables as extraneous, the Kendall's tau-c value between female and male should be equal and not have a difference larger than .10, and the Phi value should be small (between -0.3 and +0.3) as shown in Table 4.27.

In this case the differential value (-.036) between the female and male Kendall's tau-c value is not greater than the .10 figure, and the Phi value (.270) is small (Table 4.31). From these findings it can be concluded that this is an extraneous relationship.

4.3.5.4 Stage 4: Determining a joint relationship

4.3.5.4 (a) Testing for a joint relationship

To determine if this relationship is a joint relationship, the Fisher exact test was conducted on two interactions: (1) the independent variable and the dependent variable and (2) the control variable and the dependent variable. In this instance the dependent variable was affected only by the control variable and resulted in a significant relationship; the relationship between the independent variable and dependent variable is not significant, thus inferring that this is not a joint relationship as shown in Table 4.85.

	Relationship	Fisher Exact Test Value	Significant
(1)	Independent and dependent variable (Table 4.79)	Fisher's Exact test: p = .477 (2-tailed)	No
(2)	Control variable and dependent variable (Table 4.26)	Fisher's Exact Test: p = .000 (2-tailed)	Yes

Table 4.85: Significance of the relationship regarding critical thinking

4.3.5.5 Stage 5: Determining a statistical interaction

4.3.5.5 (a) Testing for a statistical interaction

From Table 4.84 it can be determined whether a statistical interaction between the two partial table values exists. The difference between the Kendall's tau-c value for female Science teachers (.037) and male Science teachers (.073) reflects a difference of -.036, which is within the .10 range, showing that there is a statistical interaction between the two partial tables. Table 4.86 reflects the composite results of all statistical analyses carried out in the sequence to define and explains the relationship that exists between teachers attending TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science.

[1] = 1.496	[3] = .037	[5] = 4.609	[7] = No
[2] = .063	[4] = .073	[6] = .270	[8] = Yes

Table 4.86: Composite statistical results regarding critical thinking

The values that populate Table 4.86 were derived from a range of statistical techniques as outlined in Table 4.87.

Code	Analysis
[1]	Fisher's Exact Test (Table 4.79)
[2]	Kendall's tau-c (Table 4.80)
[3]	Kendall's tau-c (Table 4.83)
[4]	Kendall's tau-c (Table 4.86)
[5]	Fisher's Exact Test (Table 4.29)
[6]	Phi value (Table 4.31)
[7]	Fisher's Exact test for statistical significance (Table 4.85)
[8]	Fisher's Exact test for statistical significance (Table 4.85)

Table 4.87: Summary of statistical analyses used regarding critical thinking

Table 4.88 represents the decision process undertaken to determine and define the type of relationship(s) that best describes the interaction between teachers attending TpD in improving learners' critical thinking or inquiry skills and their use of computer software in teaching Science.

[2] = [3] = [4]	Direct relationship	■ True □ False
[3] = [4] and [6] = small	Extraneous relationship	■ True □ False
[7] = significant and [8] = significant	Joint relationship	□ True ■ False
[3] <> [4]	Statistical interaction	■ True □ False
[4] < [2] and [3] < [2]	Intervening/spurious relationship	□ True □ False
[3] >[2] and [4] > [2]	Suppressed relationship	□ True □ False

Table 4.88: Decision process to determine the type of relationship regarding critical thinking

From Table 4.88 it is evident that a statistical interaction does exist between the two variables under analysis (*Teachers attending TpD in improving learners' critical thinking or inquiry skills* and *The use of computer software in teaching Science*) and as a result no further analysis was conducted to elaborate on the type of relationship present.

4.3.6 Teachers attending professional development in Science assessment and their use of computer software to teach Science

4.3.6.1 Stage 1: Bivariate analysis of dependent and independent variables

4.3.6.1 (a) Frequency of teachers using software to teach Science

From the total sample of Grade 9 Science teachers (n = 316), a total of 91% (n =286) responded to this question and 9% (n = 30) did not respond. Table 4.89 displays the frequencies of all Science teachers who attended Teacher Professional Development (TpD) in Science assessment and their subsequent use of computer software in teaching Science. A total of 170 teachers indicated that they had attended TpD in Science assessment, and from these 40% (n = 10+58) indicated that they did use computer software in their Science teaching compared to 60% (n = 102) who indicated not having used computer software.

		Professional development in Science assessment				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	10	6	3	2	13
	Supplement	58	34	30	26	88
	Not used	102	60	83	72	185
Total		170	100	116	100	286

Table 4.89: Frequency of teachers' use of computer software regarding Science assessment

4.3.6.1 (b) Statistical significance of teachers using software to teach Science

The relationship between teachers attending TpD in Science assessment and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .110, n = 286) as shown in Table 4.90.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.598	2	.100	.105	
Likelihood ratio	4.740	2	.093	.099	
Fisher's Exact Test	4.456			.110	
Linear-by-Linear Association	4.582	1	.032	.036	.020
N of valid cases	286				

Table 4.90: Fisher's Exact Test of teachers' use of computer software regarding Science assessment

4.3.6.1 (c) Strength of the relationship of teachers using software to teach Science

The Kendall's tau-c value (τ = .118, n = 286) as reflected in Table 4.91 defines the strength of the relationship between teachers attending TpD in Science assessment and their use of computer software in teaching Science. By matching this value to the Kendall's table of values (Table 4.17) it can be established that the Kendall's tau-c value (τ = .118) is greater than 0.10, thus showing that this relationship is weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.118	.055	2.156	.031	.037
N of valid cases		286				

Table 4.91: Kendall tau-c of teachers' use of computer software regarding Science assessment

4.3.6.2 Stage 2: Bivariate analysis between dependent and independent variables with a control variable

4.3.6.2 (a) Frequency of female teachers using software to teach Science

Two partial tables were generated, one for each of the categories of the control variable (female and male). Each underwent statistical analysis procedures.

