ASSESSING NEW ZEALAND HIGH SCHOOL SCIENCE TEACHERS' TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

A thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Education in the University of Canterbury

by

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DEDICATION

To my wife Gifty-

Sorry for not being around during your pregnancy

And daughter Nyamedo-

I cannot wait to hold you for the first time!

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This thesis could not have been successful without the diverse contributions of a lot of people and I wish to express my gratitude to these people. Forgive me if I am not able to mention your name but know that you are much appreciated.

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“Now unto him that is able to keep you from falling, and to present you faultless before the presence of his glory with exceeding joy, to the only wise God our Saviour, be glory and majesty, dominion and power, both now and ever. Amen”. Jude 1:24-25.

ABSTRACT

Technological pedagogical content knowledge (TPACK) is the knowledge required for effective technology integration in teaching. In this study, New Zealand high school science teachers' TPACK was assessed through an online survey. The data and its analysis revealed that New Zealand's high school science teachers in general had a high perception of their understanding of TPACK and its related constructs. Science teachers had high mean scores on all the constructs on a five- point Likert scale except technological knowledge. There is thus an indication that science teachers in New Zealand perceived themselves as being able to teach with technology effectively. Correlation analysis revealed that all six constructs correlated significantly with TPACK (also referred to as TPCK). Multiple and stepwise regression analyses revealed that Technological Pedagogical Knowledge (TPK) and Technological Content Knowledge (TCK) made statistically significant unique contributions to Technological Pedagogical Content Knowledge (TPCK). Pre-registered teachers indicated that their levels of TCK and Pedagogical Content Knowledge (PCK) were lower than more experienced teachers. This implied that recently graduated teachers found it difficult to appropriate the affordances of technology to affect the content they taught. Also, these recently graduated teachers lacked the experience to represent content in a format that made it comprehensible to their learners.

The contextual factors that influenced teachers' use of technology as well as teachers' TPACK levels were investigated through multiple embedded case studies of six teachers who were regular users of technology in their teaching. The case studies revealed that science teachers used technology to support inquiry learning in a wide range of ways in lower levels of high school but mostly to clarify concepts and theories when it came to the senior level of high school. Teachers demonstrated different levels of expertise and engagement in the use of technology for transferring different types of knowledge from one teaching and learning

context to another and for addressing differences amongst learners. This signalled that science teachers' TPACK apparent developmental levels shifted depending on the context of the assessment requirements of the students. This is a major finding in this study because although previous researchers have assumed that context influences teachers' TPACK characteristics and development, this study provides evidence of how specific aspects of context influences teachers' TPACK. This evidence shows examples of how the development of an individual's TPACK can be considered as dynamic where the interacting constructs and characteristics shift and change based on the context.

The recommendations from this study propose that teacher education programmes should ensure that there is a focus on teaching preservice teachers how to appropriate the affordances of technology to teach specific content instead of teaching one technology skills based course. The evidence from this study indicates that teachers in New Zealand schools use collegial approaches in the use of technology. Therefore professional learning programmes should target groups of teachers in the same school or cluster of schools rather than targeting individual teachers. This will enable teachers to share ideas and provide leadership for their colleagues in terms of how to use technology. Again, technology related professional development programmes should move away from enriching teachers' technological skills to emphasising how teachers can appropriate the affordances of technology in their classroom practices to meet their instructional goals as well as students' learning outcomes. There is a consequent obligation for teacher educators, educationists and stakeholders to enable teachers to understand how best to harness the increased knowledge retrieval capacity that Information and Communication Technology affords, its information sharing abilities as well as the capacity to engage young people to act as experimenters, designers and creators of knowledge.

CONFERENCE PRESENTATIONS/ PUBLICATIONS ARISING FROM THIS THESIS

Owusu, K.A., Conner, L. & Astall, C. (2012). Wish list for successful/effective ICT use in science classes. SciCon 2012, July 1-4, Auckland University.

Owusu, K.A., Conner, L & Astall, C. (2013). Contextualized use of technology in science classrooms by high school science teachers. 4th World Conference on Science and Technology Education, 2013. 29 Sept.- 4 Oct, 2013, Kuching, Malaysia.

Owusu, K.A., Conner, L. & Astall, C. (2014) Assessing New Zealand high school science teachers' technological pedagogical content knowledge (Submitted to Journal of Computers in Mathematics and Science Teaching)

CHAPTER 1

INTRODUCTION

This chapter provides the background to the study in terms of previous research and the development of key concepts related to the use of technology in education, a statement of the problem, research focus, aim/purpose and outlines the research questions that this study seeks to answer.

Background to the study

The 21st century has different features from those of the 19th and the 20th centuries. The emergence into the 21st century as postulated by Niess (2005) features different tools, communication and information which has affected how we live, play and work (Alayyar, Fisser, & Voogt, 2012) as well as teach and learn. We now live in an era whereby knowledge develops rapidly (Yalçın & Çelikler, 2011), technology plays an integral role in our daily lives (Guerrero, 2010) and technological devices have become an indispensable part of our daily lives (Yalçın & Çelikler, 2011). Technology has become part and parcel of the everyday life of the citizens of this era such that today's societies rely heavily on technology with technological advances modifying how society and individuals behave (Hixon & Buckenmeyer, 2009).

Mishra and Koehler (2006) accentuated that the advent of digital technology has changed the routines of most arenas of human work dramatically which has compelled advocates of technology to expect similar influences in the education process. There has been interest in how students (Sutherland, Facer, Furlong, & Furlong, 2000) and teachers are using technology in the classroom (Albion, Jamieson-Proctor, & Finger, 2010). Everyday educational debate and discourse over the last decade has been full of how technology can and does affect teaching and learning (Al-Bataineh & Brooks, 2003; Hofer & Swan, 2008; Selwyn, 2012). The prospects of using emerging and digital technologies to improve the teaching and learning process as well as students' academic performance have been recognised by researchers, scholars, teachers and teacher educators (S. M. Lee, Brescia, & Kissinger, 2009; Šorgo, Verčkovnik, & Kocijančič, 2010) with some proponents of technology hailing technology as a panacea to education's problems (Lai & Pratt, 2008). There is the belief that the potential to succeed in life, to compete well in industry and to engage in lifelong learning in the 21st century depends on one's ability and competence to work with Information and Communication Technology (ICT) (Law & Yuen, 2006; Šorgo et al., 2010).The call for technology integration in the education system is influenced by the nature of the current crop of learners (Green, Facer, Rudd, Dillon, & Humphreys, 2005; Prensky, 2001) and the assumed affordances (Gibson, 1979; Valanides & Angeli, 2006) technology provides.

Today's learners have grown up surrounded by technology (Oblinger & Oblinger, 2005; Prensky, 2001, 2005), with technology being an integral part of their everyday lives (Green et al., 2005). These learners are already using technology in their informal learning endeavours (Green et al., 2005) as well as their everyday entertainment and play tools. Digital cameras, computers, videogames, video cameras, digital music recorders and players are part of the daily lives of the young learner in this generation. Prensky (2001) therefore called these learners the 'digital natives' because they have been born into the technology crazed world and are therefore "native speakers" of the technology language. Oblinger and Oblinger (2005) called them the 'Net Generation' while Perillo (2007) called them the Generation Y. Although these labels have been criticised and debunked by other researchers (Bennett & Maton, 2010; Bennett, Maton, & Kervin, 2008; C. Jones & Czerniewicz, 2010; C. Jones & Healing, 2010; Kennedy, Judd, Dalgarno, & Waycott, 2010), the reality is that current students think and process information differently from their predecessors (Prensky, 2001) and we therefore cannot continue to teach them as we did to their predecessors. Educators, as identified by Al-Bataineh and Brooks (2003), are serving a generation of students who enter formal schooling with better understanding of computers and technology in general than their predecessors. It fits into the theory of constructivist learning to use what your learners already know and leverage the learning of new ideas through using students' prior knowledge of content and skills (Conner, 2013). Given generation Y's technological knowledge and skill development, it is no surprise that society expects students to be taught with technology.

Advocates of technology believe that it has affordances for effective teaching in general (Valanides & Angeli, 2006) and science in particular (Webb, 2005). Gibson (1979) postulated that affordance is what the environment offers an organism. Applying this term in educational technology, Norman (1988) argued that affordance covers all the properties of a system that make certain actions possible and which go a long way to encouraging specific learner behaviours. The New Zealand Ministry of Education (2007) advocated that information and communication technology (ICT) and for that matter technology has the potential to support effective pedagogy. There is a plethora of opportunities technology affords the teaching and learning of science in the literature. For example, Ryan and Cowie (2009) claimed that technology can foster independent as well as collaborative learning while Osborne and Hennessy (2003) asserted that ICT has the ability to enhance investigative learning in science. Technology has features that can enhance both the investigative and practical aspects of teaching as declared by Osborne and Hennessy (2003). The ability to provide interactive content, give immediate feedback, diagnose student needs, provide effective remediation, assess learning, and store examples of student work that are provided by technological advancement (Watson & Watson, 2011), help improve students' learning. Students' reflective process can be supported by computers which can make them alert and can direct students in their thinking and thereby put the students in charge of their own learning (Lai, 2008). Jimoyiannis (2010) noted that in science education, technology has been advocated to facilitate students' ability to reason at higher cognitive levels, support constructivists’ learning approaches, encourage scientific inquiry as well as promote active and participatory learning.

Voogt and van den Akker (2001) inferred that technological advancements such as data presentation software, word processor and other applications support students in their day to day classroom and out of classroom academic activities. The internet has provided an easy and convenient way to send conventional educational or course materials to students in remote areas (Kaldoudi, Konstantinidis, & Bamidis, 2010). Therefore technology has provided more efficient ways to communicate to and with students who are far away from the instructor. Thus, technology has made distance learning, be it synchronous or asynchronous, a little bit less laborious and difficult. Such asynchronous learning and delivery of educational and learning information as well as materials are being facilitated by blogs and wikis. Lai (2008) emphasised that the sharing of ideas by teachers and students through emails and video conferences have helped to facilitate students understanding on concepts and issues. There is the evidence of improved communication among students and academics when collaborating on projects because of technology (Kaldoudi et al., 2010).

As part of a three year study, Lai and Pratt (2008) gathered evidence on the outcomes of teachers’ use of ICT in schools in the Otago region of New Zealand. They found that ICT has enabled the teachers to organize their work better, prepare their lessons, and improve their communication with students and colleagues. Teachers reported that ICT has given them access to resources on the internet as well as improving the manner students’ present their work.

The use of technology in education has not always been general and amorphous. Technology can and has been tailored to suit specific courses, students and environments. For example, in science education, Otrel-Cass, Cowie, and Khoo (2010) in a study in New

Zealand whereby teachers used ICT to teach two topics in the Planet Earth and Beyond strand of the curriculum, articulated that the use of technology helped the students to overcome challenges associated with earth sciences. These researchers asserted that the students in their research were able to visualize large geographical areas as well as make connections to real life observations with long term geological processes. In a more emphatic manner, these researchers stated that "integrating ICTs into the learning experience expanded the ability of students to think and learn like scientists (Nature of Science strand) and understand Planet Earth and Beyond" (Otrel-Cass et al., 2010, p. 15).

Digital technology can provide students the opportunity to engage in 'virtual reality'. Students are given a virtual environment in which they can explore without encountering the risks they would have had if they were learning such content in the 'real' world. Students in one country are now able to sit in a virtual laboratory, conduct experiments and share ideas across countries through technology as reported by Jaus (2002). Christou (2010) upheld that experiences through interacting with their environment is the principal medium through which humans learn and that environments created by virtual realities allow students to experience and interact with scenarios and situations rather than imagining them. Thus, the affordances of technology give students the ability to learn more directly about abstract concepts by providing visual representations (Bybee, Carlson-Powell, & Trowbridge, 2008). Consequently, technology can be used as a tool to provide authentic, hands-on learning experiences (Knezek, Lai, Khaddage, & Baker, 2011). Osborne and Hennessy (2003) summarized the potential of ICT in education more succinctly by indicating that they help in expediting and enhancing production of school work; improving motivation and engagement; supporting exploration and experimentation as well as fostering self-regulated and collaborative learning.

The use of technology in teaching is not devoid of problems and constrains. There are issues of properly trained staff, adequate and appropriate devices, funding (Al-Bataineh & Brooks, 2003) coupled with adaptability, connectivity and compatibility issues. Notwithstanding these problems, technology is seen to have the ability to present rich learning environments for students (Yalçın & Çelikler, 2011) therefore governments and stakeholders in education are investing in them (Chai, Koh, & Tsai, 2010) with the hope that the affordances technology brings will facilitate and improve teaching and learning. The expectations associated with technology have given rise to high interest in the manner, extent and purpose for which different technological tools are being used in the teaching and learning process (Hogarty, Lang, & Kromrel, 2003). Public interest in the effectiveness of technology in education is not only due to the availability of different and advanced technologies, but also due to the huge investments governments are making in technology for schools. Public interest in how technology is being used and its effectiveness in schools are justifiable since investments in technology for schools are financed primarily through the taxes of the people (Alayyar et al., 2012). The rapid development of technology as well as the public's quest for accountability on how technology is being used in schools have challenged educational establishments to incorporate technology to help facilitate teaching and learning (Kankaanranta, 2005).

The International Society for Technology and Education has therefore challenged teachers as noted by Niess et al. (2009) to conceptualize the technological skills and knowledge students would need in an increasingly technology savvy society. Teachers are being encouraged and may have no choice but to integrate technology in their classrooms, not just for the sake of it but to facilitate their practice as well as improve and maximize their students' learning. This is because the capacity of learners to engage in lifelong learning (through self-directed and collaborative inquiry) and connectedness (through communication and collaboration with peers and experts) can be supported by these technologies that assist with knowledge and skill development (Law & Yuen, 2006).

Even as technology is affecting and influencing the learning of students, the roles and activities played by teachers are also changing. Karper, Robinson, and Cassado-Kehoe (2005) observed that a different atmosphere within which educators are required to integrate new approaches and philosophies of teaching in the classroom in order to properly challenge and stimulate students has been created in the classroom. Technology has changed the teaching methods of teachers so that the needs of the 21st century learners who have developed in a technology-rich environment can be met (Pedersen, 2004). Teachers needed to change their approaches, methods and philosophies because their old methods were not necessarily engaging learners who are very digitally aware and able (Bolstad & Gilbert, 2006a).

In this technology infused era where information is readily available, the teacher is no longer the holder of knowledge but rather seen as a coach, mentor, enabler, facilitator, or an advisor (Pedersen, 2004). The teacher's role is creating the right environment for the students to learn as well as guiding them in the right direction. This role should not be done through the old methods alone but rather teachers need to be aware of the potential of technologies to help them facilitate effective teaching and learning.

In New Zealand schools, teachers are expected to find out and be open to the various new and different ways of learning and teaching by using technology as recommended by the Ministry of Education (2007). Unfortunately, most teachers have tended to use technology to aid teacher transmission of knowledge. Otrel-Cass et al. (2010) reported that New Zealand teachers' technology-oriented classroom practices were modest with the predominant use being for lesson preparation, writing reports and other administrative tasks. Teachers' teaching philosophy and pedagogy did not change even though they were using ICT (Lai & Pratt, 2008). The modest use of technology by teachers in their teaching is not peculiar to

New Zealand. In an analysis of teachers' use of technology in Singapore, Chai et al. (2010) noted that technology- infused student-centred teaching and learning was still an exception rather than a norm in classrooms.

Teachers' use of technology in their teaching can in part be as a result of how they were prepared during their initial teacher education as claimed by some researchers (Chai et al., 2010; Kay, 2006; Swain, 2006). This is because most teacher education programmes have focussed on taking preservice teachers through one specific technology skills-based oriented course (Chai et al., 2010; Niess, 2005) which does not necessarily emphasise the pedagogical uses and adaptive applications of technology (Chai et al., 2010). However, it is accepted that technological skills alone do not necessitate effective use of technology in teaching (Angeli & Valanides, 2005; Chai et al., 2010; Graham et al., 2009; Hardy, 2010; So & Kim, 2009). This is because "preparing preservice teachers for ICT integration is a complex job given the fast changing nature of ICT and the multiple sources of knowledge which need to be synthesized" (Chai et al., 2010, p. 64). They agreed that for the successful integration of technology in the classroom, teachers should be able to blend technology effectively with pedagogy and content (Chai et al., 2010; Mishra & Koehler, 2006; Otrel-Cass et al., 2010). This is because teaching with technology encompasses technological skills, pedagogical skills and content knowledge. For effective teaching with technology, these constructs are expected to be in a blend and treated in unison rather than in isolation. Since New Zealand teachers in general tend to have limited uses of technology in their teaching (Otrel-Cass et al., 2010), it is pertinent that the knowledge behind their use of technology is explored.