Table 4.92 represents the first partial table with the control variable (female gender) included in the analysis. The table displays the frequencies of female Science teachers who attended TpD in Science assessment and their use of computer software in teaching Science. A total of 91 female teachers indicated that they had attended TpD in Science assessment, and from these a cumulative of 30% (n = 4+23) indicated that they used computer software in their Science teaching compared to 70% (n = 64) who indicated not having used computer software. Further analysis of Table 4.92 shows that of all female teachers (those that attended and did not attend TpD) 24% (n = 6+33) used computer software in teaching Science and 76% (n = 122) did not use computer software in teaching Science.

		Professional development in Science assessment of female teachers				**Total**
		YES	**%**	**NO**	**%**	
Use of computer software for Science instruction	Basis for instruction	4	4	2	3	6
	Supplement	23	26	10	14	33
	Not used	64	70	58	83	122
Total		91	100	70	100	161

Table 4.92: Frequency of computer software use by female teachers regarding Science assessment

4.3.6.2 (b) Statistical significance of the relationship of female teachers using software to teach Science

The relationship between female teachers attending TpD in Science assessment and their use of computer software in teaching Science reflects a non-statistically significant relationship (Fisher's Exact Test: p = .195, n = 161) as shown in Table 4.93.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.402	2	.183	.205	
Likelihood ratio	3.490	2	.175	.196	
Fisher's Exact Test	3.369			.195	
Linear-by-Linear Association	2.819	1	.093	.099	.062
N of valid cases	161				

Table 4.93: Fisher's Exact Test of female teachers' use of computer software regarding Science assessment

4.3.6.2 (c) Strength of the relationship of female teachers using software to teach Science

The Kendall's tau-c value (τ = .122, n = 161) presented in Table 4.94 was derived from the analysis of the relationship between female teachers attending TpD in Science assessment and their use of computer software in teaching Science. Comparing this value with the Kendall's table of values (Table 4.17) it can be noted that the Kendall's tau-c value is greater than 0.10, showing that the relationship is a weak relationship.

	Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal Kendall's tau-c	.122	.065	1.879	.060	.082
N of valid cases	.161				

Table 4.94: Kendall tau-c of female teachers' use of computer software regarding Science assessment

4.3.6.2 (d) Frequency of male teachers using computer software to teach Science

Table 4.95 is the second partial table in which the control variable (male gender) is included in the analysis. The table shows the frequencies of male Science teachers who attended TpD in Science assessment and their use of computer software in teaching Science. From the male teachers who attended TpD in Science assessment a total of 79 indicated attending such a programme. From these a cumulative of 52% (n = 6+35) indicated that they used computer software in their Science teaching compared to 48% (n = 38) of the teachers who indicated not having used computer software.

		Professional development in Science assessment of male teachers				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	6	8	1	2	7
	Supplement	35	44	20	44	55
	Not used	38	48	25	54	63
Total		79	100	46	100	125

Table 4.95: Frequency of computer software use by male teachers regarding Science assessment

4.3.6.2 (e) Statistical significance of male teachers using computer software to teach Science

The relationship between male teachers attending TpD in Science assessment and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .496, n = 125) as presented in Table 4.96.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.755	2	.416	.432	
Likelihood ratio	1.991	2	.369	.432	
Fisher's Exact Test	1.554			.496	
Linear-by-Linear Association	1.093	1	.296	.356	.187
N of valid cases	125				

Table 4.96: Fisher's Exact Test of male teachers' use of computer software regarding Science assessment

4.3.6.2 (f) Strength of the relationship of male teachers using computer software to teach Science

The Kendall's tau-c value (τ = .080, n = 125) as shown in Table 4.97 was derived from the analysis of the relationship between male teachers attending TpD in Science assessment and their use of computer software in teaching Science. When this value is compared to Kendall's table of values (Table 4.17) it should be noted that the Kendall's tau-c value is less than 0.10, showing that the relationship is very weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.080	.086	.925	.355	.370
N of valid cases		125				

Table 4.97: Kendall tau-c of male teachers' use of computer software regarding Science assessment

4.3.6.3 Stage 3: Determining a direct relationship

4.3.6.3 (a) Testing for a direct relationship

Table 4.98 tabulates and draws a comparison between the three Kendall's tau-c values. The first value (τ =.118) represents the whole sample of Grade 9 Science teachers; the second (τ = .122) and third (τ = .080) set of values represent the Kendall's tau-c value for the female and male Science teachers respectively. The second and third values were derived from the two partial tables (Tables 4.94 & 4.97).

Group	Kendall's tau-c values
All Science teachers	.118
Female Science teachers	.122
Male Science teachers	.080

Table 4.98: Kendall tau-c values of Science teachers' use of computer software regarding Science assessment

To determine if this is a direct relationship, all three the Kendall's tau-c values should be equal to one another with no one greater than a .10 difference between them. From Table 4.98 it can be seen that the difference between all three the groups is within the .10 value range, thus making it a direct relationship.

4.3.6.3 (b) Frequency of the control and dependent variable

Table 4.25 tabulates the use of computer software to teach Science based on the gender of the Science teachers. It should be noted that the percentage of both female and male Science teachers regarding the use of computer software in teaching Science is low. The cumulative percentage of both genders that used computer software for teaching Science is 35% (n = 13 + 88) and 65% (n =188) for teachers who did not use computer software.

4.3.6.3 (c) Statistical significance of the relationship between the control and dependent variable

The relationship between Science teachers (female and male) and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .000, n = 289) as shown in Table 4.26.

4.3.6.3 (d) Level of association of the control and dependent variable

Running the Phi analysis and determining its value within the context of this research helped determine the degree of association of the control variable (*Gender*) and the dependent variable (*Use of computer software in teaching Science*) shown in Table 4.28.

The relationship between the control variable and the dependent variable reflects a strong positive association: χ^2 (n = 289) p = 0.00, ϕ =.270 as derived from Table 4.26 and Table 4.28 (Neill, 2011).

4.3.6.3 (e) Testing for an extraneous relationship

To describe the relationship between the variables as extraneous, the Kendall's tau-c value between female and male should be equal and not have a difference larger than .10, and the Phi value should be small (between -0.3 and +0.3) as shown in Table 4.27.