Statement of the problem

The benefits and the potential of technology in education in general and science classrooms in particular have been well documented (Bingimlas, 2009; Lai & Pratt, 2008). This has shifted the debate from whether computers and for that matter technology should be incorporated and used in teaching and learning (Valanides & Angeli, 2008) to how best technology should be integrated into education for effective teaching and learning to occur. The mere introduction of technology into the classroom will not necessarily yield the needed results of students maximizing their learning (Koehler & Mishra, 2005; Osborne & Hennessy, 2003; So & Kim, 2009). The teacher is required not only to have knowledge of specific technology but also the knowledge of the affordances and constraints of the technology, use adaptive strategies coupled with how to use these properties of technology to enhance comprehensive learning (Kereluik, Mishra, & Koehler, 2011). The problem summarised might be to understand how best to harness the increased knowledge retrieval capacity that ICT affords, how to share ideas and information generated, how to engage with young people's capacity potentially to act as experimenters, designers and creators of knowledge. These ideas have huge implications for how teachers perceive their role as teachers and what they consider they need to do to advance these educational aspirations.

The *New Zealand Curriculum* (Ministry of Education, 2007) acknowledged the potentials of ICT in the teaching and learning process across the curriculum and recommended that teachers should use technological tools in their teaching. As provided by the Ministry of Education's recommendation, laptops and other ICT tools are being used by New Zealand teachers to stimulate the interest and motivation of learners; support the learners to explore their ideas as well as pose questions as shown by Harlow and Cowie (2010). However, educators have realised that technology is not educational by default but rather a tool whose successful integration into the classroom requires that teachers repurpose it to suit their students' needs (Kereluik et al., 2011). Teachers using ICTs are often required to negotiate a balance of technology, pedagogy and content (Angeli & Valanides, 2009; Otrel-Cass et al., 2010). Effective technology integration for teaching requires that teachers have "knowledge not just of content, technology and pedagogy, but also of their relationship to each other" (Koehler, Mishra, & Yahya, 2007, p. 740). Harris and Hofer (2009) posited that teachers' planning must take into consideration the curriculum requirements, effective pedagogical practices as well as the affordances and constraints of the available technology when they are integrating technology into their instruction. Koehler and Mishra (2008) argued that "at the heart of good teaching with technology are three components: content, pedagogy, and technology and the relationships between them" (p. 12). Teachers should therefore be able to choose the appropriate technology to be used through the appropriate pedagogical approach to deliver particular content material. The knowledge required for successful integration of technology into the teaching and learning process is termed technological pedagogical content knowledge (TPACK) (Chai et al., 2010; Koehler & Mishra, 2005, 2008, 2009; Niess, 2005, 2008).

The TPACK concept builds on Shulman's idea of pedagogical content knowledge. Koehler and Mishra (2008) observed that TPACK describes how teachers' understanding of technologies and pedagogical content knowledge interact to produce effective teaching with technology. Graham et al. (2009) claimed that TPACK is achieved when a "teacher knows how technological tools transform pedagogical strategies and content representations for teaching particular topics and how technology tools and representations impact a student's understanding of these topics" (p.71). The TPACK framework has been accepted as a helpful framework for thinking about the knowledge that teachers require in order to successfully integrate technology into their classrooms (Kereluik et al., 2011).

Though technology is being used by New Zealand teachers, it is acknowledged that for successful integration of technology teachers need to develop the 'specialized' knowledge of technological pedagogical content knowledge (Abbitt, 2011a; Harris & Hofer, 2011; Koehler & Mishra, 2005; Mishra & Koehler, 2006; Otrel-Cass et al., 2010). TPACK is a knowledge construct that combines technology, pedagogy and content in a blended fashion and is a very important construct since the effectiveness of technology in teaching and learning relies heavily on a teacher's pedagogical orientations (Webb, 2005). Unfortunately, the literature indicates that little research has been conducted on TPACK in New Zealand. The research studies available in the body of literature on TPACK in New Zealand schools are those conducted by Nordin, Morrow, and Davis (2011) and Otrel-Cass, Khoo, and Cowie (2012). Nordin, Morrow, and Davis' (2011) research looked at preservice teachers' TPACK whereas Otrel-Cass et al. (2012) investigated two science teachers' TPACK through videos. Although Otrel-Cass et al. (2012) looked at inservice teachers' TPACK, they used only two teachers which means that their study had a small sample size. Therefore my study sought to assess New Zealand high school science teachers' TPACK through a large sample as well as identify the contextual factors that influence teachers' TPACK levels in their teaching. This study brings to fore new knowledge about New Zealand science teachers TPACK and how effectively they are integrating technology into their teaching since the sample size for the current study is relatively large as compared to the previous study.

Although many researchers of TPACK (Harris & Hofer, 2009; Koehler & Mishra, 2005, 2008; Mishra & Koehler, 2006; Niess, van Zee, & Gillow-Wiles, 2010) have posited that context factors influence teachers' TPACK, prior to my study there has not been a conscious effort to find out what specific context influences teachers' TPACK. This research sought to provide new knowledge about New Zealand science teachers' TPACK and how this might be modified by selected contextual factors.

New Zealand school context

This section provides some background to the New Zealand teaching and learning context. In New Zealand, schools are independent establishments that are administered by principals, staff, and a Board of Trustees ensuring there is a community involvement. The role of the Ministry of Education (MOE) is to set the national agenda through curricular and administrative documents. Schools develop their own curriculum, including aims and objectives for student achievement, which must be agreed upon by the Ministry of Education based on the MOE's policies and in response to community needs and circumstances (Vannier, 2012).

In New Zealand, students are not required to sit any formal external examinations until Year 11 of schooling (age 16). Although students in Year 1 to Year 10 are formatively assessed on aspects related to the school curriculum, the lack of formal external examinations often means that teachers who teach students in Years 1-10 are not under the same demands with regard to external accountability as those teachers who have students sitting external examinations. Teachers of children from Years 1-10, therefore, have greater freedom to implement the school's curriculum at their own pace where the content is not as prescribed. Students in Years 11 to 13 select courses they would like to pursue and gain qualifications in the selected curriculum areas. During this period, students start to sit formal qualifications that are organised into three levels (Level 1-3) under the National Certificate of Educational Achievement (NCEA). NCEA Level 1 is usually sat at Year 11 and by the end of Year 13 students would have sat Level 3. My research used case studies to illustrate how teachers adapted their technology use and application between different science subjects and the different year levels they taught.

Research Focus

This study sought to assess science teachers' technological pedagogical content knowledge (TPACK). In so doing, an online survey whose items were adapted from already developed TPACK surveys was sent to science teachers across New Zealand to measure how they perceived their understanding of the various constructs of TPACK. A total of 1o2 science teachers responded to the survey. However, four responses were deleted remaining 98 which were used in the analysis. The various constructs of the TPACK model as proposed by

Mishra and Koehler (2006) were tested to find out how they correlated to each other. A regression analysis was conducted to find out which of the constructs was the major contributor to TPCK. Then, six teachers were selected as cases in order to find out how teachers adapted their use of technology in teaching and also to find out which contextual factors seemed to influence teachers' use of technology in teaching.

Aim/Purpose

This research measured the TPACK of science teachers in New Zealand through an instrument that had high reliability coefficients as well as good construct validity achieved through factor analysis. It also tried to understand why and how teachers adapted their use of technology in the different contexts they taught.

Research Questions

The study was guided by these research questions:

1. What are New Zealand science teachers' perceptions of their understanding of the constructs of the TPACK framework?
2. How do the constructs on the TPACK framework correlate with each other?
3. How do teachers' adapt the use of technology in their classrooms?

Scope

This study did not involve any professional development or learning for the participating teachers. The study aimed at gaining a national snapshot of teachers' personal assessment of their technology use and knowledge and to identify factors that influenced their use of technology in their teaching. This was deemed feasible because A. Jones, Harlow, and Cowie (2003) asserted that technology has become part and parcel of our society and New Zealand teachers across different school types and levels have been integrating technology in their teaching. The New Zealand's teachers use of technology has been necessitated by the government's efforts to provide technological tools as well as technology focussed professional development to teachers. Thus, it was important that research was conducted to identify how teachers were using technology in their classrooms to enhance learning in science teaching contexts.

Organization of the rest of the thesis

Excluding the 'Introduction' chapter, there are five other chapters made up of Literature review (Chapter 2), Methodology (Chapter 3), Results (Chapter 4), Discussion (Chapter 5) and Summary, conclusion and recommendations (Chapter 6). The literature review chapter takes a critical look at the relevant literature that is related to this research. This comprised how technology has been adopted into education, the various constructs of TPACK, TPACK and its relation to teaching contexts; theoretical underpinnings of the TPACK framework; and how TPACK has been measured since its inception.

The methodology chapter describes the research design and the broad paradigm under which this study falls; methods of data collection, selection of participants, the instrumentation process and how the collected data were analysed. The results chapter presents the results of both the quantitative and the qualitative aspects of this study. The quantitative part includes the means of the national survey, correlation and regression analysis of the TPACK constructs. The interview narratives, observation reports and the analysis of teachers' responses to the TPACK items formed the qualitative aspect of the results chapter.

Chapter five discusses the results. The discussion draws upon both the quantitative and qualitative results to make the necessary inferences. The thesis ends with the summary, conclusion and recommendation chapter where an overall summary of the research, its key findings and limitations, conclusion, recommendations and suggestions for future research are provided.

Summary of the chapter

The tone for the research was set in this chapter. The justification for the study was made in the Statement of the problem section after a brief expose of the benefits of technology in education in the Background to the study section. Since the research was dealing with specialised words, a section was provided to define such words so that readers are clear about their meanings when they come across them in the thesis. Due to the uniqueness of New Zealand's high school system, a section was provided to throw more light on the New Zealand school context. The *research focus*, *aim/purpose of the study*, *research questions* and the *organization of the rest of the thesis* formed the remaining sections of this introductory chapter to this thesis.

The argument as provided in this chapter was that although the benefits of technology has been well documented and teachers are using technology in their teaching, New Zealand's science teachers' TPACK has not been assessed on a large scale. Unfortunately, TPACK has been mooted as the knowledge that science teachers should acquire if technology is to successful integrated into their teaching. Therefore it was prudent that New Zealand's science teachers' TPACK were assessed. The problem summarised might be to understand how best to harness the ever increasing affordances ICT provides, how to share ideas and information generated, how to engage with young people's capacity potentially to act as experimenters, designers and creators of knowledge. These ideas have huge implications for how teachers perceive their role as teachers and what they consider they need to do to advance these educational aspirations.

Definition of terms

Technology/Information and Communication Technology

Though technology has become an integral part and ubiquitous in this generation, its definition is quite nebulous. McCrory (2008) posited that technology is broadly defined to include tools or techniques that are used for practical purposes. Koehler and Mishra (2008) put technology as the "tools created by human knowledge of how to combine resources to produce desired products, to solve problems, fulfil needs, or satisfy wants" (p. 5). Koehler and Mishra (2008) and McCrory (2008) agreed that the definition of technology implies both the tools, such as computers and internet, as well as skills, techniques and knowledge required to effectively perform a given task. The definition of technology covers analog and digital technologies as well as old and new technologies (Koehler & Mishra, 2009), or conventional tools that have been used for science teaching for decades (McCrory, 2008). In order to make it clear in the minds of their readers what they meant by 'technology', Koehler and Mishra (2009) emphasized that " as a matter of practical significance, however, most of the technologies under consideration in current literature are newer and digital and have some inherent properties that make applying them in straightforward ways difficult" (p. 61). McCrory (2008) on the other hand declared straight away that her use of the word technology referred to new technologies like computers, hand held devices, digital cameras, internet and all that software that make these devices function.

The use of the word 'technology' in this thesis refers to the new or digital technologies and it is synonymous to Information and Communication Technology (ICT). Thus, technology and ICT are used interchangeably and synonymously in this work. This is being done due to the manner that the New Zealand Ministry of Education defines technology and ICT. The Ministry of Education (2002) document, *Digital horizons-learning through ICT* divided ICT into two components: Information technology (IT) and Communication technology (CT) and defined them as the hardware and software that enable us to "access, retrieve, store, organise, manipulate, and present information by electronic means" and "equipment through which information can be sought, sent and accessed" respectively (p.5).

This definition entails all the hardware and software as well as the gadgets that fit into the categorisation of what is called newer technologies or digital technologies.

TPCK/TPACK

Technology, pedagogy, content knowledge and the related constructs form the framework known as Technological Pedagogical Content Knowledge (TPCK). The acronym was changed from TPCK to TPACK to emphasize the integrated nature of the components, its ‘total’ package and for ease of pronunciation (Thompson & Mishra, 2007). Technological Pedagogical Content Knowledge (TPCK) was used to represent the intersecting construct of the technology, pedagogy and content in this thesis. TPACK or TPACK framework was used to represent the whole framework.

CHAPTER 2

LITERATURE REVIEW

This study sought to identify New Zealand high school science teachers' perceptions of their use of technology using the TPACK framework and its related constructs as well as investigated the contextual factors that influenced the teachers' use of technology and how they adapted their use of technology in different situations. This review of related relevant literature encompassed technology adoption in education, the various constructs of the TPACK framework, and theoretical underpinnings of the model as well as how teachers' TPACK has been measured so far since the inception of the framework.

The review process followed the three main steps of literature review of searching, reviewing and writing the literature review (Galvan, 2006, 2009). The search for appropriate literature was conducted through the University of Canterbury library's MultiSearch engine. MultiSearch allows users of the library to quickly search across a range of the Library's resources in one place, including the library catalogue, most library databases, and some digital collections. The university also has an inter loan system where one can borrow material which is not available in the library. Therefore papers and books that were thought to be appropriate for this review but were not available in the university's library were requested through the inter loan system. In using MultiSearch, the frequent key words and terms used were TPACK, TPCK, technology in education and ICT in education. Further searches were accomplished through backward referencing in order to get the primary material.

Only peer-reviewed papers and published books were considered for this literature review so as to ensure a quality review. Abstracts of the publications found were read and if a publication was relevant to the research then it was downloaded and marked for further reading. The materials downloaded and/or borrowed from the library were then read extensively to make sense of it in order to summarize and fit it into the review.

Technology adoption in education

Every aspect of human endeavour has been influenced by technology in this era and therefore it is not surprising that technology has found its way into the educational system. Hixon and Buckenmeyer (2009) agreed that today's societies rely heavily on technology and that technological advances are modifying society and how individuals behave in their everyday life.

The prospects of using emerging and digital technologies to improve the teaching and learning process as well as students' academic performance have been noted by researchers, scholars, teachers and teacher educators (S. M. Lee et al., 2009; Šorgo et al., 2010). Governments, schools and groups with interest in education have therefore recognised and acknowledged this impact of technology and have invested hugely in technological resources with the hope that technology will facilitate and improve teaching and learning. Hogarty, Lang and Kromrel (2003) have indicated that "as the availability of computers and the internet has grown, so has the interest in the extent and purpose for which these technologies are being used" (p 139). Public interest in the effectiveness of technology in education is not only due to the availability of different and advanced technologies, but also to the huge investments governments are making in technology for schools. Public interest in how technology is being used and its effectiveness in schools are justifiable since investments in technology for schools are financed primarily through the taxes of the people (Alayyar et al., 2012). The rapid development of technology as well as the public's quest for accountability on how technology is being used in schools; have challenged educational establishments to incorporate technology to help facilitate teaching and learning as noted by Kankaanranta (2005).

Proponents of technology in educational establishments therefore argue that it has the tendency to empower learners to develop new ways of thinking and be able to do things that their previous generation could not achieve due to the affordances of various technologies (Bolstad & Gilbert, 2006b). Pedersen (2004) indicated that ICT is changing the teaching methods of teachers in order for them to meet the needs of the 21st century learners who have grown up in an environment which is rich in technology in the form of computers, internet, cell phones and games which are normal part of their lives and therefore teachers need new methods of teaching because “the ‘old’ ones just aren’t going to work with the digital generation” (Bolstad & Gilbert, 2006a, p. 5). The teacher is therefore expected to change her teaching approaches and philosophy accordingly. Schools and teachers are expected to find out and be open to the various new and different ways of learning and teaching technology provides as recommended by the Ministry of Education (2007).

The Ministry of Education of New Zealand has therefore indicated that effective teaching with ICT depends on teachers’ confidence to use and understand how to integrate ICT into their teaching (Harlow & Cowie, 2010). This is because different classroom settings influence the value of ICT tools and therefore the effectiveness of such tools to support teaching and learning will depend on how such tools are used (Otrel-Cass et al., 2010). Unfortunately, most teachers use technology to aid teacher transmission of knowledge and that technology infused student-centred teaching and learning is still an exception rather than a norm in classrooms (Chai et al., 2010). Teachers’ use of technology can be viewed through the lens of a technology acceptance model (TAM) (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989). Technology acceptance model has been accepted as a useful theoretical model which can facilitate the elucidation and prediction of people’s behaviour with information technology (Park, 2009).

The TAM was derived from theory of reasoned action (TRA) which is a general intention model designed to explain every human action and behaviour (Ajzen & Fishbein, 1980). TAM tries to illuminate the reasons behind a user’s acceptance or rejection of a particular information technology. TAM thrives on two main beliefs of users of technology to predict their actions in relation to technology. These are perceived usefulness and perceived ease of use. Davis (1989) accentuated that perceived usefulness is the extent to which a person believes that his or her job performance will be improved when they use a particular tool or system. He noted that the extent to which a person believes that his work will be free of effort when he uses a particular tool constitutes the person's perceived ease of use. The technology acceptance model postulates and clarifies how external factors affect attitude, belief and intention to use a particular technological device. This is because TAM notes that perceived usefulness of a system, perceived ease of a system, attitude and behavioural intentions directly or indirectly affect and influence a person's actual use of technology.

Thus, although teachers acknowledge the effectiveness of technology in the teaching and learning process, their actual of technological tools may be affected by how easy they are able to integrate technology effectively in their classrooms. Since technological tools are not educational by default teachers need to repurpose it to suit their classroom learning environments as well as their learning objectives in order to derive maximum impact from the tool (Kereluik et al., 2011). Teachers therefore needed to have a unified concept through which they can effectively integrate technology in their teaching.

Technological Pedagogical Content Knowledge (TPACK) framework

The debate about technology in education has shifted from whether it should be used in the classroom to how it should be integrated into teaching and learning more generally (Angeli, 2005; Sutherland et al., 2000). Earlier attempts to use technology in teaching and learning focussed on teaching technology skills to preservice teachers (Angeli & Valanides, 2005; Thompson & Mishra, 2007). However, educators have recognized that technology skills alone did not serve them well in the pursuit of teaching with technology (Angeli & Valanides, 2009; Chai et al., 2010; Graham et al., 2009). Hardy (2010) asserted that both preservice and inservice teachers agreed that technological skills alone are not sufficient to prepare and enable them to effectively teach with technology. There has therefore been the realization that "technology in and of itself is not a transformative mechanism…rather a tool invoked by its users to reconstruct the subject matter from the knowledge of the teacher into the content of instruction" (Angeli & Valanides, 2009, p. 157). Successful technology integration as argued by Harris and Hofer (2009), is not dependent on the smart use of educational technologies but rather based on curriculum content and the processes through which students learn such content.

This realisation has brought about a shift from just teaching technological skills to preservice teachers to facilitating how to encourage and value teaching that incorporates technology knowledge into teaching. Thus, it has become pertinent that teachers develop and nurture an overarching conception of their subject matter with respect to technology and what it means to teach with technology as suggested by Niess (2005). Koehler and Mishra (2008) argued that "at the heart of good teaching with technology are content, pedagogy, and technology and the relationships between them" (p. 11-12). They posited that the effectiveness of technology in education is dependent on the interactions between and among technology, pedagogy and content and that the knowledge of these interactions accounts for the varying degrees of the effectiveness of use of technology in teaching. Schmidt et al. (2009) claimed that at the intersection of these three knowledge constructs (technology, content and pedagogy) is a visceral conception of teaching content with the appropriate pedagogical approaches and technologies.

Unfortunately, there was no one unifying conceptual framework for educational integration of technology in the past (Archambault & Barnett, 2010). This was a major setback for educators interested in the use of technology in the classroom because there was no framework to guide their work. Selfe (as cited in Angeli & Valanides, 2009) noted that educators interested in the use of technology needed to share some theoretical vision otherwise there was not any meaningful direction and guidance for their work. This seemed to be the frustrations of most educators, teachers and teacher-educators who were interested in the integration of technology in their practice (Angeli & Valanides, 2009; Mishra & Koehler, 2006).

The lack of a unifying framework for technology use in education culminated in different terminologies from different scholars as well as different models. This brought about a different conception of how technology could be used in teaching and learning with the associated different epistemological beliefs. Most scholars used the phrase "Technology integration" to depict and characterise their attempt to use technology in education (Graham et al., 2009). There were models like Levels of Technology Integration (LoTI) (Glazer, Hannafin, Polly, & Rich, 2009) and the enGauge model from the North Central Regional Educational Laboratory (Lemke, 2003). There was PCK of educational technology (Margerum-Leys & Marx, 2002); ICT-related PCK (Angeli & Valanides, 2005), Technology PCK (TPCK) (Niess, 2005) and Technogogical Content Knowledge (Slough & Connell, 2006).

In an attempt to propose a model of how technology can be used most effectively in teaching, Mishra and Koehler (2006) argued that teaching with technology demands knowledge in technology, pedagogy and the content to be taught. The emphasis they articulated was how a teacher can put these constructs together in their teaching. They put together the three constructs (technology, pedagogy and content knowledge) to form the framework known as Technological Pedagogical Content Knowledge (TPCK). The acronym was changed from TPCK to TPACK to emphasize the integrated nature of the components, its 'total' package and for ease of pronunciation (Thompson & Mishra, 2007). The TPACK framework presents an effective frame for thinking about integrating technology through the provision of specific knowledge associated with technology integration into learning environments (Polly & Brantley-Dias, 2009).

The TPACK framework is built upon or is an extension of Shulman's (1986) concept of pedagogical content knowledge, which identifies the distinctive features of knowledge for teaching. The TPACK framework has seven constructs: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological Pedagogical Content Knowledge (TPCK) (Mishra & Koehler, 2006). A brief description of the various constructs of the TPACK framework is provided below.

Technological Knowledge

Defining technology is notoriously difficult because it is always in a state of flux (Harris, Mishra, & Koehler, 2009). It is therefore difficult to keep up to date with technology which makes it more difficult to define technological knowledge because such definition has a very high propensity of becoming obsolete within the shortest possible time. Technology knowledge is therefore one of the constructs of TPACK which is defined differently by different researchers. Cox and Graham (2009) limited their definition to cover only what they termed 'emerging technologies'. To them, technological knowledge is the ability to use emerging technologies. Cox and Graham (2009) reasoned that technological knowledge in the TPACK framework should be about how to use emerging technologies. This definition aimed at bringing out the difference between TPACK and PCK. They believed that technology become common place with time and become more integrated as part of the teacher's pedagogical knowledge.

Other researchers defined technological knowledge as knowledge of both old and new technologies such as black board, chalk, books, as well as internet and video conferencing

(Koehler & Mishra, 2005; Koehler et al., 2007; Mishra & Koehler, 2006). This is an overarching definition which means that every act of teaching should be based on TPACK. However, it is important that a distinction is made between technologies that have become common place and ones that are emerging. It is therefore appropriate to define technological knowledge in the TPACK framework in the context of digital and emerging technologies. Thus, in the broader sense technological knowledge is the ever evolving knowledge base of how to use different digital and emerging technologies in different settings. This means TK has no finality about it but rather assumes a developmental posture which means that it will be "evolving over a time of generative interactions with multiple technologies" (Harris et al., 2009).

Pedagogical Knowledge

In order to teach effectively, a teacher must possess a repertoire of skills needed for teaching. Pedagogical knowledge encompasses knowledge of teaching approaches, theories and concepts underlying teaching. It includes knowledge of the nature of teaching and learning (Abbitt, 2011a). Pedagogical knowledge includes the skills, beliefs and conceptions about teaching (Grossman, 1990). It encompasses knowledge of how students learn, instructional planning and implementation, classroom management, and student assessment and thus encapsulates the conception of the overall purposes of education, values, goals and strategies of education as well as the processes and practice of teaching and learning (Harris et al., 2009; Koehler & Mishra, 2005).

Shulman (1987) theorised that teachers' understanding of the underlying philosophy and approaches to classroom management and organization constituted their pedagogical knowledge. Teachers with good pedagogical knowledge should be able to understand how students construct knowledge and learn (Harris et al., 2009) as well as have appropriate and varying ways of assessing students. They should be able to meet the requirements and responsibilities of their job and end up fostering effective learning in students.

Content Knowledge

Content Knowledge (CK) emphasizes knowledge of the subject matter that is to be taught or learnt. This is the knowledge about the concepts, frameworks, and processes in a given field. Shulman (1987) claimed that "teaching necessarily begins with a teacher's understanding of what is to be learned" (p.7). Science teachers are expected to have mastery over the subject they teach. This includes both the 'process' and 'product' of science (Jaus, 2002). Science teachers should be able to teach the concepts and theories of science as well as organize and supervise laboratory sessions, organize field trips, explain scientific observations to students and lead them to make valid and reliable conclusions. They should be able to understand the "disciplinary 'habits of mind' appropriate to the subject they teach" (Harris et al., 2009, p. 397).

Pedagogical Content Knowledge

Pedagogical Content Knowledge (PCK) indicates the manner in which the content can be represented and formulated to make it comprehensible to others (Shulman, 1986). PCK goes beyond just pedagogy and content. It looks at how these two relate and interact for effective teaching. Segall (2004) explained that the relationship between pedagogy and content is a complicated one in which the boundaries between them are weak and porous. Thus, teachers' pedagogical and content knowledge are inextricably linked.

PCK encompasses knowledge of pedagogies and the planning processes that are appropriate and applicable to the teaching of a given content at any given time (Abbitt, 2011b). For effective teaching, Harris et al. (2009) maintained that knowledge of teaching and learning, assessment procedures, awareness of students' prior knowledge and content-related misconceptions are very essential. The awareness of these issues constitutes teachers'

PCK. It deals with how to design specific subject matter or problems and teach it effectively to suit learners of diverse abilities. "It is a teacher's understanding of how to help students understand specific subject matter….and its influence on teachers' practice is necessary to foster the improvement of science teaching and science teacher education" (Magnusson, Krajcik, & Borko, 1999, p. 96).

Technological Content Knowledge

Technological Content Knowledge (TCK) represents knowledge of subject matter representation with technology. Koehler and Mishra (2008) inferred that it is "an understanding of the manner in which technology and content influence and constrain one another" (p. 16). This is the ability to determine how the content a teacher wants to teach is affected by affordances of technology and vice versa. The availability of specific technology can help make the delivery of certain content easy to learn, concrete and real to students. It is the knowledge of how to utilize an emerging technology to represent specific concepts in a given content domain (Cox & Graham, 2009). "Teachers must understand which technologies are best suited for addressing which types of subject-matter, and how content dictates or shapes specific educational technological uses, and vice versa" (Harris et al., 2009, p. 400).

Technological Pedagogical Knowledge

Technological Pedagogical Knowledge (TPK) refers to knowledge of using technology to implement different teaching methods. It is the "knowledge of how various technologies can be used in teaching and to understanding that using technology may change the way teachers teach" (Schmidt et al., 2009, p. 125). TPK deals with the ability to realise how technology affects the methods and strategies of teaching and how effective teaching and learning can be achieved with technology. It includes the realisation of the constraints and affordances that technology can bring to bear on pedagogical strategies, approaches and designs (Abbitt, 2011b). A teacher with TPK should be able to realise that the technology they want to use does affect their teaching approaches, methods and design. Basically, it is the realisation and conceptualisation of how teaching and learning can be affected or changed when particular technologies are used in a particular manner (Koehler & Mishra, 2009).

Technological Pedagogical Content Knowledge

TPCK depicts knowledge of using technology to implement teaching methods for different types of subject matter. TPCK treats technology, content and pedagogy in unison and blends these three constructs in a complex relationship. TPCK is the understanding that emerges from the interactions and interplays between and among technology, content and pedagogical knowledge that underlies meaningful teaching with technology (Koehler & Mishra, 2009).

Abbitt (2011a) insisted that the complex relationships between the constructs provide a basis for understanding teacher knowledge that supports successful technology integration into classroom learning environments. The constructs are intertwined and interwoven and therefore it is not sufficient for preservice teachers to just learn about technology, content or pedagogy alone and independently of each other. Koehler and Mishra (2008) asserted that

> TPCK is different from knowledge of all three concepts individually. It is the basis of effective teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (p. 17-18).

It is therefore critical that teachers understand the complex relationship among the constructs and the contexts in which they are formed and co-exist to constrain and co-create each other (Harris et al., 2009). This could enable teachers to use technology in student-centred approaches to foster inquiry learning in students instead of using it to support teacher transmission of knowledge (Chai et al., 2010; Lim & Chai, 2008) and as a presentational tool (Harris et al., 2009).

These seven constructs constitute the TPACK framework. There is emphasis in the model on the interactions between and among the three core components of technology, pedagogy, and content. Effective teaching with technology requires TPACK (Abbitt, 2011b; Harris et al., 2009). TPACK helps us to conceptualise the movement away from relying on technological skills as the main ingredient needed for meaningful teaching with technology. It provides a framework for conceptualising instruction using effective technology integration that includes a consideration of appropriating the multiple uses of technology, in relation to content and effective pedagogy (Koehler & Mishra, 2005). Moreover, TPACK seeks to provide the knowledge required by teachers to be able to integrate technology into teaching in a more meaningful manner rather than in oversimplified approaches that treat technology as an "add-on" (Koehler & Mishra, 2009). Figure 1 shows the relationship between the components of TPACK.

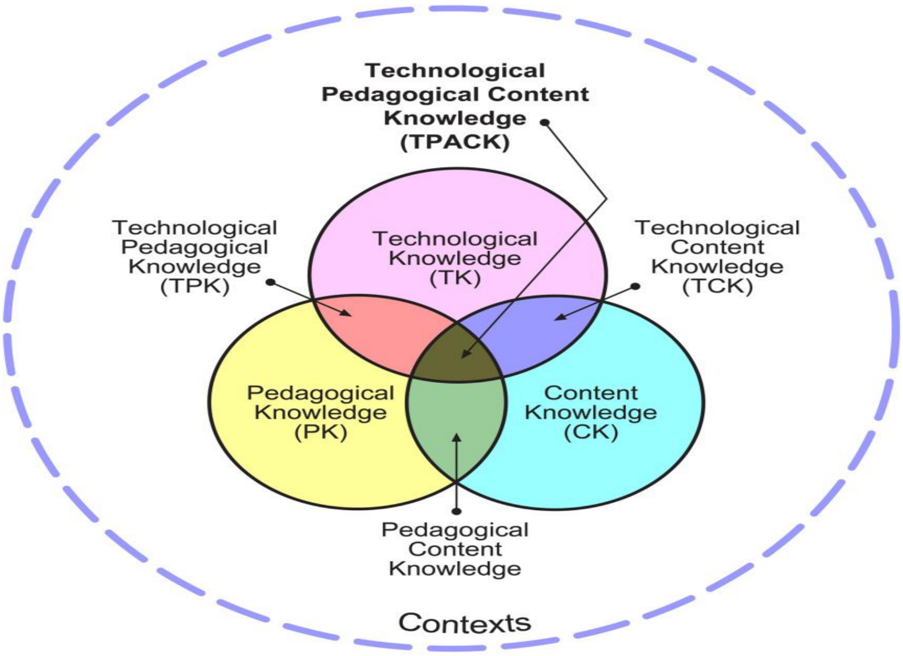

Figure 1: TPACK Framework (Mishra & Koehler, 2006)

TPACK and teaching contexts

Much research has considered the TPACK and its related constructs. However, one area that has not received conspicuous attention is to consider how the context influences teachers' use of technology and how teachers adapt their planning and teaching with varying levels of TPACK characteristics to suit different contexts. This is very alarming and unfortunate since the TPACK framework is embedded within specific contexts. Moreover, TPACK researchers have made it explicitly clear how context plays an integral part of the framework (Koehler & Mishra, 2009) because every form of teacher knowledge is situated and contextually sensitive (Harris & Hofer, 2009). Learning is also most effective when content is framed within a context or specific situation that students can relate to and therefore consider it purposeful and relate it to their lives (Lave, 1997). Yet little evidence is provided in the literature about the influence of context of teachers' appropriation of technologies.

"Technology use in the classroom is context bound and is, or at least needs to be, dependent on subject matter, grade level, student background" (Mishra & Koehler, 2006, p. 13); therefore TPACK is context bound. Mishra and Koehler (2006) considered that quality teaching requires an understanding of the subtlety of the complex associations among technology, pedagogy and content. With such understanding teachers can appropriate and develop context-specific approaches to suit their learners and take account of the constraints and interrelations of these factors (Harris et al., 2009). The ability to appreciate the subtleties of the context (learning, content, social, etc.) within which one is teaching with technology is critical because "social and contextual factors also complicate the relationships between teaching and technology"(Koehler & Mishra, 2009, p. 61).