In this case the differential value (.042) between the female and male Kendall's tau-c value is within the .10 figure, and the Phi value (.270) is small (Table 4.28). Based on these findings it can be concluded that this is an extraneous relationship.

4.3.6.4 Stage 4: Determining a joint relationship

4.3.6.4 (a) Testing for a joint relationship

To determine if this relationship is a joint relationship, the Fisher's Exact Test was conducted on two interactions: (1) the independent variable and the dependent variable, and (2) the control variable and the dependent variable. In this instance the dependent variable was affected only by the control variable and resulted in a significant relationship and the relationship between the independent variable and dependent variable is not significant, thus indicating that this is not a joint relationship as shown in Table 4.99 (Wicherts, et al. 2011, p. 9).

	Relationship	Fisher exact test value	Significant
(1)	Independent and dependent variable (Table 4.90)	Fisher's Exact Test: p = .110 (2-tailed)	No
(2)	Control variable and dependent variable (Table 4.26)	Fisher's Exact Test: p = .000 (2-tailed)	Yes

Table 4.99: Significance of the relationship regarding Science assessment

4.3.6.5 Stage 5: Determining a statistical interaction

4.3.6.5 (a) Testing for a statistical interaction

From Table 4.98 it can be determined whether a statistical interaction between the two partial table values exists. The difference between the Kendall's tau-c value for female Science teachers (.122) and male Science teachers (.080) reflects a difference of .042, which is within the .10 range, showing that there is a statistical interaction between the two partial tables.

Table 4.100 reflects the composite results of all statistical analyses carried out in the sequence to define and explain the relationship that exists between teachers attending TpD in Science assessment and their use of computer software in teaching Science.

[1] = 4.456	[3] = .122	[5] = 4.609	[7] = No
[2] = .118	[4] = .080	[6] = .270	[8] = Yes

Table 4.100: Composite statistical results regarding Science assessment

The values that populate Table 4.100 were derived from a range of statistical techniques as outlined in Table 4.101.

Code	Analysis
[1]	Fisher's Exact Test (Table 4.93)
[2]	Kendall's tau-c (Table 4.94)
[3]	Kendall's tau-c (Table 4.97)
[4]	Kendall's tau-c (Table 4.100)
[5]	Fisher's Exact Test (Table 4.29)
[6]	Phi value (Table 4.31)
[7]	Fisher's Exact test for statistical significance (Table 4.99)
[8]	Fisher's Exact test for statistical significance (Table 4.99)

Table 4.101: Summary of statistical analyses used for Science assessment

Table 4.102 represents the decision process undertaken to determine and define the type of relationship(s) that best describes the interaction between teachers attending TpD in Science assessment and their use of computer software in teaching Science.

[2] = [3] = [4]	Direct relationship	■ True □ False
[3] = [4] and [6] = small	Extraneous relationship	■ True □ False
[7] = significant and [8] = significant	Joint relationship	□ True ■ False
[3] <> [4]	Statistical interaction	■ True □ False
[4] < [2] and [3] < [2]	Intervening/spurious relationship	□ True □ False
[3] >[2] and [4] > [2]	Suppressed relationship	□ True □ False

Table 4.102: Decision process to determine the type of relationship regarding Science assessment

From Table 4.102 it is evident that a statistical interaction does exist between the two variables under analysis (*Teachers attending TpD in Science assessment* and *The use of computer software in teaching Science*) and as a result no further analysis was conducted to elaborate on the type of relationship that might be present.

4.3.7 Teachers attending professional development in addressing individual learners' needs and their use of computer software to teach Science

4.3.7.1 Stage 1: Bivariate analysis of dependent and independent variables

4.3.7.1 (a) Frequency of teachers using software to teach Science

From the total sample of Grade 9 Science teachers (n = 316) 90% (n = 285) responded to this question and 10% (n = 31) did not respond. Table 4.103 displays the frequencies of all Science teachers who attended Teacher Professional Development (TpD) in addressing individual learner needs and their subsequent use of computer software in teaching Science. A total of 113 teachers indicated that they had attended TpD in addressing individual learner needs, and from these 37% (n = 6+36) indicated that they did use computer software in their Science teaching compared to 63% (n =71) who indicated not having used computer software.

		Professional development in addressing individual learner needs				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	6	5	7	4	13
	Supplement	36	32	52	30	88
	Not used	71	63	113	66	184
Total		113	100	172	100	285

Table 4.103: Frequency of teachers' use of computer software regarding learner needs

4.3.7.1 (b) Statistical significance of teachers using software to teach Science

The relationship between teachers attending TpD in addressing individual learner needs and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .807, n = 285) as shown in Table 4.107.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.375	2	.829	.847	
Likelihood ratio	.372	2	.830	.847	
Fisher's Exact Test	.456			.807	
Linear-by-Linear Association	.346	1	.556	.600	.313
N of valid cases	285				

Table 4.104: Fisher's Exact Test of teachers' use of computer software regarding learner needs

4.3.7.1 (c) Strength of the relationship of teachers using software to teach Science

The Kendall's tau-c value (τ = .030, n = 285) reflected in Table 4.105 defines the strength of the relationship between teachers attending TpD in addressing individual learner needs and their use of computer software in teaching Science. By matching this value with the Kendall's table of values (Table 4.17) it can be established that the Kendall's tau-c value (τ = .030) is less than 0.10, thus showing that this relationship is very weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.030	.056	.539	.590	.597
N of valid cases		285				

Table 4.105: Kendall tau-c of teachers' use of computer software regarding learner needs

4.3.7.2 Stage 2: Bivariate analysis of dependent and independent variables with a control variable

4.3.7.2 (a) Frequency of female teachers using software to teach Science

Two partial tables were generated, one for each of the categories of the control variable (female and male). Each underwent statistical analysis procedures.

Table 4.106 represents the first partial table with the control variable (female gender) included in the analysis. The table displays the frequencies of female Science teachers who attended TpD in addressing individual learner needs and their use of computer software in teaching Science. A total of 64 female teachers indicated that they had attended TpD in addressing individual learner needs, and from these a cumulative of 25% (n = 3+13) indicated that they used computer software in their Science teaching as compared to 75% (n = 48) who indicated not having used using computer software. Supplementary analysis of Table 4.106 shows that of all female teachers (those that attended and did not attend TpD) 24% (n = 6+33) used computer software in teaching Science and 76% (n = 121) did not use computer software in teaching Science.

		Female teachers' professional development in addressing individual learner needs				Total
		YES	%	NO	%	
Use of computer software for Science instruction	Basis for instruction	3	5	3	3	6
	Supplement	13	20	20	21	33
	Not used	48	75	73	76	121
Total		64	100	96	100	160

Table 4.106: Frequency of computer software use by female teachers regarding learner needs

4.3.7.2 (b) Statistical significance of the relationship of female teachers using software to teach Science

The relationship between female teachers attending TpD in addressing individual learner needs and their use of computer software in teaching Science reflects a non-statistically significant relationship (Fisher's Exact Test: p = .902, n = 160) as shown in Table 4.107.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.261	2	.878	.902	
Likelihood ratio	.256	2	.880	.902	
Fisher's Exact Test	.388			.902	
Linear-by-Linear Association	.093	1	.760	.879	.436
N of valid cases	160				

Table 4.107: Fisher's Exact Test of female teachers' use of computer software regarding learner needs

4.3.7.2 (c) Strength of the relationship of female teachers using software to teach Science

The Kendall's tau-c value (τ = .013, n = 160) presented in Table 4.108 was derived from the analysis of the relationship between female teachers attending TpD in addressing individual learner needs and their use of computer software in teaching Science. By comparing this value to the Kendall's table of values (Table 4.17) it can be noted that the Kendall's tau-c value is less than 0.10, showing that the relationship is a very weak one.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.013	.067	.198	.843	.862
N of valid cases		.160				

Table 4.108: Kendall tau-c of female teachers' use of computer software regarding learner needs

4.3.7.2 (d) Frequency of male teachers using computer software to teach Science

Table 4.109 is the second partial table in which the control variable (male gender) is included in the analysis. The table shows the frequencies of male Science teachers who attended TpD in addressing individual learner needs and their use of computer software in teaching Science. For the male teachers who attended TpD in addressing individual learner needs, a total of 49 indicated attending such a programme. From this a cumulative of 53%

(n = 3+23) indicated that they used computer software in their Science teaching compared to 47% (n = 23) who indicated not having used computer software.

		Male teachers' professional development in addressing individual learner needs				Total
		YES	**%**	**NO**	**%**	
Use of computer software for Science instruction	Basis for instruction	3	6	4	5	7
	Supplement	23	47	32	42	55
	Not used	23	47	40	53	63
Total		49	100	76	100	125

Table 4.109: Frequency of computer software use by male teachers regarding learner needs

4.3.7.2 (e) Statistical significance of male teachers using computer software to teach Science

The relationship between male teachers attending TpD in addressing individual learner needs and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .795, n = 125) as presented in Table 4.110.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.389	2	.823	.834	
Likelihood ratio	.389	2	.823	.834	
Fisher's Exact Test	.496			.795	
Linear-by-Linear Association	.353	1	.552	.648	.328
N of valid cases	125				

Table 4.110: Fisher's Exact Test of male teachers' use of computer software regarding learner needs

4.3.7.2 (f) Strength of the relationship of male teachers using computer software to teach Science

The Kendall's tau-c value (τ = .055, n = 125) as shown in Table 4.111 was derived from the analysis of the relationship between male teachers attending TpD in addressing individual learner needs and their use of computer software in teaching Science. When this value is compared to Kendall's table of values (Table 4.17) it should be noted that the Kendall's tau-c value is less than 0.10, showing that the relationship is very weak.

		Value	Asymp. Std. Error	Approx. T	Approx. Sig.	Exact Sig.
Ordinal by Ordinal	Kendall's tau-c	.055	.089	.618	.536	.547
N of valid cases		125				

Table 4.111: Kendall tau-c of male teachers' use of computer software regarding learner needs

4.3.7.3 Stage 3: Determining a direct relationship

4.3.7.3 (a) Testing for a direct relationship

Table 4.112 tabulates and draws a comparison between the three Kendall's tau-c values. The first value (τ = .030) represents the whole sample of Grade 9 Science teachers: the second (τ = .013) and third (τ = .055) set of values represent the Kendall's tau-c value for the female and male Science teachers respectively. The second and third values were derived from the two partial tables (See Tables 4.108 and 4.111).

Group	Kendall's tau-c values
All Science teachers	.030
Female Science teachers	.013
Male Science teachers	.055

Table 4.112: Kendall tau-c values of Science teachers' use of computer software- learner needs

To determine if this is a direct relationship, all three the Kendall's tau-c values should be equal to one another with no one greater than a .10 point difference between them. From Table 4.112 it can be seen that the difference between all three the groups is within the .10 value range, thus making this relationship a direct relationship.

4.3.7.3 (b) Frequency of the control and dependent variable

Table 4.25 tabulates the use of computer software to teach Science based on the gender of the Science teachers. It should be noted that the percentage of both female and male Science teachers regarding the use of computer software in teaching Science is low. The cumulative percentage of both genders that used computer software for teaching Science is 35% (n = 13 + 88) and 65% (n = 188) for the teachers who did not use computer software.

4.3.7.3 (c) Statistical significance of the relationship between the control and dependent variable

The relationship between Science teachers (female and male) and their use of computer software in teaching Science is not statistically significant (Fisher's Exact Test: p = .000, n = 289) as shown in Table 4.26.

4.3.7.3 (d) Level of association of the control and dependent variable

Running the Phi analysis and determining its value within the context of this research helped determine the degree of association as shown in Table 4.28 of the control variable (*Gender*) and the dependent variable (*Use of computer software in teaching Science*).

The relationship between the control variable and the dependent variable reflects a strong positive association: χ^2 (n = 284) p = 0.00, ϕ = .270 as derived from Table 4.26 and Table 4.28 (Neill, 2011).