Theoretical underpinnings of the TPACK framework

The emergence of TPACK seems to have revolutionized the philosophy and knowledge with regards to the integration of technology in the classroom (Chai, Koh, Tsai, & Tan, 2011; Chai et al., 2010; Hewitt, 2008; Niess, 2005; Voogt, Fisser, N., Tondeur, & van Braak, 2013). It has shifted the focus from teaching just technological skills to preservice teachers to how technology can be used most effectively to impact teaching and learning. It provides a succinct framework outlining the knowledge required so that teachers can effectively use technology. Mishra and Koehler's (2006) concept of TPACK and the associated constructs is a huge step in the development of a theoretical framework for effective integration of technology in the teaching and learning process.

TPACK is an all-encompassing framework for all those interested in the use of technology in teaching and learning. As recommended by Niess (2011), teacher educators should provide the necessary technological, pedagogical and content experiences required for developing the knowledge, skills, and dispositions that teachers need in order for them to be able to integrate technology effectively in their teaching. To educational scholars and researchers, she asserted that their duty is to engage in framing and clarifying TPACK and the associated constructs so that teacher educators' emerging questions and concerns can be answered. It is important that the TPACK framework is scrutinized to find out its strengths and weaknesses as a framework. The next sections will take a critical look at the theoretical strengths and weaknesses of the TPACK framework. This theoretical critique is done based on the suggestions of Gess-Newsome (1999) who explained that knowledge organisation, prediction of new knowledge, degree of precision and heuristic power are some of the attributes of a sound theory.

Organisation of TPACK constructs

TPACK has proved to be a useful concept and framework which is being used to impact the integration of technology in the teaching and learning process. It has "inspired teachers, teacher educators, and educational technologists to re-evaluate their knowledge and use of technology in the classroom" (Cox & Graham, 2009, p. 60). Mishra and Koehler's TPACK has been influential due to the organisational integrated structure of the framework. The framework has organised the knowledge required for effective technology integration in a very simplified manner. It is a very useful framework when viewed from how the various constructs have been organized (Archambault & Barnett, 2010).

The organised nature of the TPACK framework may be due to the fact that it is built on an already advanced concept, PCK (Angeli & Valanides, 2009; Archambault & Barnett, 2010; Archambault & Crippen, 2009; Graham, 2011; Harris & Hofer, 2011; Koehler & Mishra, 2005, 2009; Mishra & Koehler, 2006). The depiction of the concept through a Venn diagram brings to light the various components of the framework and therefore guides users as to what they should be on the lookout for. The emphasis on the relationships among the constructs as well as the need to treat the concepts in unison rather than in isolation has influenced many teacher educators as well as educational technologists. Due to its organisation, Graham (2011) recognised that TPACK has a high degree of parsimony and goes on to declare that it is easy to understand TPACK at a surface conceptual level. Though TPACK looks clear, succinct and easy to understand on face value, "the model hides a deep underlying level of complexity, in part because of all the constructs being integrated are broad and ill-defined" (Graham, 2011, p. 1955). Archambault and Barnett (2010) reasoned that TPACK faces the same problem as PCK in that it is difficult to separate out each of the domains and this questions whether the various constructs really exist in practice. It is however worth noting that TPACK seeks to move from the isolation of the constituent knowledge domains. It emphasizes the complex relationships and blending between and among the contributing domains. The complex interactions emphasized by TPACK make the separation and isolation of the constituent constructs difficult. The arduous task that researchers may face in their quest to tease out the constructs was identified by Mishra and Koehler (2006) when they concluded that separating the components of TPACK will be an analytic act which may be difficult to tease out in practice. Nonetheless, the organisational structure of TPACK as well as the uniqueness of each construct has been questioned by researchers (Archambault & Barnett, 2010; Graham, 2011).

Prediction of new knowledge

TPACK has emerged as a new knowledge required for teaching effectively with technology (Chai, Chin, Koh, & Tan, 2013; Chai et al., 2010; Cox & Graham, 2009; Graham et al., 2009; Harris & Hofer, 2011; Harris et al., 2009; H. Lee & Hollebrands, 2008; Niess, 2012; Niess et al., 2009). The TPACK framework has put together almost all the concepts that sought to elicit the knowledge required for effective technology integration in teaching under one concise umbrella. Technological pedagogical content knowledge is the knowledge that underlies meaningful and deeply skilled teaching with technology (Koehler & Mishra, 2008).

TPACK seeks to explain the knowledge required by teachers and educators to effectively use technology in their teaching. It is a framework through which teachers can think about the knowledge required for making instructional decisions that will facilitate effective integration of digital technologies as learning tools in their teaching (Niess, 2011). The practice of teaching one isolated technology course to preservice teachers is gradually fading away and a more blended approach whereby technology, pedagogy and content are treated together has taken over. TPACK therefore indicates how effective integration of technology in teaching is important and for this reason many teacher education programmes and professional development programmes have used it as their theoretical underpinning for their technology focussed projects (Jimoyiannis, 2010). Although teacher educators use TPACK as a framework for effective integrating technology in teaching, they are aware that different teachers take different routes to develop their own TPACK. For example, Koehler and Mishra (2005) used a design course to help facilitate graduate students' TPACK. In this project, the authors organized the students to work collaboratively with faculty members to develop an online course. Students in this project were put in small groups and exposed to a range of different technologies through which they developed an online course. The students in this project used different technologies with reference to the content and the pedagogical approaches they wanted to use to deliver the content.

As another example, in order to develop preservice teachers' TPACK, Niess (2005) and her team integrated technology into their one year teacher education programme for science and mathematics teachers. The student-teachers were taken through problem-based activities that enabled them to learn about different technologies, how to teach and learn with these technologies and the various pedagogical considerations that should go with the selected technology. During the course of the programme, students were expected to plan and teach hands-on lessons by incorporating technology. The course required the students to reflect on their actions and practices. Moreover, the students were expected to incorporate technology in at least one lesson during their microteaching.

Without focusing on the technology and its affordances first, Harris and Hofer (2009) asserted that teachers' TPACK can be developed through a series of technology-enriched learning activity types. They claimed that their approach does not prioritise the affordances of the technology but rather emphasizes the curriculum learning goals and then requires teachers to appropriate technologies to achieve those learning goals. These researchers accentuated that students' learning and appropriation of educational technology are maximized when teachers select technology to suit the learning goals. Harris and Hofer (2009) hypothesised that teachers' TPACK is developed authentically when attention is first paid to curriculum-based learning activities for students. They have therefore developed what they called "Learning activity types." These learning activity types provide the various technologies that can be used to achieve certain classroom activities which teachers and students undertake. Harris and Hofer (2009) reasoned that their learning activity types help to align content, pedagogy and technology in a unique way which helps teachers to develop their TPACK.

Although the above examples of developing TPACK differ from each other, they all agree that content, pedagogy and technology should be treated in unison rather than in isolation and thus subsumes to the central tenet of TPACK. Niess (2012) declared that a different conception of knowledge that draws on technology, pedagogy and content, which is needed for effective teaching, has been promulgated by TPACK. TPACK seems to have provided the much awaited framework for effective teaching with technology since there have not been a unifying conception on how to use technology to teach before its emergence (Archambault & Barnett, 2010; Cox & Graham, 2009; Niess, 2012).

Precise definitions of TPACK constructs

Although TPACK has stimulated research and directed knowledge on effective integration of technology in teaching, definitions of the associated constructs of the framework from literature are "fuzzy, lacking sufficient clarity to give a reader confidence in what the constructs represent" (Graham, 2011, p. 1955). Unclear and ambiguous constructs may lead to the generation of different ideas, inaccurate definitions and explanations. Graham (2011) highlighted that precise definitions are essential for the development of coherent theories. This is because the development and assessment of a construct depends on how precise it is when it comes to its definition (Angeli & Valanides, 2009).

Cox and Graham (2009) in their conceptual analysis of TPACK found two definitions for all the constructs of the TPACK framework. The approaches of conceptual analysis as argued by Cox and Graham (2009) consist of a set of guidelines that can be modified to suit the context of the analysis and which are not guided by any strictly stated rules or procedures. Through five techniques of conceptual analysis- technical use analysis, model cases, contrary and related cases, borderline cases and invented cases- they found an expansive definition and precising definition for the various constructs of TPACK. The expansive definition considers the breadth and complexity of the constructs of TPACK whilst the precise definition seeks to highlight the unique features of the constructs (Cox & Graham, 2009).

Cox (as cited in Graham, 2011) found 89 different definitions for TPCK, 13 for TCK, and 10 for TPK. These differences were not minor as emphasized by Graham (2011) but rather they were major variations which had the tendency to affect the understanding and assessment of the various constructs and the TPACK framework in general. Angeli and Valanides (2009) emphasized that the definition for TCK and TPK are fuzzy which to them depicts a weakness in the framework in terms of its ability to discriminate and accurately categorize knowledge. They concluded that the framework lacks precision. Graham (2011) also mentioned that the difference between TCK and TPK is not clear to many researchers. He noted that many researchers included pedagogical knowledge in TCK even though there is no interaction between PK and TCK as depicted by the Venn diagram of TPACK framework.

Aside from TPCK, TPK and TCK, technology knowledge (TK) is another construct whose definition is nebulous. Its definition mainly centres on what the author thinks constitutes technology. Consequently, different researchers define technology differently. Whilst some look at just the tools others consider both tools and processes, others also even differ in their categorisation of ‘old’ and ‘new’ technologies. McCrory (2008) for instance claimed that technology is broadly defined to include tools or techniques used for practical purposes. Koehler and Mishra (2008) recognised that all the “tools created by human knowledge of how to combine resources to produce desired products, to solve problems, fulfil needs, or satisfy wants” can be classified as technology. It is the tools with which we deliver content and implement practices in better ways as reasoned by Earle (2002). In its broadest sense, technology is not only the tools but the knowledge and processes used by humans to solve their everyday problems.

Thus the lack of clarity in defining what is meant by technology is problematic for TPACK framework. In order to make the definition of technological knowledge explicit in their research, some have tried to indicate what they mean by technology by identifying a particular “flavour” of TPACK (Graham, 2011). These researchers sought to make it easier for readers to identify what technology was under scrutiny. M.-H. Lee and Tsai (2010) talked about TPACK-W when they tried to find out how teachers used the World Wide Web in their instruction and their attitudes toward Web-based instruction. In their quest to indicate what they meant by technology and to explicitly express their focus, Angeli and Valanides (2009) propounded ICT-TPCK. They posited that “ICT-TPCK’s constituent knowledge bases include TPCK’s three contributing knowledge bases, namely, subject matter knowledge, pedagogical knowledge, and technology (restricted to ICT in this case)” (p. 158). Their emphasis was on Information and Communication Technology. Though they highlighted the addition of two elements -knowledge of students and knowledge of the context within which learning takes place- (Angeli & Valanides, 2009) to the original TPACK framework, a careful and critical look indicates that these two elements are not new to TPACK. Geographical TPACK (G-TPACK) was proposed by Doering and Veletsianos (2008). They claimed that the use of geospatial technologies will not be successful until teachers are exposed to G-TPACK. The authors used geospatial technologies in their study yet they are proposing geographical TPACK. It is difficult to decipher whether they are putting every technology that can be used in the teaching of geography under one umbrella or not.

The idea of distinguishing TPACK by explicitly indicating the technology being used in the framework seems appropriate superficially. However, one wonders the number of TPACKs we will have if all the available technologies and those yet to come are added to the TPACK name. It therefore sounds plausible that researchers can define the technology being used without necessarily indicating the technology they are referring to the in TPACK acronym. Koehler and Mishra (2008) did not distinguish between old and new technologies. However if such a view is assumed, then every act of teaching encompasses TPACK and that every teacher no matter what tool he or she is using should have TPACK. This is because it is impossible to teach without a tool, be it whiteboard, marker, chalk or book. These tools are in themselves technology and were once considered as breakthrough inventions. Cox and Graham (2009) explained that such technologies have become commonplace such that they are not considered as technology anymore and that they have become transparent. They therefore differentiated between transparent technologies and emerging technologies. To them, technological knowledge in the TPACK framework should be about the ability to use these emerging technologies. They believed that by restricting their meaning of technology to emerging technologies, the focus could be placed on technologies that are not yet transparent.

This differentiation by Cox and Graham (2009) is an excellent way to comprehend the technological knowledge in TPACK. If authors and researchers in TPACK can take such a simplistic yet overarching view, there would not be any confusion in and about research on TPACK. The use of technology in the current research is modelled around Cox and Graham’s (2009) view of technology. Thus, ‘technology’ in this research is restricted to digital technologies or emerging technologies.

Heuristic nature of TPACK

In addition to the above mentioned criticisms, the heuristic nature of TPACK has also come under discussion. The heuristic value of any model, as suggested by Gess-Newsome (1999), is judged by its capacity to predict missing knowledge, to acknowledge gaps in the model as well as the potential of the model to supply explanations for similar data. She proposed a continuum of teacher knowledge to examine the heuristic value of PCK. These were transformative and integrative models. The integrative model views PCK as not existing as a unique body of knowledge and that teaching becomes an act of integrating knowledge across the three domains. The transformative model however sees PCK as the synthesis of all knowledge required for effective teaching (Gess-Newsome, 1999). Table 1depicts how Gess-Newsome (1999) summarised integrative and transformative views of teacher cognition of PCK.

Table 1: Summary of Integrative and Transformative models of Teacher Cognition

	Integrative Model	Transformative Model
Knowledge domains	Knowledge of subject matter, pedagogy, and context are developed separately and integrated in the act of teaching.	Knowledge of subject matter, pedagogy, and context, whether developed separately or integratively, are transformed into PCK.
Teaching expertise	Teachers are fluid in the active integration of knowledge bases for each topic.	Teachers possess PCK for all topics taught.
Implications for teacher preparation	Knowledge bases can be taught separately.	Knowledge bases are best taught in an integrated fashion.

Thus, the transformative view sees PCK as a unique body of knowledge required for effective teaching whilst the integrative view does not see PCK as existing separately and as a unique body of knowledge.

Since TPACK is an extension of PCK, it is not far-fetched that researchers have extended these models to TPACK. Angeli and Valanides (2009) and (Graham, 2011) agreed that it is important that TPACK researchers understand whether the constructs in TPACK are transformative or integrative since such knowledge is critical to the establishment of construct validity for instruments that seek to measure TPACK. Again, such understanding will direct how TPACK is developed in preservice teachers.

The integrative model of TPACK does not view TPACK as a distinct and unique body of knowledge that exist independently (Angeli & Valanides, 2009; Graham, 2011). In this view, teachers teaching with technology will have to draw on knowledge from the three bases of the TPACK framework i.e. technology, pedagogy and content. The teacher who wants to teach effectively with technology therefore must be able to appropriately select and draw upon the knowledge bases of their technological skills, content knowledge and pedagogical knowledge. Teaching in this approach "depends upon the presentation of content to students in some context using an appropriate form of instruction" (Gess-Newsome, 1999, p. 11). Effective teaching with technology based on this approach means the teacher should have requisite, well-organized knowledge in technology, content and pedagogy. The teacher's knowledge in these constructs should be flexible such that they can easily draw upon them during teaching. An expert teacher in this approach will be able to move from one knowledge base to the next seamlessly which will give an appearance of a single knowledge base for teaching (Gess-Newsome, 1999). Thus, the teacher combines technology, pedagogy and content knowledge during teaching (Chai et al., 2010).

The transformative view however sees TPACK as a unique body of knowledge required for effective teaching with technology (Angeli & Valanides, 2009; Graham, 2011). "It recognizes the value of a synthesized knowledge base for teaching" (Gess-Newsome, 1999, p. 12) effectively with technology. In this approach, technology, pedagogy and content knowledge are unexpressed resources for a teacher and they become useful for effective teaching only when they are transformed into TPACK. Thus, to be able to teach effectively with technology, a teacher must demonstrate characteristics of high level of TPACK.

The problem with TPACK's heuristic value stems from the fact that "most researchers have skirted the transformative versus integrative issue by measuring TPACK as if it were another name for technology integration without making reference to the other elements in the model" (Graham, 2011, p. 1957). This has brought different approaches to measuring TPACK. Some researchers measure it as if it were an integrative model whereby TPACK is not considered as a unique body of knowledge whilst others do it in the transformative way in which TPACK is seen as a unique body of knowledge that teachers should demonstrate. Though most researchers in the TPACK arena do not overtly indicate whether they are for one model, their approach shows how they view TPACK.

Graham (2011) accentuated that the use of a Venn diagram to depict TPACK expresses an intergrative model, however the language used by Mishra and Koehler (2006) reflected a transformative approach to the constructs. Moreover, Koehler et al. (2007) in their work *Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology* sought to develop the TPACK of teachers. However their questions concentrated on the contributing constructs without asking specific questions related to TPCK. They discussed and inferred the presence of TPCK from these contributing constructs. Thus, though they discussed TPACK as a unique body of knowledge their measurement depicted an integrative model (Angeli & Valanides, 2009). Guzey and Roehrig (2009) and

Mouza and Wong (2009) also measured TK, PK, and CK and used the evidence to project the existence of TPCK. These researchers inferred the presence of TPCK from the existence of the contributing constructs. Thus, they did not treat TPACK as existing as a unique body of knowledge but rather as a knowledge construct that is derived from its constituent constructs.

Other researches (Archambault & Crippen, 2009; Chai et al., 2013; Chai et al., 2010; Graham et al., 2009; Koh, Chai, & Tsai, 2010; M.-H. Lee & Tsai, 2010; Polly, 2011; Schmidt et al., 2009; Shin et al., 2009) treated TPACK as a unique body of knowledge and thereby followed the transformative approach. These researches sought to develop and/or measure TPACK as a unique body of knowledge so the authors drafted specific questions and hypotheses to solicit knowledge on TPACK. Although these researchers measured TPACK as a unique body, it should be noted that different authors chose which of the other six constructs of the TPACK framework they wanted to measure depending on their research focus. The underlying and common factor was the fact that they did not measure the contributing constructs (content, technology, pedagogy) and used the outcome to predict and infer the presence of TPACK. They treated TPACK as a distinct knowledge and therefore specifically measured and/or developed it which therefore depicted a transformative model of TPACK.

Interestingly, most TPACK researchers have avoided the integrative-transformative argument (Graham, 2011) which has led to few research studies having been conducted to find out whether TPACK is either integrative or transformative in nature. It seems most researchers, as noticed by Angeli and Valanides (2009), assumed that growth in the any of the three (content, pedagogy, technology) knowledge bases gives rise to growth in TPACK. In order to find out whether TPACK is transformative or integrative, Angeli and Valanides (Angeli, 2005; Angeli & Valanides, 2005; Valanides & Angeli, 2006, 2008) tested whether growth in any of the three knowledge bases of TPACK lead to automatic growth in TPACK.

They worked with both preservice and inservice teachers and realized that teachers teach better with technology when they are specifically instructed on how to teach with technology. They underscored that teacher educators need to specifically teach preservice teachers how the affordances of technology affect their teaching. Angeli and Valanides (2009) insisted that their findings acknowledged that TPACK does not develop without specific instruction targeting its development and that technology, content and pedagogy are contributing knowledge in which development in one or all of them does not yield to growth in TPACK. They therefore concluded that TPACK is a unique body of knowledge and that their research supported the transformative model.

Current research therefore seems to favour the transformative view rather than the integrative view of TPACK. This supports the view that the constructs in the TPACK framework are intricately interconnected to form an amalgam of a unique body of knowledge (Graham et al., 2009; Koehler & Mishra, 2008; Niess, 2008). Again, the argument that technological skills alone are not enough to enable one to teach effectively with technology (Angeli & Valanides, 2009; Graham et al., 2009; Kereluik et al., 2011) is supported by the transformative model. Notwithstanding the support the transformative view has from current literature, it is evident that one can never have the knowledge about all technology at any given point in time. Again, technology keeps changing so having a fixed body of knowledge means that at a point in time that knowledge may become obsolete. Thus, more research may be needed with regards to the integrative-transformative argument.

Although the focus of this research is not to investigate whether TPACK is integrative or transformative as a framework, a critique of the framework in that direction is appropriate for this study. This will help guide the study and facilitate the selection of the appropriate measurement methods. This research project which is the subject of this thesis treats TPACK as a unique body of knowledge with unique contributing constructs- transformative view. The aim of this study is to measure New Zealand high school science teachers' TPACK. An effort is being made to find out how the teachers perceive their understanding of the various constructs, find out if the constructs correlate with each other and find out which of the constructs contribute more to the TPACK construct. Moreover, this study investigates how contexts influence how teachers' appropriate the affordances of technology in their classes as well as how they use their TPACK in different circumstances. The next section takes a look at how TPACK has been measured since it came into existence.

Measuring TPACK

Since TPACK's inception and acceptance as a framework (Koehler & Mishra, 2005; Mishra & Koehler, 2006), there has been a burgeoning interest in measuring teachers' (both preservice and inservice) TPACK (Chai et al., 2010). Various researches have been conducted to assess teachers' TPACK. Koehler, Shin, and Mishra (2012) identified 303 articles, papers and dissertations that used, mentioned or measured TPACK in their work *How do we measure TPACK? Let me count the ways*. Voogt et al.'s (2013) literature search produced 243 articles and papers on TPACK in their literature review on TPACK. Most of these research studies were conducted in the U.S. as opined by Koh et al. (2010) with Chai et al. (2010), Chai et al. (2011), Chai et al. (2013), Koh et al. (2010), Koh and Divaharan (2011) and M.-H. Lee and Tsai (2010), having done some work on TPACK in Singapore. The following section presents some of the research that has been conducted in the TPACK arena.

Through a learning by design approach Koehler and Mishra (2005) sought to find out the TPACK of four faculty members and 13 students. The participants worked collaboratively to design an online course and in the process completed surveys developed by the researchers. They focussed on how participants' thinking about technology changed after the course. The researchers concluded that the learning by design approach helped the participants to develop the spectrum of knowledge suggested by the TPACK framework. The drawback of this study was the use of few questions (not more than two questions) to solicit information on the various constructs of TPACK. Again, the sample size of 17 was a little on the low side. Nonetheless, this research paved the way and set the agenda for other more rigorous research on TPACK. In another study, Koehler et al. (2007) used both quantitative and qualitative analyses of two groups that underwent the design of online courses to show that the participants moved from considering the individuality of technology, content and pedagogy into thinking about them as being very connected. Thus, at the end of the course the researchers reported that their participants had improved considerably on the various constructs of TPACK. Harris and Hofer (2011) also reported that seven social studies teachers had their standards for technology integration being raised after participating in the TPACK-oriented professional development programme. The teachers developed the ability to select learning activities and technologies and became more conscious and strategic after the programme.

Archambault and Crippen (2009) surveyed online teachers to examine their knowledge levels with respect to the domains of the TPACK framework. They found that the teachers had increased knowledge levels in the areas of pedagogy, content and pedagogical content. Further correlation analysis showed that there were large correlations among pedagogy and content (.690), technological content and technological pedagogy (.743) and technological pedagogical content and both technological pedagogy (.787) and technological content (.733). Archambault and Crippen (2009) argued that the correlation among the domains brought into question the distinctiveness of the domains. However, the TPACK framework seems to emphasize the intersection and the interconnectedness of the constructs. Thus, Archambault and Crippen's (2009) study rather supported the idea that the constructs are related and should not be isolated. A regression analysis would have helped to bring out the contribution each of the construct makes towards the TPACK of teachers.

Shin et al. (2009) used a one-group pretest-posttest design to identify how teachers understood the relationship between technology, content, and pedagogy after an educational technology course. They concluded that their results showed that the teachers' understanding of the relationship between technology and content, that of technology and pedagogy as well as that of technology, pedagogy and content improved over time. There were increases in participants' mean scores on the various constructs after the course.

Graham et al. (2009) sought to measure the TPACK confidence of inservice science teachers by focussing on four (TPCK, TPK, TCK and TK) constructs of the framework. Their study assessed 15 teachers on these constructs before and after they participated in a professional development programme. They insisted that the participants started and ended the programme with a higher confidence in TK, TPK, TPCK and TCK in decreasing order. They reported that their study showed that one needed to have the basics of technological knowhow before the other constructs can be developed. Abbitt (2011a) sought to identify the relationship between preservice self-efficacy beliefs about technology integration and their TPACK and realized that knowledge in the TPACK domains contribute significantly to self-efficacy beliefs.

Chai et al. (2010) however did a regression analysis in a study in Singapore where they assessed the TPACK of preservice teachers who went through an ICT course. The course focused on the students' pedagogical knowledge (PK), technological knowledge (TK) and TPCK. The participants were assessed before and after the delivery of the course. The participants in this study rated themselves slightly above average in terms of TK, PK, CK and TPCK before they underwent the ICT course. T-tests conducted after the study showed that there had been significant increases in how the participants rated their abilities in the TPACK constructs that were being measured. The study also found that TPCK was positively correlated with TK and PK for both the pre and post course surveys with PK having the strongest correlation in both pre and post course surveys. Further stepwise regression analyses revealed that TK, PK, and CK contributed significantly to TPCK in both pre and post course surveys with PK accounting for more than half of the total variance.

Chai et al. (2010) did not look at the intersecting constructs of TCK, PCK and TPK. They sought to measure only the general constructs of TK, PK and CK and how they predict TPCK. They seemed to have relegated the importance of the other constructs (TCK, PCK TPK) to the background and downplayed their relative role in the development of TPACK. It would have been interesting to see how much contribution the other constructs will make to TPACK. Again, it was not surprising that they found PK accounting or contributing more to TPCK when they did the regression analysis in the post course survey. Since the participants' PK was already high before the study, one stands to wonder whether their programme was effective because the PK which was already high among the participants happened to be the highest contributor to the TPCK at the end of the study.

Chai et al. (2011) improved upon the study of Chai et al. (2010) by adding all the other intersecting constructs to the framework. However, their factor analysis yielded only five factors (TK, PK, CK, TPK and TPCK). They however sought to find out which of the constructs (TK, PK, CK and TPK) predicted TPCK the most. They realised that of all the four constructs, TPK made the most significant prediction of TPCK. This happened in both the pre and post course analysis.

In New Zealand, Nordin et al. (2011) examined preservice teachers TPACK before, during and after their field experience (teaching practice or practicum) and found out that these preservice teachers understanding of the TPACK concepts developed throughout their field experience. Otrel-Cass et al. (2012) unpacked two science teachers' TPACK when the teachers used digital videos to scaffold their students' learning. The researchers used video and audio recordings of lessons, field notes, and teacher and student interviews to illustrate the teachers' ICT-TPACK. They noted that their observations provided evidence of how teachers' ICT-TPACK was exemplified when they used digital videos to teach science. Otrel-Cass et al. (2012) concluded that teachers in their study provided a variety of scaffolds for their students when they drew on their ICT-TPACK through which they considered content, pedagogy and technology as opportunities to maximize their teaching and students' learning.

Pamuk, Ergun, Cakir, Yilmaz, and Ayas (2013) developed a TPACK instrument and used it to explore the relationships among the constructs of TPACK in Turkey. Using over 800 preservice teachers in different programmes (elementary education, science education, mathematics education, social studies and instructional technology), they assessed the relationships among the various TPACK constructs. Their research stressed that although all the six constructs correlated with TPACK, it was TCK and TPK that had strong effects on TPACK with the effect of TCK slightly higher than that of TPK. They showed that the core knowledge bases of TK, PK, and CK had no direct effects on the development of TPACK. Pamuk et al. (2013) concluded that "although core knowledge bases have effect on TPACK, these are mostly indirect effects" (p.14).

Horzum (2013) sought to find which construct (TK, TCK, and TPK) predicted 239 preservice teachers' TPACK. The students were taken through an instructional technology and material development course. In the pre-instructional analysis, Horzum (2013) noticed that TCK and TPK made significant contributions to TPACK and accounted for more than 70% of the variance in TPACK. After the course, TK, TCK and TPK accounted for 82% of the variance in TPACK with TCK and TPK making significant contributions to TPACK. TK was found to have modest impact on TPACK.

Niess, Sadri and Lee (as cited in Niess, 2012; Niess et al., 2009) announced that teachers progressed through different levels of TPACK in the course of their teaching with technology or learning to integrate technology in their teaching. They therefore categorized TPACK into five different levels based on Roger's model of innovation-decision process: *recognizing*, *accepting*, *adapting*, *exploring* and *advancing*. Niess (2012, p. 6) defined the various levels as:

1. *Recognizing* (knowledge), where teachers are able to use the technology and recognize the alignment of the technology with the content yet do not integrate the technology in their teaching and learning of the subject.
2. *Accepting* (persuasion), where teachers form a favourable or unfavourable attitude toward teaching and learning the content with an appropriate technology.
3. *Adapting* (decision), where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics with an appropriate technology.
4. *Exploring* (implementation), where teachers actively integrate teaching and learning of mathematics with an appropriate technology.
5. *Advancing* (confirmation), where teachers evaluate the results of the decision to integrate teaching and learning mathematics with an appropriate technology.

Teachers at the *recognizing* level consider technology as a low level tool for learning the subject matter and seldom incorporate technology in their teaching; teachers who do not consistently consider how technology might influence and support their teaching although they practice with technology are at the *accepting* level; at the *adapting* level, teachers incorporate technology in their teaching but only allow students to use technology for low-level thinking activities which are very much teacher directed; teachers are more ready to allow students to explore with technology through student centred approaches and demonstrate different ways of teaching the concepts with technology at the *exploring* level;

when teachers purposefully encourage students to use technology and willingly use technology to develop the content ideas then they are at the *advancing* level (Niess, 2012).

In an effort to find the impact of an online course, Niess et al. (2010) used the TPACK levels model to depict how science/mathematics teachers used spreadsheet in their teaching. Through observations of teaching episodes of participants, transcripts of interviews and online course discussions they categorized each of the 12 participants into one of the five levels of TPACK. Eight of the participants were at the *accepting* level, two at the *adapting* level, and two were moving into the *exploring* level. Niess et al. (2010) accentuated that the two teachers at the *exploring* level exhibited student centred teaching strategies which enabled their students to be engaged with their learning. The teachers at the *adapting* level used teacher centred strategies and were more concerned about meeting curricular and grade-level needs. "Teachers at the adapting level exhibited a more cautious outlook on trying ideas with their students"(Niess et al., 2010, p. 46). The teachers at the *accepting* level were committed to their teacher directedness approach of teaching and used technology to confirm already learned concepts. Niess et al. (2010) asserted that teachers at *adapting* and *exploring* levels provided students with opportunities to work with technology which invariably led to students having stronger conceptual understanding of the content whereas those at the *accepting* level were interesting in teaching the content through traditional approaches first before adding technology as a related activity.

Teachers' conceptualizations and comprehensions even as they integrate technology through the understandings of the TPACK framework are portrayed by the levels of TPACK (Niess, 2012). Although these TPACK levels are progressive they are not linear and moving from one level to the other does not display an increasing regular consistent pattern (Niess et al., 2009). The development of TPACK should therefore be seen as a dynamic and fluid process (Niess, 2012) and that teachers TPACK levels are susceptible to be affected even as they are “confronted with different content classes, different technologies, varying availability of technologies, different students, and other contexts within which they implement technologies” (Niess et al., 2010). Thus, it is appropriate that the context(s) within which teachers integrate technology into their teaching are explored.

Though there has been a lot of work done on TPACK and the related constructs, the available research has largely ignored the specific contexts within which teachers apply technology. There are some examples of context related research that looked at the TPACK of teachers teaching a specific subject. For example, Archambault and Crippen (2009) looked at the TPACK of online educators; Akkoç (2011) looked at TPACK of mathematics teachers; the geo-spatial group of Doering, Scharber, Miller, and Veletsianos (2009) used TPACK as their framework to teach geography. Graham et al. (2009) looked at the TPACK of science teachers. However, most of these research projects sought to measure the constructs of TPACK. Although Law (2009) reported that teachers’ pedagogical practices and how they use technology may be affected by contextual factors, there is little previous research that has considered the conditional knowledge of TPACK that teachers employ in their teaching based on the needs of the learning context. The contextual subtleties for teaching and learning differ from country to country, school to school and to some extent class to class. One of the aims of this research was to find out how context affects teachers use of technology and their TPACK level. Specifically, the demands of content as depicted in the junior and senior levels of New Zealand high school was the focus.

While there is a general consensus about the TPACK framework being helpful for thinking about technology integration (Archambault & Crippen, 2009; Koehler & Mishra, 2005; Koehler et al., 2007), there is no consensus as to how the various constructs are related and how much each contribute to the framework. Again, there seems to be little research on TPACK in New Zealand and the available ones (Nordin et al., 2011) were conducted on preservice teachers and did not include inservice teachers. Neither was it done with science teachers specifically. The other TPACK research in New Zealand (Otrel-Cass et al., 2012) used only two teachers as their participants. My study sought to examine New Zealand's science teachers' TPACK. In so doing, a survey instrument was validated in the New Zealand context as well as used for investigating the relationship among the constructs of the TPACK framework. Moreover, teachers were interviewed and observed during their teaching to find out the reasons behind their use of technology and the role the technology played in their teaching.