4.3.7.3 (e) Testing for an extraneous relationship

To describe the relationship between the variables as extraneous, the Kendall's tau-c value between female and male should be equal and not have a difference larger than .10 and the Phi value should be small (between -0.3 and +0.3) as shown in Table 4.27.

In this case the differential value (.042) between the female and male Kendall's tau-c value is within the .10 figure, and the Phi value (.270) is small (Table 4.28). Based on these findings it can be concluded that this is an extraneous relationship.

4.3.7.4 Stage 4: Determining a joint relationship

4.3.7.4 (a) Testing for a joint relationship

To determine if this relationship is a joint relationship, the Fisher's Exact Test was conducted on two interactions: (1) the independent variable and the dependent variable, and (2) the control variable and the dependent variable. In this instance the dependent variable was affected only by the control variable and resulted in a significant relationship; the relationship between the independent variable and dependent variable is not significant, thus indicating that this is not a joint relationship as shown in Table 4.113.

	Relationship	Fisher exact test value	Significant
(1)	Independent and dependent variable (Table 4.104)	Fisher's Exact Test: p = .807 (2-tailed)	No
(2)	Control variable and dependent variable (Table 4.26)	Fisher's Exact Test: p = .000 (2-tailed)	Yes

Table 4.113: Significance of the relationship

4.3.7.5 Stage 5: Determining a statistical interaction

4.3.7.5 (a) Testing for a statistical interaction

From Table 4.112 it can be determined whether a statistical interaction between the two partial table values exists. The difference between the Kendall's tau-c value for female Science teachers (.013) and male Science teachers (.055) reflects a difference of .042, which is within the .10 range, showing that there is a statistical interaction between the two partial tables.

Table 4.114 reflects the composite results of all statistical analyses carried out in the sequence to define and explain the relationship that exists between teachers attending TpD in addressing individual learner needs and their use of computer software in teaching Science.

[1] = .456	[3] = .013	[5] = 4.609	[7] = No
[2]= .030	[4] = .055	[6] = .270	[8] = Yes

Table 4.114: Composite statistical results regarding learner needs

The values that populate Table 4.114 were derived from a range of statistical techniques as outlined in Table 4.115.

Code	Analysis
[1]	Fisher's Exact Test (Table 4.104)
[2]	Kendall's tau-c (Table 4.105)
[3]	Kendall's tau-c (Table 4.108)
[4]	Kendall's tau-c (Table 4.111)
[5]	Fisher's Exact Test (Table 4.26)
[6]	Phi value (Table 4.28)
[7]	Fisher's Exact test for statistical significance (Table 4.113)
[8]	Fisher's Exact test for statistical significance (Table 4.113)

Table 4.115: Summary of statistical analyses used regarding learner needs

Table 4.116 represents the decision process undertaken to determine and define the type of relationship(s) that best describes the interaction between teachers attending TpD in addressing individual learner needs and their use of computer software in teaching Science.

[2] = [3] = [4]	Direct relationship	■ True □ False
[3] = [4] and [6] = small	Extraneous relationship	■ True □ False
[7] = significant and [8] = significant	Joint relationship	□ True ■ False
[3] <> [4]	Statistical interaction	■ True □ False
[4] < [2] and [3] < [2]	Intervening/spurious relationship	□ True □ False
[3] >[2] and [4] > [2]	Suppressed relationship	□ True □ False

Table 4.116: Decision process to determine type of relationship regarding learner needs

From Table 4.116 it is evident that a statistical interaction does exist between the two variables under analysis (*Teachers attending TpD in addressing individual learner needs* and *The use of computer software in teaching Science*) and as a result no further analysis was conducted to elaborate on possible relationships.

4.3.8 Summary of statistical analysis

Table 4.117 reflects the composite analysis of all the data analysis done in this study.

Independent Variables		Dependent variable		Control variable	Statistical Significance		Strength of relationship		Type of relationship			Statistical interaction
					Fisher's Exact Test Value	Statistical significance	Kendall's tau-c	Degree of strength	Direct	Extraneous	Joint	
BTBS28A	Teacher professional development in Science content	BTBS20D	Using computer software for Science instruction		0.227	No	0.097	Very weak	Yes	Yes	No	Yes
				Female	0.193	No	0.116	Weak				
				Male	0.553	No	0.099	Very weak				
BTBS28B	Teacher professional development in Science pedagogy				0.195	No	0.096	Very weak	Yes	Yes	No	Yes
				Female	0.557	No	0.058	Very weak				
				Male	0.099	No	0.159	Weak				
BTBS28C	Teacher professional development in the Science curriculum				0.332	No	0.068	Very weak	Yes	Yes	No	Yes
				Female	0.477	No	0.069	Very weak				
				Male	1.000	No	0.007	Very weak				
BTBS28D	Teacher professional development in information communications technology				0.042	Yes	0.135	Weak	Yes	Yes	Yes	Yes
				Female	0.007	Yes	0.064	Very weak				
				Male	0.783	No	0.060	Very weak				
BTBS28E	Teacher professional development in improving learners' critical thinking or inquiry skills				0.477	No	0.063	Very weak	Yes	Yes	No	Yes
				Female	0.813	No	0.037	Very weak				
				Male	0.671	No	0.073	Very weak				
BTBS28F	Teacher professional development in Science assessment				0.110	No	0.118	Weak	Yes	Yes	No	Yes
				Female	0.195	No	0.122	Weak				
				Male	0.496	No	0.080	Very weak				
BTBS28G	Teacher professional development in addressing individual learner needs				0.807	No	0.030	Very weak	Yes	Yes	No	Yes
				Female	0.902	No	0.013	Very weak				
				Male	0.795	No	0.055	Very weak				

Table 4.117: Data analysis composite

4.3.9 Summary of statistical analysis

Table 4.118 shows the analysis of the dependent variable and the control variable.