Summary of the literature review

Technological Pedagogical Content Knowledge (TPACK) framework has been promulgated to solve the lack of a unifying concept in the quest to teach with technology (Archambault & Barnett, 2010). The framework as theorized by (Koehler & Mishra, 2005; Mishra & Koehler, 2006) is an extension of Shulman's (1986) concept of pedagogical content knowledge, which identifies the distinctive features of knowledge for teaching. The TPACK framework has seven constructs set within the contexts of education: technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPCK). Each of the seven constructs was defined.

The definition for Technological Knowledge (TK) in the literature was found to be difficult as noted by (Harris et al., 2009). Some researchers argued that TK should be limited to digital and emerging technologies (Cox & Graham, 2009) others as (Koehler & Mishra, 2005; Koehler et al., 2007; Mishra & Koehler, 2006) defined TK to include both old and new technologies such as black board, chalk, internet and computers as internet and video conferencing. This research agreed with the digital and emerging technologies definition.

Teachers Pedagogical Knowledge (PK) was theorised to include their understanding of the underlying philosophy and approaches to classroom management and organization (Shulman, 1987). It included the knowledge of the nature of teaching and learning (Abbitt, 2011a) as well as the skills, beliefs and conceptions about teaching (Grossman, 1990). The ability to comprehend the concepts, frameworks, and processes in a given field constituted teachers' Content Knowledge (CK).

The TPACK framework as proposed by (Koehler & Mishra, 2005; Mishra & Koehler, 2006) laid emphasis on the intersecting constructs between TK, PK, and CK which led to the formation of PCK, TCK, TPK and TPCK. Teachers' pedagogical and content knowledge are inextricably linked and amalgamated to form Pedagogical Content Knowledge (PCK) in the TPACK framework. PCK goes beyond just pedagogy and content. It looks at how these two relate and interact for effective teaching. PCK depicts the manner in which the content can be represented and formulated to make it comprehensible to others (Shulman, 1986). Technological Content Knowledge (TCK) is the ability to determine how the content a teacher wants to teach is affected by affordances of technology and vice versa. It is the knowledge of how to utilize an emerging technology to represent specific concepts in a given content domain (Cox & Graham, 2009). Technological Pedagogical Knowledge (TPK) deals with the ability to realise how technology affects the methods and strategies of teaching and how effective teaching and learning can be achieved with technology. The final construct of the framework, TPCK, is the understanding that emerges from the interactions and interplays between and among technology, content and pedagogical knowledge that underlies meaningful teaching with technology (Koehler & Mishra, 2009). The TPACK framework advocates the treatment of the various constructs in unison rather than in isolation. The constructs are intertwined and interwoven and therefore it is not sufficient for preservice teachers to just learn about technology, content or pedagogy alone and independently of each other.

Although a lot of research has been conducted with TPACK as the framework (Voogt et al., 2013), a critique of the theoretical underpinnings of the framework was conducted by Graham (2011). He noted that TPACK looks clear and simple on the surface but hides a deep level of complexity. This has led to some researchers questioning the uniqueness of the various constructs of the framework (Archambault & Barnett, 2010; Graham, 2011). Although some of the constructs within the TPACK framework lack clarity as far as their definitions are concerned (Graham, 2011), TPACK has still been able to explain the knowledge required by teachers and educators to effectively use technology in their teaching and has evolved as the knowledge required for effective teaching with technology (Chai et al., 2013; Cox & Graham, 2009; Niess, 2012). The literature on TPACK seems to suggest a transformative model as opposed to an integrative one (Angeli & Valanides, 2009) which therefore supports the view that TPACK is a unique body of knowledge which should be developed for effective teaching.

The development, use and application of TPACK have been seen to be in levels as predicted by (Niess, 2012; Niess et al., 2009; Niess et al., 2010). They indicated that the levels are *recognizing, accepting, adapting, exploring* and *advancing* levels of TPACK. Each level has certain characteristics that teachers operating at that level depict and demonstrate when it comes to the use of technology in teaching. Due to the dynamic nature and the influence of contextual factors on TPACK, teachers' levels of TPACK may shift and change depending on the circumstances within which they find themselves as far as teaching with technology is concerned (Niess et al., 2010).

The literature review has brought to fore the burgeoning interest in TPACK since its inception. There has been a range of research on TPACK that uses different methodological approaches. Koehler et al. (2012) and Voogt et al. (2013) counted over 200 research studies that mentioned, measured or used TPACK as the framework. Some of this research sought to measure preservice teachers' TPACK (Chai, 2010; Chai et al., 2011; Horzum, 2013) whilst others used inservice teachers (Graham et al., 2009). The studies that sought to predict TPACK found out that of all the constructs it was TPK and TCK that made significant contribution to the development of TPACK (Chai et al., 2011; Horzum, 2013; Pamuk et al., 2013). The researchers noted that the development of TPACK should be considered as a blend whereby emphasis is placed on the relationships among the various constructs rather than treating the basic constructs of TK, PK, and CK in isolation.

Although a burgeoning interest in TPACK was noted, only two studies, Nordin et al. (2011) and Otrel-Cass et al. (2012) were found to have been conducted on TPACK in New Zealand. The former study was conducted on preservice teachers whilst the latter was on two science teachers. Thus, the need for research on investigating teachers' TPACK in New Zealand was identified. In addition, I identified a gap in definite research on the contextual factors that affect the application of teachers' TPACK in practice even though researchers have speculated that TPACK is influenced by contextual factors. This study therefore sought to fill that gap in the literature as far as TPACK for science teachers is concerned.

CHAPTER 3

METHODOLOGY

This chapter describes the design that was employed for this study, the participants and how they were selected. The instruments used for the study, data collection procedure as well as how the data were analysed have been presented.

Research Design

The aim of this research was twofold. First, the study sought to assess and measure New Zealand's high school science teachers' perception of their understanding of TPACK framework and its related constructs and thus have a baseline data on the levels of TPACK of science teachers in New Zealand since not much research has been conducted on TPACK in New Zealand. The second aim of the research was finding out how science teachers used technology in different contexts and how they adapted technology in their teaching in general. The first aim required a quantitative approach whereby data is generated from a large sample whilst the second aim needed an in-depth observation and interview of the actual practices of what science teachers did with technology in their classrooms. Thus, some data collected were quantitative in nature whilst others were qualitative.

Since the research required both quantitative and qualitative data, a mixed methods approach (Creswell, 2008; Yin, 2009) was employed in this study. This approach helped to bring to light New Zealand's high school science teachers' perception of their understanding of TPACK as well as how they used technology in the different contexts they taught. The mixed method approach combines both quantitative and qualitative approaches through the collection and analysis of both qualitative and quantitative data and mixes the two forms of data (Creswell & Plano Clark, 2011) and therefore helps to provide a comprehensive analysis of the topic under discussion (Creswell, 2008). The mixed methods approach helps to answer questions that cannot be answered by only quantitative or qualitative approaches alone (Creswell & Plano Clark, 2011).

Convergent parallel design, explanatory sequential design, exploratory sequential design, embedded design, transformative design and multiphase design are the six major mixed methods designs advocated by Creswell and Plano Clark (2011). They urged researchers to use a design that is best suited to their research problem. They recommended that their classifications provide a framework that can guide the researcher in selecting the appropriate research methods which will yield a high quality and rigorous research design.

The convergent parallel design was employed in this study because there was the need for complementary quantitative and qualitative results which will lead to a better understanding of science teachers' TPACK and how different contexts influence science teachers' use of technology. The different methods were prioritized equally, the strands were kept independently during analysis and then the results were mixed during interpretation as suggested by Creswell and Plano Clark (2011).

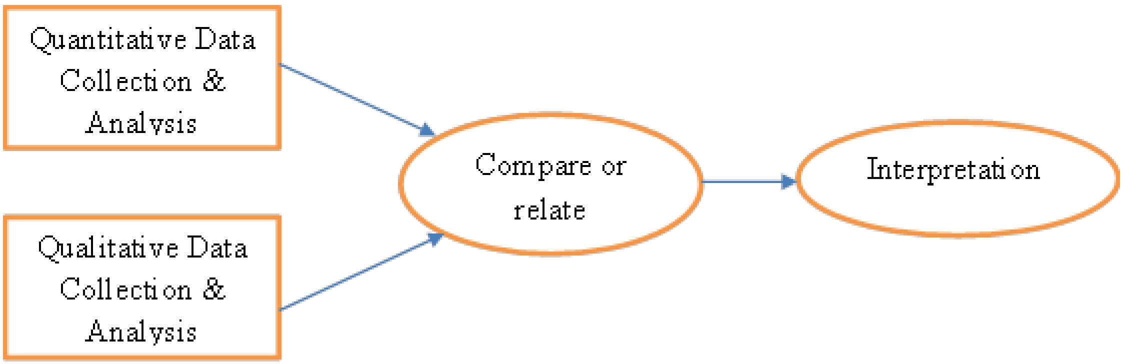

Figure 2: Convergent parallel design (Creswell & Plano Clark, 2011).

The mixed methods approach falls under the pragmatism paradigm (Fraenkel, Wallen, & Hyun, 2012; Gray, 2009) which holds the view that knowledge is constructed based on the realities of our experience in the world as well as being socially constructed (Gray, 2009). This worldview is different from the positivists' who believe that knowledge is objective and outside the world of the researcher and also different from the interpretivists' who opine that knowledge is basically constructed. The pragmatic worldview takes a midway between the two extreme worldviews of quantitative and qualitative paradigms. Pragmatists believe that the duty of the researcher is to use whatever works (within the realms of academic rigor and appropriateness) to conduct their research (Fraenkel et al., 2012) which therefore presupposes that the researcher should look out for methods that will help them answer their research question(s) rather than being dogmatic (Fraenkel et al., 2012; Gray, 2009).

The use of the mixed methods for evaluating TPACK was sanctioned by Shin et al. (2009) who suggested that triangulated methods which contain observations, interviews and questionnaires should be used to assess teachers' TPACK. This is because the mixed methods approach broadens the understanding of a phenomenon (Creswell, 2009). Moreover, mixed methods provide the opportunity to use one approach to explain and/or better understand the outcomes of the other approach. Thus, both TPACK of science teachers were assessed and contexts which influence their use of technology were explored. This was done because the TPACK model posits that different contexts potentially influence how technology is used (Abbitt, 2011b; Koehler & Mishra, 2005).

Quantitative approach

The quantitative aspect of the study was achieved through the use of an online survey to collect data to identify teachers' perception of their understanding of the various constructs of the TPACK framework (Appendix 5). A survey was used because surveys are able to assist "gather data at a particular point in time with the intention of describing the nature of existing conditions, or identifying standards against which existing conditions can be compared, or determining the relationships that exist between specific events" (Cohen, Manion, & Morrison, 2007, p. 169). Surveys have been found to have the ability to provide an opportunity to reach a large sample size which increases the generalization of the findings. They also provide an opportunity for the participants to respond to the items on the survey in a place and time convenient to them as well as producing responses that are easy to code (Gray, 2004). There is greater anonymity associated with surveys. They also provide consistent and uniform measures and respondents are not affected by the presence and or attitudes of the researcher (Sarantakos, 2013). They are also capable of providing descriptive, inferential and explanatory information that can be used to ascertain correlations and relationships between the items and themes of the survey (Cohen et al., 2007).

On the other hand, surveys also have their own deficiencies among which are the inability to ask probing questions as well as seek clarifications, inability to determine the conditions under which the respondent responded to the questionnaire items as well the ability to generate high unresponsive rate (Sarantakos, 2013).

Despite the weakness, it was considered that the strengths of gaining many teachers' responses far outweighed the weaknesses in this study; hence the survey was considered an appropriate design for the quantitative aspect of the research. An online survey was therefore used in an attempt to reach as many as possible high school science teachers to participate in the study; generate data that can describe and help draw inferences with regards to New Zealand's high school science teachers' perception of their understanding of technological, pedagogical and content knowledge framework.

Instrumentation

Instruments are tools used to collect data and for the survey of this study the questionnaire was deemed the appropriate data collection tool. The questionnaire was developed as an online questionnaire because the survey was conducted via the internet. The development and validation process of the online questionnaire will be found in the subsequent sections.

Online Survey

An online questionnaire was developed based on the seven constructs of the TPACK framework (Koehler & Mishra, 2005, 2008; Mishra & Koehler, 2006) to form the instrument for data collection for the quantitative part of the study. The items on the online questionnaire were adopted and adapted from Archambault and Crippen (2009); Graham et al. (2009); Sahin (2011) and Schmidt et al. (2009) surveys for assessing TPACK. This was done because Punch (2009) suggested that for a complex and multidimensional variable, it is appropriate to use an existing instrument if one exists. However, the items on these surveys were not used without due critique and evaluation. Some items were modified to suit the focus of the research whilst others were used as was found in the original text of the authors.

Notably missing from the list of surveys that guided the development of the questionnaire for this study is Koehler and Mishra (2005) survey. Since they are the proponents of the TPACK framework, one would assume that their survey should be the model for researchers when it comes to the development of TPACK surveys. However, their survey had a sample size of 15 which is considered to be too small for rigorous statistical analysis. Due to the small sample size they did not take the instrument through construct validation. Their survey sought to find out views of participants who underwent a specific course which the authors were in charge (Schmidt et al., 2009). Moreover, the survey did not try to measure participants TPACK per se but it sought to look at how participants' knowledge has evolved as far as TPACK was concerned. Again, the instrument did not have items targeted at all the seven constructs of TPACK. Thus it was very difficult to generalize the findings with such an instrument. The items on their questionnaire were therefore not included when it came to finding items to help develop a TPACK questionnaire for this study.

On the contrary, the surveys with the exception of Graham et al. (2009) from which items were selected for this study used a large sample (above 150). Archambault and Crippen (2009); Sahin (2011) and Schmidt et al. (2009) also took the items through construct validation. Construct validity seeks to make sure that the instrument is measuring the construct which it purports to measure. With regards to internal consistencies, these questionnaires had reliability coefficients of 0.7 and above for the various constructs of the TPACK framework. Reliability seeks to determine how measures will yield consistent results over time. Internal consistency reliability is performed to find out how the items on a survey are related to each other. This gives an indication of how much the items are measuring the same construct. Thus, reliability values of 0.7 and above indicate that the items on the survey were fairly reliable. Moreover, the authors with the exception of (Graham et al., 2009) developed items on all the seven constructs of TPACK the items were grouped based on the various constructs on the TPACK model. Items from Graham et al. (2009) survey did not capture all the seven constructs but were used because their study was directed at science teachers and therefore served as a very good model for this study since this study was also in science. The survey of Graham et al. (2009) specifically looked into inservice science teachers' TPACK confidence. The items were geared towards teachers who were teaching science. Items on this survey were therefore constructed to elicit information from science teachers. It was therefore useful to use this survey as a guide to the development of the questionnaire for this study since this study also tried to look at science teachers' TPACK.

The items on the various constructs of the TPACK framework from the above - mentioned surveys were therefore pooled. Most of the items were selected without any modification but few were modified to suit this research. For example, a generic item 'use digital technologies that allow scientists to observe things that would be otherwise be difficult to observe' was changed to 'I can use technology to make students observe phenomenon that would be otherwise be difficult to observe in my subject matter'. Items that were not personalized in their original texts were personalized with 'I can', 'I know' or 'I am able' in this study. This was done to make sure that the teachers would associate with the items and respond based on their own abilities. Some items were also added to capture the unique setting of the New Zealand curriculum. Since there is a focus on the Nature of Science in the New Zealand curriculum items were written to capture these ideas. For example, 'I have a good understanding of the Nature of Science' and 'I explicitly target aspects of the Nature of Science when teaching' were added to the 'Content Knowledge' and 'Pedagogical Content Knowledge' respectively.

The items on the online questionnaire for this study were close-ended with responses having a five-point Likert scale of strongly agree, agree, neither agree or disagree, disagree and strongly disagree. Though there is no consensus on the number of points that a Likert scale should have, Cox III (1980) extoled that a scale should have a point range between five and nine. McKelvie (1978) however found the five-category scale more reliable as compared to the other scales. Moreover, most of TPACK surveys especially those that served as a model for this study used a five-point Likert scale so this study also used a five-point Likert.

The constructs of the TPACK framework on the questionnaire had items ranging between seven and eight soliciting information about them on this questionnaire. The constructs with their items constituted a subscale on the questionnaire. The items on TPACK constituted the main items for the online questionnaire. However, there were other items that sought information about respondents' demographics, their experiences with ICT technologies and how they use technology in general in their classes. Some of these items were open-ended in nature. Thus in all there was a section on demographics and seven other sections having items on the seven constructs of TPACK.