Dependent variable		Control Variable		Fisher's Exact Test Value	Statistical Significance	Degree of association	
						Phi value	Degree
BTBS20D	Using computer software for Science instruction	BTBG02	Gender	**0.00**	**Yes**	0.270	Little or no association

Table 4.118: Data analysis composite

Chapter 5

RESEARCH SUMMARY, FINDINGS, DISCUSSION AND RECOMMENDATIONS

5.1 Introduction

The aim of this research was to investigate the influence that attending teacher professional development programmes by Grade 9 Science teachers has on their use of computer software in the teaching of Science. In this chapter the findings are interpreted and related to the context created in the literature review (Chapter 2) and the research methods adopted (Chapter 3). Chapter 5 starts with a summary of the research (5.2), followed by a summary of the findings supported by a discussion (5.3) and finally followed by suggested recommendations of the findings that could inform policy and practice (5.4).

5.2 Summary of the research

The advancement of technology in education over the past thirty years has resulted in an intense and sustained focus on identifying strategies for eliminating or circumventing barriers that schools and teachers experience in the integration of ICT in instruction and learning (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur & Sendurur, 2012, p. 423). This has led to a renewed focus and re-emphasis on teacher professional development to support the integration of ICT in teaching. According to Probert (2009, p. 24) ensuring that teachers become computer literate is an expansive goal that not only should embrace the mastery of ICT skills but place an equal emphasis on developing specific pedagogic skills to integrate ICT into subject teaching as well as alter the attitudes and beliefs of teachers. The purpose of this research was to investigate whether attending the related professional development programmes influences teachers to use computer software to teach Science. According to Vasumathi (2009, p. 1) to ensure that the benefits of ICT are cascaded to learners, teachers need to spend more time attending teacher professional development programmes. The focus of teacher professional development in the 21st century should not be exclusively fixated on ICT as a tool but rather on using the tool to teach with an equal emphasis being placed on technology, subject content and pedagogical content (Vasumathi, 2009, p. 4).

The framework of this research as outlined in Chapter 1 presents the approach, scope and the context of the research, followed by a summary of the research design and activities. Chapter 2 reviews the body of literature relevant to this research, which includes aspects that address (1) local and international perspectives on teacher professional development, (2) the role of ICT in teacher professional development, (3) approaches to teacher professional development in Science within the South African schooling system, (4) the use of ICT in the teaching of Science, (5) findings and discourse from previous TIMSS studies, and (6) the use and analysis of secondary data. The various aspects of the literature review support the main research question and the seven sub-research questions. However, the literature review did not provide sufficient evidence to answer the sub-research questions, thus making it obligatory to conduct this research. Chapter 3 positioned the research in terms of the philosophical and methodological approaches that guided the research. Chapter 4 focused on the analysis of the data mined from the IEA's online repository.

5.3 Findings from and discussion of the research

This section answers the main research question, ***What is the relationship between teachers attending professional development programmes in Science and their use of computer software in the teaching of Science?*** The main research question comprises seven sub-research questions, each focusing on a particular professional development programme. This chapter underscores the findings relating to five of the seven sub-research questions, four of which look at specific programmes in Science (*content, pedagogy, curriculum and assessment*) that support and enhance the teaching of Science in Grade 9; the fifth investigates the integration of ICT in teaching of Science as reflected in Table 5.1. These sub-research questions are elaborated on in Chapter 1 of this thesis. The findings in relation to the sub-research questions were presented, followed by a discussion and finally recommendations relevant to the sub-research questions. The two sub-research questions omitted from the findings and discussion component of this chapter are number 5 (*Improving critical thinking of learners*) and number 7 (*Addressing individual learner needs*). The omission of these questions was based on the argument that these development programmes did not specifically focus on Science as a subject.

	Sub-research question number	Question
1	**Sub-research question 1**	What is the relationship between teachers attending professional development programmes in **Science content** and their use of computer software in the teaching of Science?
2	**Sub-research question 2**	What is the relationship between teachers attending professional development programmes in **Science pedagogy** and their use of computer software in the teaching of Science?
3	**Sub-research question 3**	What is the relationship between teachers attending professional development programmes in the **Science curriculum** and their use of computer software in the teaching of Science?
4	**Sub-research question 4**	What is the relationship between teachers attending professional development programmes in **integrating information technology** into Science and their use of computer software in the teaching of Science?
5	**Sub-research question 6**	What is the relationship between teachers attending professional development programmes in **Science assessment** and their use of computer software in the teaching of Science?

Table 5.1: Sub- research questions used in the discussion

The construction of each of the sub-research questions is based on the relationship between the two core variables extracted from the TIMSS 2011 Grade 9 Science teacher questionnaire, namely (**BTBS28A-G**): *In the past two years, have you participated in professional development in the following programs …* ? and (**BTB220D**): *Do you use computer software for Science instruction*? The answer to each of the sub-research questions was presented by looking at the results of the various statistical procedures relating the two relevant variables within each of the five sub-research questions.

5.3.1 Findings from the research

The finding of the sub-research questions were deliberated on using a three level process: (1) defining the statistical significance of the relationship, (2) defining the degree of strength in the relationship, and (3) stating the type of relationship(s) prevalent in each of the questions. As stated earlier in this chapter, the findings of the identified five sub-research questions were discussed conjointly and not as individual sub-research questions, a procedure which is supported by literature that maintains that teacher development and the use of technology should be integrated into all teaching practices and not seen as a separate skill or process to be mastered by teachers (Ärlebäck, Doerr, & O'Neil, 2013, p. 104; Kreijns, Vermeulen, Kirschner, Van Buuren & Van Acker, 2013, p. 56).

5.3.1.1 Statistical significance of relationships

The relationship between the variables in each of the four sub-research questions (1, 2, 3 and 6) was found to be statistically not significant with only the relationship between the variables in sub-research question 4 being statistically significant (Table 4.117).

5.3.1.2 Strength of relationship

From the degree of strength of the original bivariate relationship for all five the sub-research questions it is clear that the strength of the relationship between the variables in sub-research questions 1, 2 and 3 are very weak and the relationship between the variables in sub-research questions 4 and 6 are weak (Table 4.117).

5.3.1.3 Type of relationship

5.3.1.3 (a) Direct relationship

The Kendall's tau-c values obtained from the analysis of the original bivariate table and both partial tables for each of the five sub-research questions (Table 4.117) are practically similar with not more than a .10 value difference between them, which is indicative of a direct relationship (Losh, 2004, p. 5). The fact that such a situation is present where the Kendall's tau-c values of the original bivariate relationship in each of the five the sub-research questions did not radically change with the inclusion of the control variable (*Gender*) highlights the robustness of the original bivariate relationship (Argyrous, 2011, p. 161).

5.3.1.3 (b) Extraneous relationship

In the case of all five the sub-research questions, two key conditions are present: (1) Kendall's tau-c value of the two partial tables (female and male) as reflected in Table 4.117 is almost equal in value with less than a .10 difference between them, and (2) the existence of a small *Phi* value (ϕ =. 270) to describe the degree of association between the control and dependent variable. The presence of these two conditions describing the relationship between the variables in each of the five sub-research questions permits each to be defined as an extraneous relationship.

5.3.1.3 (c) Joint relationship

From all five sub-research questions, only sub-research question 4 (See Table 5.1) reflects the presence of a joint relationship between the variables, in which the relationship between the dependent variable and both the independent and control variables is statistically significant.

5.3.2 Discussion of the findings

As alluded to earlier in this chapter, attention was given to five of the seven sub-research questions, four of which comprise teacher professional development programmes directly related to aspects in the teaching of Science in Grade 9; the fifth teacher development programme relates to the integration of ICT in the teaching of Science. The integration of ICT in the teaching of Science allows teaching to become more versatile and at the same time inspires teachers to be active in creating more authentic contexts in which instruction and learning takes place (Lavonen et al., 2006, p. 159).

Of the five sub-research questions (See Table 5.1), four (numbers 1, 2, 3 and 6) reflect relationships between the variables that are statistically not significant. Sub-research questions 1 and 2 focus on teacher development in *Science content* and *Science pedagogy* respectively, and sub-research questions 3 and 6 focus on teacher development in *the Science curriculum* and *Science assessment*. From these findings it can be concluded that there was no relationship between teachers who attended these four programmes and their subsequent use of computer software to teach Science. In respect of the strength of the relationship of the variables in sub-research questions 1, 2 and 3) all relationships were identified as being very weak, which implies that teacher development programmes in *Science content*, *Science pedagogy* and *Science curriculum* did not influence the teachers to use computer software to teach Science. In respect of sub-research question 6, the strength of the relationship between the variables was identified as weak, which indicates that teachers attending a teacher development programme in *Science assessment* were influenced very moderately to use computer software to teach Science.

In respect of the four sub-research questions (numbers 1, 2, 3 and 6) the presence of the two key conditions (See 5.3.1.3 (b)) implies that in all four the questions, the relationship between the variables can be classed as direct extraneous relationships, which indicates that gender did not play an influential role when it came to teachers attending the four teacher development programmes and subsequently using computer software to teach Science.

Sub-research question 4 is the solitary question in which the relationship between the variables was found to be statistically significant. This question focuses on teachers' attending a teacher development programme in the integration of information communications technology in their teaching of Science. It can be concluded from the analysis of the data that teachers who attended this training programme were more likely to be influenced to use computer software in their teaching of Science. The strength of the relationship between the variables in sub-research question 4, which was identified as being weak, implies that a teacher development programme in the integration of ICT into Science influenced the teachers to use computer software moderately to teach Science. In sub-research question 4 the two key conditions (See 5.3.1.3 (b)) present imply that the relationship between the variables is a direct extraneous relationship that indicates that gender did not play a role when it came to teachers attending the specific teacher development programme and their using computer software to teach Science. The relationship between the variables in this question was also identified as a joint relationship, which implies that a statistically significant relationship between teachers who use computer software to teach Science (dependent variable) and teachers who attended teacher professional development programmes in ICT (independent variable) as well as a statistically significant relationship between teachers who use computer software to teach Science (dependent variable) and gender (control variable) was present.

5.3.3 Similar studies conducted

According to Shulman (1987) the act of teaching is a cyclical process. A teacher must first grasp the relevant content knowledge, at which point the teacher transforms the content knowledge by using pedagogical content knowledge into an approach which can be taught to learners; it is at this point that actual teaching takes place. The TPACK model views content and pedagogy as an amalgam. However, the Shulman approach did not compensate for the introduction of technology into education. The revised approach proposed by Mishra and Koehler (2006, p. 1025) compensated for the entry of technology into the educational environment. According to Mishra and Koehler (2006, p. 1018) the mere introduction of technology to the educational process is not adequate. Teachers need to know how to incorporate technology effectively into their teaching.

From the discussion of the findings it becomes evident that in order to develop teachers to use computer software in their teaching, the teacher development programmes cannot be homogeneous in approach. Development programmes that focus purely on Science content, Science pedagogy, Science assessment or the Science curriculum using an insulated approach saw negligible change in teachers' use of computer software to teach Science. There is a reasonable body of literature that articulates the importance of ICT skills being integrated into content and pedagogic knowledge (Guzey & Roehrig, 2009; Ono & Ferreira, 2010; Engida, 2011; Lustick, 2011). According to Ward and Parr (2010, p. 113) the findings of the 2001 *British Educational Communities and Technology Agency* (BECTa) study show that the impact of ICT in a particular subject is strongest when ICT is integrated across the subject curriculum, covering both content and pedagogy. This point is supported by Niessa, Van Zee and Wilesa (2014, p. 41) who state that in-service teachers need to have an integrated knowledge of content, pedagogy and technology that reflects instruction and learning in the 21st century. Teacher professional development programmes in Science need to include the three core areas: content, pedagogy and technology.

Based on the study conducted by Mishra and Koehler (2006, p. 1029) in which it is stated that if technology is used by the teacher to allow learners to construct their own understanding and knowledge of the content it becomes the basis for good teaching with technology. This point is consistent in the work of Guzey and Roehrig (2009, p. 27) and Mdlongwa (2012, p. 4) in which both look at teacher professional development with a view to using technology to support the teaching of Science. The initial observation was that Science teachers who used technology effectively and appropriately during the Science lesson inadvertently allowed learners to become more engaged in the content, which led to knowledge construction.