Validity and reliability of the online survey. In order to find out whether items on their questionnaires measured what the questionnaires sought to measure, Archambault and Crippen (2009), Graham et al. (2009), Sahin (2011) and Schmidt et al. (2009) from whose survey items were pooled from for this study conducted different validity tests. Smith and Mackie (2000) maintained that one way to ensure construct validity is through self-reporting. This is a situation where people with similar characteristics as the respondents are asked to respond to the items. Archambault and Crippen (2009); Sahin (2011); and Schmidt et al. (2009) therefore gave their instruments to experts in TPACK and educational technologists to review to find out whether the items were really measuring TPACK. They made modifications per the suggestions of the experts. Sahin (2011) and Schmidt et al. (2009) went further and performed Exploratory Factor Analysis to determine the construct validity of their questionnaires.

Graham et al. (2009) however constructed their items based on literature definitions of the constructs of TPACK and therefore did not have an expert review of their items. They could not perform factor analysis on their items because of the small sample size. Though Archambault and Crippen (2009) did not perform factor analysis as well, they took their instrument through rigorous think-aloud process of review to determine the validity of the various items.

Since the items for this research came from different authors, it was deemed appropriate that the validity and reliability of the items should be ensured. The items on the online questionnaire for this study were given to one science adviser, three science teachers who have been teaching with ICT and my two supervisors to review (The review committee). The science advisor’s opinion was sought as she interacts more often with the science teachers on a regular basis and was in a good position to provide advice on what teachers are doing in their schools with regards to technology as well as provide informed decisions with regards to the items' relation to the curriculum. Science teachers of similar experience of using technology in teaching as the sampled population were used to review the questionnaire as Punch (2009) contended that it is a very good idea to have a small group of people who are typical of your population to go through an instrument before it becomes finalized. My supervisors are experienced science educators and have been using technology in their teaching. The review committee's role was to check to make sure that items on the questionnaire fell within the TPACK framework. They also checked to make sure the items were appropriate for New Zealand high school settings as well as to ensure they were really measuring TPACK. The suggestions of this group of people led to modifications, deletions and additions of some items. Items that were not clear in meaning were deleted. Items that this group of people thought were necessary but were not included were added to the instrument. Having experts review the instrument as urged by Archambault and Crippen (2009) was to ensure that items were complete, relevant and arranged in appropriate format which would yield a high level of content validity.

Piloting of the survey. The refined questionnaire was transformed into an online survey through the Qualtrics Survey Software. It was then piloted on a small group of science teachers. The online questionnaire was sent to science teachers of two schools for them to try it out. Ten teachers completed the trial/pilot online questionnaire**.**

The responses from these teachers were collated and used to determine the reliability of the instrument before it was sent out for the main study. Since the TPACK framework is made up of different variables, it is multidimensional in nature. In view of this, the instrument developed to measure it was also multidimensional and therefore the reliabilities for the various subscales were determined separately. This was done through the use of Cronbach's alpha reliability since the items on the instrument were not scored dichotomously. Moreover, the emphasis was on how items under subscales related to each other. Thus, the internal consistencies of the scale were determined. The SPSS version 19 was used for the statistical analysis. Technological Knowledge (TK) had a coefficient alpha of 0.884, Pedagogical Knowledge (PK) 0.833, Content knowledge (CK) 0.901, Pedagogical Content Knowledge (PCK) 0.545, Technological Content Knowledge (TCK) 0.649, Technological Pedagogical Knowledge (TPK) 0.826 and Technological Pedagogical Content Knowledge (TPACK) 0.665. These reliabilities were conducted to find out the internal consistencies of the items i.e. how the items under a subscale relate to each other. Reliability coefficients are measured by using a scale from 0.00 (very unreliable) to 1.00 (perfectly reliable) (Gray, 2004). Since all the values were above 0.5, none of the items was deleted though the sample was small. The items were deemed to be very reliable to fairly reliable therefore none of the items was deleted at this stage since there was going to be another reliability test after the actual data has been collected.

Participants

Every high school science teacher in New Zealand was targeted as a potential participant for the survey aspect of the study. Concerted efforts were made by the researcher and the supervisors to reach as many as possible science teachers. Since the survey was conducted online, e-mails containing the link to the survey were sent to various regional and the national science associations in New Zealand. The associations that the email containing the link to the survey was sent to for onward submission to their members were: New Zealand Association of Science Educators (NZASE), The Royal Society of New Zealand, Canterbury Science Teachers' Association (CSTA), Auckland Science Teachers Association (ASTA), Horticulture and Agriculture Teachers Association of New Zealand (HATANZ), Earth and Space Science Educators (ESSE), Biology Educators Association of New Zealand (BEANZ), New Zealand Institute of Chemistry-Chemistry Teachers Group(NZIC), Waikato Science Teachers Association (WSTA), Capital City's Science Educators (CCSE), Central

Association of Science Educators (CASE), Central Northland Teachers of science (CENTOS), East Coast Science Teachers (ECSTA), Far North Science Teachers Association (FNSTA), Nelson Association of Science Educators (NASE), Otago Science Teachers Association (OSTA) and New Zealand Institute of Physics-Physics Teachers Group(NZIP).

These associations were used because most New Zealand science teachers are members of one or more of these associations. Therefore, it was assumed that it would be easy to get access to more science teachers through these associations. Again, sending the survey through the associations helped us to eliminate the possibility of recognizing the respondents. Thus, respondents' anonymity was ensured. In addition to the emails, letters which contained the uniform resource locator (URL) of the survey were sent to Heads of Science departments of about 400 high schools throughout New Zealand. The Heads of Science in the various schools were asked to give the link to their science teachers so that the teachers can respond to the survey. Efforts were made to identify the exact number of secondary science teachers in the country. However, the Ministry of Education indicated that because of the flexibilities in the schools, it was very difficult for them to have the number of secondary science teachers in the country.

These measures were taken with the view of reaching as many as possible science teachers. Again, since the memberships of some of these associations cut across the nation it was assumed that science teachers from different parts of the country were reached to respond to the survey. This brought about representativeness of the sample. Moreover, the survey was also sent to the regional associations as well. The idea was that if some teachers were missed through the national associations, these teachers could be reached through the regional associations. Finally, the Heads of Science who were sent the personal letters were from different schools across the country. Since the survey was an online survey, any teacher who responded to the invitation and responded to the survey items was used for the study.

A total of 102 secondary science teachers responded to the online survey. Out of this number, 53 (52%) were females. Most of the respondents (48) (47.1%) were aged above 45 years whilst four (3.9%) were in the age group 20-25. The rest of the respondents (49%) comprised of other age groups ranging between 26 and 45. The study divided the nation into four zones: North Island urban, North Island rural, South Island urban and South Island rural. Fifty-two science teachers representing 51% of the respondents were teaching in schools in the north island urban areas whilst 15 (14.7%) were from north island rural schools. South island urban teachers who responded to the question were 22 (21.6%) in number whilst 13(12.7%) were from south island rural schools.

A total of 65 (63.7%) of the teachers who responded to the questionnaire had taught for more than 10 years, 15 (14.7%) had taught for six to 10 years, eight (7.8%) of the teachers were still in their pre-registration period whilst the remainder had taught between one to five years. Respondents came from schools in different deciles. Deciles are a way in which the Ministry of Education of New Zealand allocates funding to schools. A decile is a 10% grouping, there are ten deciles and around 10% of schools are in each decile. A school's decile rating indicates the extent to which it draws its students from low socio-economic communities. Decile 1 schools are the 10% of schools with the highest proportion of students from low socio-economic communities, whereas decile 10 schools are the 10% of schools with the lowest proportion of these students. The lower a school's decile rating, the more funding it gets. The increased funding given to lower decile schools is to provide additional resources to support their students' learning needs. A decile does not indicate the overall socio-economic mix of the students attending a school or measure the standard of education delivered at a school (New Zealand Ministry of Education, 2013). In this study, twelve (11.8%) of the respondents came from schools within deciles one and three (1-3), 23 (22.6%) of the respondents came from schools in deciles four and five (4-5), teachers from deciles six and seven (6-7) were 26 representing 25.5% of the total sample. Deciles eight to ten produced 41 teachers representing 40.2% of the total sample.

Science teachers who responded to the survey had varying experience of teaching with ICT. Forty of the respondents (39.2%) had been teaching with ICT for over 10 years; 30 (29.2%) had taught with ICT for between six to ten years. Four respondents reported that they have not been teaching with ICT; six (5.9%) had been teaching with ICT for less than a year whilst 25 (24.5%) had been teaching with ICT between one to five years.

Quantitative data collection procedure

The mode of data collection for the quantitative aspect of the research was through email. Though the email containing the link to the survey was sent to the secretaries of the various science associations for onward submission to the teachers, it was framed in a personal manner with the salutation "Dear Science teacher." The email contained the name and institution of the researcher, the reasons for the survey and the duration it may take to respond to the survey. Teachers' anonymity was assured in the email even though the first page of the survey sought to seek their consent. This was done to assure teachers of the confidentiality of their responses before they will click on the link to the survey. A thank you note was added to the email to thank the teachers for their time in advance. The respondents had to click on the Qualtrics link in their email in order to get access to the survey. Respondents then provided responses to the various items on the questionnaire. Respondents had the option of pausing and returning to the survey at a later time. Responses were collected by the Qualtrics software.

Data Analysis Procedures

The responses from the online survey were exported to SPSS version 19 for analysis. Only responses from completed questionnaires were used for the analysis. The process of deleting the uncompleted questionnaires formed the data cleaning process. Factor analysis was conducted to determine the items that should be used in the analysis.

Factor analysis

After the data had been collected from the online survey, exploratory factor analysis (EFA) with principal component analysis as the extraction and rotated with Varimax rotation was conducted. Factor analysis is a technique used to determine if items of a particular construct are really measuring that construct and thus helps to yield a rigorous instrument. Principal component analysis is concerned with establishing which linear components exist within a data set and how variables might contribute to that component or construct (Field, 2009).

A critical look at the TPACK literature revealed two main approaches to EFA by authors. Some authors (Koh et al., 2010; Lux, Bangert, & Whittier, 2011) chose to pool all their items together and then run factor analysis to determine the number of factors that will come out and which items fell (loaded) under the extracted factors whilst others (Sahin, 2011; Schmidt et al., 2009) run separate factor analysis for each of the constructs of the TPACK framework. The former authors sought to determine whether TPACK really had all the seven constructs whilst the latter authors decided that TPACK had all the seven constructs from literature and thus were interested in finding out items that will help measure the various constructs. Since this research did not aim to test whether there were seven constructs but rather assumed so from literature, the EFA was run for each of the separate subscales of the TPACK framework as depicted in Sahin (2011) and Schmidt et al. (2009).

The data were subjected to the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's Test of Sphericity (BTS) to find out its appropriateness for the EFA. The outcome of the KMO and BTS analyses is presented in Table 2. Since the KMO for all the subscales were between 0.8 and 0.9 and the BTS for all the subscales were significant, the data were deemed to be fit for factor analysis (Field, 2009; Sahin, 2011).

Table 2: KMO and BTS values for the TPACK constructs

Constructs	KMO Values	BTS Values	Significant Values (p)
Technological Knowledge (TK)	0.89	421.02	< 0.001
Pedagogical Knowledge (PK)	0.91	514.22	< 0.001
Content Knowledge (CK)	0.89	603.49	< 0.001
Pedagogical Content Knowledge (PCK)	0.90	533.70	< 0.001
Technological Content Knowledge (TCK)	0.88	500.81	< 0.001
Technological Pedagogical Knowledge (TPK)	0.90	769.45	< 0.001
Technological Pedagogical Content Knowledge (TPCK)	0.88	706.65	< 0.001

During the analysis only factors with eigenvalues greater than 1 were accepted and items with factor loadings of above 0.5 were retained. Items that did not load well (factor loading less than 0.5 and or cross loaded) under the constructs were deleted and removed from the instrument. This resulted in six items being deleted from the 'Technological Knowledge' and two from 'Technological Pedagogical Knowledge' constructs. The other constructs had all their items loading well. After the elimination of the problematic items, the factor analysis was run again and all yielded one component for all the subscales. The reliability coefficients of the constructs after items had been deleted were determined again.

Table 3: Eigenvalue and Percentage Variance for each Subscale

Factor	Eigenvalue	Percentage of variance (%)
Technological Knowledge (TK)	4.422	63.172
Pedagogical Knowledge (PK)	5.167	64.590
Content Knowledge (CK)	5.417	67.717
Pedagogical Content Knowledge (PCK)	5.163	64.540
Technological Content Knowledge (TCK)	4.721	67.440
Technological Pedagogical Knowledge (TPK)	5.349	76.417
Technological Pedagogical Content Knowledge (TPCK)	5.564	69.552

The results for the factor analysis for the various subscales indicating the factor loadings are presented in the sections below.

Technological Knowledge (TK). Thirteen items written for the technological knowledge construct before the factor analysis. The initial analysis produced four components with one with an eigenvalue of more than one. The items under the other three components did not load well. The component was rotated with Varimax rotation and one factor was retained. The retained factor had seven items which were maintained and used as part of the instrument and thus for further analysis. The results for the items and their factor loadings are presented in **Table 4**. The internal consistency coefficient (Cronbach's alpha) for the items of the Technological Knowledge construct was 0.897. These items fell within one factor accounting for 63.172% of the total variance.

Table 4: Technological Knowledge (TK) items and their Factor Matrix

Technological Knowledge Items	Factor loadings
I know how to solve my own technical problems	.854
I keep up with important new technologies	.870
I know about a lot of different technologies	.834
I have the technical skills I need to use technologies	.854
I have had sufficient opportunities to work with a range of technologies	.534
I can learn to use new software easily on my own	.838
I can install a new program that I would like to use	.722

Pedagogical Knowledge (PK). All the eight items for the construct of Pedagogical Knowledge loaded under one factor with factor loadings of more than 0.5. The items and their factor loadings are presented in Table 5.

Table 5: Pedagogical Knowledge (PK) items and their Factor Matrix

Pedagogical Knowledge items	Factor loadings
I know how to assess student performance in a classroom	.808
I can adapt my teaching based upon what students currently understand or do not understand	.796
I can adapt my teaching style to cater for diverse learners.	.858
I can use a wide range of teaching approaches in a classroom setting	.802
I can use different assessment tools and techniques	.769
I know how to organize and maintain classroom management	.786
I can determine the strategy best suited for the lessons I teach	.841
I am able to prepare lesson plans for the various topics I teach	.765

These items constituted 64.590% of the total variance and their internal consistency alpha was 0.921. No item was deleted from this construct after the factor analysis.

Content Knowledge (CK). All the eight items under Content Knowledge loaded under a single factor without any deviation, thus no item was deleted from the construct. These items accounted for 67.72% of the total variance and had internal consistency alpha of 0.93. The items and their factor loadings are summarized in Table 6**.**

Table 6: Content Knowledge (CK) items and their Factor Matrix

Content Knowledge items	Factor Loadings
I have sufficient knowledge about the subject I teach	.812
I have various ways and strategies of developing my understanding of the subject I teach	.858
I have a deep and wide understanding of the subject that I teach	.828
I can comfortably plan the scope and sequence of concepts that need to be taught within my class	.843
I know about various examples of how my subject matter applies in the real world	.862
I can use a scientific way of thinking	.890
I have good understanding of the Nature of Science	.740
I follow up-to-date resources and developments in my subject area	.736

Pedagogical Content Knowledge (PCK). The fourth domain of the TPACK framework, Pedagogical Content Knowledge (PCK), had eight items which were used in the factor analysis. It produced a single factor structure with all items having factor loadings of more than 0.5 as can be seen in Table 7. The items under this single structure accounted for 64.54% of the total variance with internal consistency coefficient of 0.92**.**

Table 7: Pedagogical Content Knowledge (PCK) items and their Factor Matrix

Pedagogical Content Knowledge items	Factor Loadings
I can select effective teaching approaches to guide student thinking and learning in my subject matter	.780
I can produce lesson plans with a good understanding of the topic in my subject matter	.838
I can anticipate likely student misconceptions within a particular topic	.799
I can assist students in identifying connections between various concepts in my subject matter	.842
I can distinguish between correct and incorrect problem solving attempts by students within my class	.765
I am familiar with common student understandings and misconceptions in my subject matter	.813
I am able to meet the objectives described in my lesson plans	.852
I explicitly target aspects of the Nature of Science when teaching	.730

Technological Content Knowledge (TCK). Technological Content Knowledge (TCK) was the fifth construct of the TPACK framework which factor analysis was run to verify whether the items sought to measure what they were supposed to measure. There were seven items that sought to measure this construct that factor analysis was conducted on. It produced a single factor structure that accounted for a total variance of 67.44% with factor loadings of more than 0.5 and above as depicted in Table 8. The internal consistency coefficient (Cronbach’s alpha) for the items was 0.91.