The findings emanating from the five sub-research questions based on the five teacher development programmes (*content, pedagogy, curriculum, assessment and ICT integration*) show that within the South African context these development programmes are treated as exclusively separate programmes, each having its own focus and goal. Kriek and Grayson (2009, p. 185) make reference to their concern about Science education in South Africa. This situation may be ascribed, in part; to some Science teachers' having limited content knowledge and weak pedagogical knowledge with unprofessional attitudes (Kriek & Grayson, 2009, p. 186). The "holistic model" of Kriek and Grayson (2009) appeals to Science teacher development in South Africa to address the integration and development of teachers' content knowledge, pedagogical content knowledge, cognitive skills and experimental skills. The work of Kriek and Grayson (2009) demonstrates a partial overlap with that of Mishra and Koehler (2006, p. 1029). However, a serious gap in the writing of Kriek and Grayson (2009) is the lack or total absence of any reference to the integration of computers and technology in the professional development programme of a Science teacher. There exists a vast body of literature internationally that draws attention to the "dynamic equilibrium" that is needed between all three knowledge elements (*content, pedagogy and technology*) within any teacher development programme (Mishra & Koehler, 2006; Guzey &Roehrig, 2009; Ward & Parr, 2010; Niessa, Van Zee & Wilesa, 2014; Srisawasdi, 2014).

In the South African context teacher professional development methods have been transformed a number of times with some proving detrimental to the teachers concerned, the most controversial being the *cascade model*, which requires teachers to transmit knowledge gained in training to their colleagues (Ono & Ferreira, 2010, p. 60). Due to the below par standards of Mathematics and Science teachers in South Africa, professional development in these subjects ultimately has become a necessity to equip teachers with adequate knowledge, skills and competences (Ono & Ferreira, 2010, p. 65) to carry out their basic duty, which is to teach using a traditional pedagogic approach. This point is elaborated on in the writing of Steyn (2011, p. 43) in which it is stated that professional development in South Africa aims at improving learner performance through the "stuffing" and equipping teachers with subject content only. Mdlongwa (2012, p. 4) lists a number of challenges that makes ICT integration in South African schools a challenge, a challenge identified in his work implying that *There are not enough qualified teachers to teach ICT subjects like CAT in the schools.* This statement conveys the crux of how many in South Africa view ICT in the context of school and education.

5.4 Recommendations

Based on the research and the findings, the following recommendations are put forward with regard to enhancing the instruction and learning of Science through the introduction or use of ICT in South African schools:

- All teacher professional development programmes planned should include a reasonable number of computer activities to ensure that participating teachers actively use a computer.
- All teachers, irrespective of grade, should have a basic level of computer literacy.
- Curriculum statements in all subjects should clearly give guidance to teachers in which they are expected to use computers to meet the aims of the statement.

- Ensure that all department officials and programme facilitators are ICT compliant and capable.
- Provide each school with a dedicated ICT support team.
- Supply schools with sufficient ICT resources to ensure all teachers have access to the technology.

5.5 Conclusion

Teacher professional development forms the cornerstone of reforms in teaching practice. Teachers in the 21st century find themselves in an information technological world in which they are expected to equip learners with the necessary skills to face the demands of the century. Ensuring that teachers have the necessary knowledge (content, pedagogic and technological) requires a concerted approach in teacher professional development programmes by policy makers, educationists and all education role players. The findings of this research show that for teachers to integrate ICT effectively in the instruction and learning of Science, they need to attend a professional development programme in ICT integration. The use of computers and technology in teaching is no longer a debatable issue in education. From this research there is evidence that professional development programmes in teaching Science have a positive impact on teaching practice.

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APPENDICES

Appendix 3.1

Resources for teaching Science

20

When you teach science to this class, how do you use the following resources?

*Check **one** circle for each line.*

		Basis for instruction	Supplement	Not used
BTBS20A	a) Textbooks	◯	◯	◯
BTBS20B	b) Workbooks or worksheets	◯	◯	◯
BTBS20C	c) Science equipment and materials	◯	◯	◯
BTBS20D	d) Computer software for science instruction	◯	◯	◯
BTBS20E	e) Reference materials (e.g., encyclopedia, dictionary)	◯	◯	◯

Appendix 3.2

Teacher professional development programmes

28

In the past two years, have you participated in professional development in any of the following?

*Check **one** circle for each line.*

		Yes	No
BTBS28A	a) Science content	◯	◯
BTBS28B	b) Science pedagogy/instruction	◯	◯
BTBS28C	c) Science curriculum	◯	◯
BTBS28D	d) Integrating information technology into science	◯	◯
BTBS28E	e) Improving students' critical thinking or inquiry skills	◯	◯
BTBS28F	f) Science assessment	◯	◯
BTBS28G	g) Addressing individual students' needs	◯	◯

Appendix 3.3

2

BTBG02

Are you female or male?

*Check **one** circle only.*

Female --- ◯

Male --- ◯

Appendix 3.4

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Department

24 March 2014

Dr Vijay Reddy

Executive Director

Human Sciences Research Council

134 Pretorius Street

Pretoria

REQUEST FOR PERMISSION TO USE DATA FROM TIMSS 2011

Dear Dr V. Reddy

My name is Moodley Meganathan and I am a Masters student at the University of Pretoria. The research I wish to conduct for my Master's thesis involves the use of data collected from the South African component of the TIMSS 2011 study of which the HSRC was involved in administration. This study will be conducted under the supervision of Professor J. Knoetze from the University of Pretoria.

I hereby seek your consent to access and use the Grade nine South African TIMSS 2011 data set labelled as **BTSZAFM5** which is accessible on the IEA' data repository. I have provided you with a copy of the approval letter which I received from the University of Pretoria's Research Ethics Committee.

If you require any further information, please do not hesitate to contact me on **0824503185** or on **mmoodley@hsrc.ac.za**

Thank you for your time and consideration in this matter.

Yours sincerely,

____

Moodley Meganathan [Mr]

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