Table 8: Technological Content Knowledge (TCK) items and their Factor Matrix

Technological Content Knowledge (TCK)	Factor Loadings
I know about technologies that I can use for teaching specific concepts in my subject matter	.876
I know how my subject matter can be represented by the application of technology	.881
I know about technologies that I can use for enhancing the understanding of specific concepts in my subject matter	.847
I can use technological representations (i.e. multimedia, visual demonstrations, etc.) to demonstrate specific concepts in my subject matter	.796
I can use various types of technologies to deliver the content of my subject matter	.858
I can use technology to make students observe phenomenon that would otherwise be difficult to observe in my subject matter	.783
I can use technology to create and manipulate models of scientific phenomenon (e.g. animations, modelling, etc)	.690

Technological Pedagogical Knowledge (TPK). The sixth domain of TPACK which items were constructed to measure was Technological Pedagogical Knowledge (TPK). Nine items were written for this construct and taken through factor analysis. It produced two components with one having an eigenvalue of 5.44 with seven items. The two items under the other component did not load well. However, the items were rotated with Varimax rotation which yielded one component. This component accounted for 76.42% of the total variance. The other two items were therefore deleted. The factor loadings of the remaining seven items are shown in Table 9.

Table 9: Technological Pedagogical Knowledge (TPK) items and their Factor Matrix

Technological Pedagogical Knowledge (TPK)	Factor Loadings
I can choose technologies that enhance the teaching approaches for a lesson	.922
I can choose technologies that enhance students learning of a concept	.931
I can choose technologies that are appropriate for my teaching	.930
I can apply technologies to different teaching activities	.888
I can effectively manage a technology-rich classroom	.773
I can use technology to help assess student learning	.789
I can use technology to actively engage students in teaching and learning	.872

These items produced an internal consistency coefficient of 0.94.

Technological Pedagogical Content Knowledge (TPCK). The central theme of the TPACK framework is the Technological Pedagogical Content Knowledge which is the intersection of the three (Technology, Content, and Pedagogy) main knowledge constructs. All the eight items produced a single factor structure with factor loadings above 0.5 and accounted a total variance of 69.55%. The internal consistency alpha was 0.93. The items and their factor loadings are presented in Table 10.

Table 10: Technological Pedagogical Content Knowledge (TPCK) items and their Factor Matrix

Technological Pedagogical Content Knowledge (TPCK)	Factor Loadings
I can teach lessons that appropriately combine my subject matter, technologies, and teaching approaches	.913
I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn	.897

I can use strategies that combine content, technologies, and teaching approaches in my classroom	.878
I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school	.697
I can choose technologies that enhance the understanding of the content for a lesson	.861
I am able to find and use online materials that effectively demonstrate a specific scientific principle	.699
I can use technology to facilitate scientific inquiry in the classroom	.879
I am able to use technology to create effective representations of content that departs from textbook approaches	.816

All the items for the instrument have been provided in Appendix 5.

Descriptive and inferential statistics

Means and standard deviations for the various constructs of the TPACK were calculated. Multiple correlation analysis was conducted to find out how the various constructs of the TPACK framework correlates to each other. This was done because multiple correlation seeks to find out the associations between two or more variables simultaneously (Cohen et al., 2007). In order to find out how much each construct contributes to the TPACK framework, regression analyses were conducted (Field, 2009; Tabachnick & Fidell, 2007). Standard multiple regression as well as stepwise regression analyses were conducted. In both scenarios, Technological Pedagogical Content Knowledge (TPCK) was the dependent variable and Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) were the independent variables. The assumptions underlying multiple regression were explored to make sure that the data fit the analysis. The outcome of the preliminary tests has been provided in the 'Regression analysis' section of the results chapter.

Qualitative approach

The TPACK framework indicates that teaching and learning contexts have an effect on how technology is used in teaching (Koehler & Mishra, 2005). This study therefore sought, as one of its aims, to identify how different contexts affect the use of technology in high school science classrooms. In order to collect appropriate data to achieve this aim, a direct observation and interviews of what teachers actually do with technology were needed. The focus and methods of this aspect of the research fell under the qualitative research paradigm. Qualitative research is focussed on understanding the meaning people construct from their own perspectives (Merriam, 1998). Sarantakos (2013) argued that qualitative research is context sensitive and focuses on gaining an impression of a particular context with the associated logic, arrangement and rules.

There are various types of qualitative research (Creswell, 2008; Merriam, 1998) that researchers can choose from depending on the aim of their research. This study sought to identify how science teachers used technology in their teaching and how different contexts influence their use of technology. Since an in-depth understanding of how science teachers used technology was needed coupled with the fact that a small group of teachers were needed to study in depth, the case study was chosen as the appropriate design to use.

Case Studies

The case study is an appropriate design for researching contemporary events in which direct observations of events as well as interviews of people in real life contexts to yield deeper understanding of a phenomenon (Cohen et al., 2007; Merriam, 1998; Sarantakos, 2005, 2013; Yin, 2009). A multiple-case study design was used in this study. The multiple-case study design was chosen so as to see whether similar or contrasting results would be produced. Moreover, multiple-case designs make it possible to replicate a case under review in one study. Yin (2009) stated that "analytic conclusions independently arising from two cases will be more powerful than those coming from a single case alone" (p.61). Within each school, three teachers were the unit of analysis. In a situation where there are subunits within a case, Yin (2009) upheld that such case study is called an embedded case study. Thus, for the qualitative aspect of this research, an embedded multiple-case design was used (Yin, 2009). In this approach, three science teachers from each of two different schools were selected for this study. The selected science teachers were asked to respond to a questionnaire on their views on the constructs of the TPACK framework. They were interviewed to find out about the training they have had in using technology to teach, technological facilities in their schools, the process they go through to select a particular technological tools to teach, how they determined the educational qualities of a technological tool, the role technology plays in their teaching and other follow up questions. Observations of their teaching episodes were then conducted. The observations provided an opportunity to get beyond teachers' opinions and self-interpretations of their use of technology towards an evaluation of their actions in practice (Yin, 2009). The observations provided an opportunity to see how teachers used technology in their different science classes.

Participants

The participants who took part in the observations and interviewed were selected purposively. In purposive sampling, cases or respondents are selected based on some characteristics being sought (Cohen et al., 2007; Trochim, 2006). In this study, science teachers who used digital technology in their teaching were the cases under discussion. The study sought to use teachers who agreed that they use technology frequently (i.e. at least 70% of the time) in their teaching. These teachers were selected because the study wanted to identify how technology is being used in the science teaching process.

Information about potential teachers, who could be possible participants, was sought from the University of Canterbury's Education Plus (UC Education Plus) science advisor as well as lecturers in the College of Education, University of Canterbury. The UC Education Plus provides professional development and learning to teachers in schools. They do this through workshops, seminars and one on one mentoring. There are different people at UC Education Plus who are responsible for organizing workshops to the teachers of different subjects. Due to their work, the staff at UC Education Plus come into contact with teachers very often and are very much aware and abreast with what teachers do in their teaching. Since this study was in science, the person in charge of science at UC Education Plus (Science Adviser) was contacted. Some lecturers of the College of Education were also contacted to help find schools and teachers who can be used for this study apart from the science adviser. The UC Education Plus science adviser and the lecturers were thought to be better placed to know what teachers do in their science teaching and potential schools that were more likely to be advanced in their use of digital technologies in their teaching programmes.

The science adviser and the lecturers suggested schools as well as science teachers that were contacted to find out if they were interested in participating in the research. These teachers were asked to invite other science teachers in the same school who used technology frequently to be part of the study, as it was desirable to consider nested cases, i.e. the school being a case and the teachers being nested cases within the school case.

Thus, in selecting science teachers for the case study, the purposive and snow ball sampling techniques were used. Purposive because the study targeted and selected science teachers who use digital technologies in their teaching. The snow ball approach was used when more science teachers were needed. The contacted science teachers invited some of their colleagues who use technology in their teaching to be part of this study. The snow ball approach is when a small number of respondents are identified and these respondents act as informants to get access to other people who qualify to be part of the study (Cohen et al., 2007; Merriam, 1998; Trochim, 2006).

Two schools were selected for the school case studies. In each school, three (3) science teachers who used technology in their teaching were selected for the case studies of teachers. The idea was to get a teacher each from the three main disciplines of science i.e. physics, chemistry and biology. However, that was not realized since in one school there was no chemistry teacher willing to be part of the study.

The two selected schools had good facilities as far as technology was concerned. They had computer laboratories to varying degrees. Both schools were using Moodle platforms for course management, had a 'bring your own technology' (BYOT) class, were using wiki spaces and encouraged a school-wide use of technology in teaching and learning. In each class of each school, there was an overhead data projector and a sound system. Each teacher of the schools in which the observation occurred had a personal laptop which they used in their teaching. Thus the schools were similar in terms of digital facilities. The demographic information for the teachers used in the case studies is provided in Table 11.

The selected teachers were of varying teaching experiences ranging from two years to above ten years. The same was their experience of teaching with technology. The teachers selected for the observation were six in number; three males and three females. There were two physics teachers, one chemistry teacher and three biology teachers.

Table 11: Demographic information of participating teachers for the Case Studies

Teachers	Classes observed		Year(s) of teaching after registration	Years of teaching with technology	Number of observations	Skills in using technology
	Year group	Subject				
Ben	9 12	Science Physics	7 years	7 years	4 4	Better than intermediate but not an expert
Sharon	9 13	Science Biology	10 years	10 years	4 4	Intermediate
Elliot	10 12	Science Biology	2 years	2 years	4 3	Intermediate
Colin	10 12	Science Physics	2 years	2 years	4 3	Better than intermediate but not an expert
Janet	10 12	Science Chemistry	41 years	22 years	4 3	Better than intermediate but not an expert
Susan	10 13	Science Biology	20 years	12 years	4 3	Better than intermediate but not an expert

Instruments

To help generate appropriate data and information for the cases, interviews and observations were used. The development of these instruments went through rigorous process as depicted in the sections below.

Interview Protocol

This study employed semi-structured interviews (Creswell, 2009) as one of the instruments for data collection. In semi-structured interviews, there are baseline questions that are asked of every interviewee. The interviewer however can ask further questions depending on the answers of the interviewees. In this study, there were baseline questions that every science teacher who participated in the case study was asked. Additionally, there were follow up questions that were asked during the interview, which varied slightly for each teacher depending on their previous responses.

The questions for the interview were generated with the aim of the interview, the issues to be discussed and the other guidelines proposed by Cohen, et al. (2007) in mind. The questions were scrutinized and critiqued by my supervisors. After their suggestions had been taken on board, a science teacher was asked these questions to find out if they were clear, understandable and exhaustive based on the research question the study seeks to answer. The teacher’s responses helped to modify some questions whilst others were added. This was done to make sure that the questions were clear and understandable to teachers. It was also to make sure that the questions were addressing the issues that they sought to address.

The questions for the interview were grouped into four thematic areas: training teachers have had in using technology to teach, available technology in the school, teaching with technology and role ICT plays in teacher’s teaching. The interview protocol outline used for this study is provided in Appendix 6.

Observation Protocol

The observation protocol for this study was developed based on Blanchard, Harris, and Hofer (2011) *Science Learning Activity Types*. These learning activity types provided a range of ways in which various technological tools can be used to achieve specific purposes. Since the aim of the observation was to find out how science teachers used technology in different classes and subjects, the *Science Learning Activity Types* was considered an appropriate guide for such observation.

The observation protocol for this study contained statements corresponding to how teachers can use technology in their classes. These statements were adopted and adapted from the *Science Learning Activity Types* (Blanchard et al., 2011). The statements were the behaviours expected to be seen during teaching. Provision was made for behaviours that were not captured by the observation protocol. Such behaviours were written down. The hard/software being used was also noted. The observation protocol is shown in Appendix 7.

Data Collection Procedure

There were three data collection procedures: observations, interviews and a survey. The observations and interviews were conducted face to face with the teachers whilst the online survey was printed and sent to the teachers who were interviewed.

Observations of Teaching

Six science teachers were observed on how they used technology in their teaching. Teachers were observed to identify how they used different technological devices in the different science classes they teach. Thus, each teacher was observed in one of his/her senior class as well as one junior class (See Table 11). Teachers were approached and the rationale of the study explained to them. They then signed the consent form. The times as well as the classes to be observed were agreed upon.

The observations were non-participant (Cohen et al., 2007; Punch, 2009) or complete observer (Creswell, 2009) in nature. This means that there was no interaction between the observer and the participants. In this approach, the researcher stood aloof from the activities of the class. The observer did not participate in the activities of the teacher and her students. The researcher was solely there to observe what was happening. There was no interruption in the teachers' work by the researcher. Students were made aware of the researcher's presence and purpose. Since the focus was not really on students, there were no apprehensions on the part of the students. The researcher sat mostly at the back of the class and observed what was going on in the class. For non-participant observation, the best approach is for the researcher to sit at the back of the classroom coding the activities that are going on through a structured set of observational protocol (Cohen et al., 2007). Thus, with the help of the observation protocol, teachers' uses of ICT in their teaching were recorded. The observation protocol had statements corresponding to behaviours expected to be seen. When such behaviours took place, the corresponding statement on the protocol was checked. There were avenues to write down behaviours that did not fall within what had been listed on the observation protocol

The breakdown of the number of times each teacher was observed can be found in Table 12.

Table 12: Number of times teachers were observed

School	Teachers	Classes observed	
		Year Group observed	No. of times
School 'A'	Colin	Year 10	4
		Year12	3
	Janet	Year 10	4
		Year 12	3
	Susan	Year 10	4
		Year13	3
School 'B'	Ben	Year 9	4
		Year 12	4
	Sharon	Year 9	4
		Year13	4
	Elliot	Year 10	4
		Year 12	3

The minimum number a teacher was observed in a particular year level was three and the maximum was four. There were interruptions in the school calendar that resulted in adjustments to the timing of observations for the research. Thus, in all a teacher was observed at least seven times and at most eight times (combining both levels). In all, 44 observations were made.

Interviews

The six teachers whose classes were observed were interviewed. The interviews were conducted in the schools of the teachers. This was done to make the teachers feel comfortable. It was also assumed that since they were going to be interviewed on what they do, it was better to conduct the interview in their work environment. The duration for the interviews ranged between 20-30 minutes. The interviews were recorded digitally with the permission of the teachers.

In order to correlate the observed and interviewed teachers' use of technology and their TPACK, they were asked to respond to a printed copy of the online questionnaire. This was the same survey that was distributed nationally via the teacher associations. These teachers had not responded to the online survey when the printed questionnaire was given to them.

Data Analysis

The responses from the interview were analysed narratively. Sarantakos (2013) noted that narrative analysis is concerned with studying the life stories of people and how they understand their world. It deals with interpreting conversation or story by paying attention to the speaker's embedded meanings and evaluations as well as their context (Wiles, Rosenberg, & Kearns, 2005). Such analysis and interpretations are garnered by analysing live or transcribed interviews as depicted by Sarantakos (2013).

Information gathered from participants through the interviews were arranged in categories or themes and analysed thematically as suggested by Riessman (2008). Teachers' responses were grouped under the four themes of the interview protocol. These themes or categories were developed into broad patterns and compared with existing literature (Creswell, 2008) on TPACK. The views of the teachers were then compared with their measure on the TPACK questionnaire. The notes from the observations were summed up for each teacher. This helped to bring to the fore how teachers used technology to facilitate their teaching in the classroom. The narratives were presented and interpreted since descriptions alone do not construct narratives (Sarantakos, 2013). In this study, the narratives were done with minimal interpretations in one chapter with the interpretations and discussion in another chapter. The discussion was interspersed with quotes from the interview.

Although it is prudent that cases should be compared and contrasted in analysing multiple cases, the cases in this study were not compared because teachers were assured that their responses will not be compared with and to that of their colleagues. This assurance was given since the teachers who were observed were not enthused about their responses being compared to that of their colleagues.

Ethical considerations

The project, information letters and consent forms were approved by the University of Canterbury Human Ethics Committee before the research started (Appendix 1). The university's ethics committee sees to it that every research undertaken by staff and higher degree students of the university that involve human participants is conducted with appropriate regard for ethical principles and cultural values, and in accordance with the Treaty of Waitangi. The committee ensures that participants of the research have appropriate and detailed information prior to agreeing to participate, are treated with respect, their safety assured, their details are kept confidential as well as deal with them in the spirit of justice and truthfulness. A letter of information about the project including a brief description with the research questions was developed, indicating the expectations of the teachers and the time commitment, information about the use of data and the guarantee of anonymity and confidentiality (Appendix 2). Consent forms for the teachers who were interviewed and observed, online survey as well as the principals of the schools in which the study was conducted were developed. These documents were sent to the university's ethics committee and they reviewed the information provided and asked for further clarification, deletions and insertions before they granted permission for the research to be conducted.

For the case studies, consent was sought from the principals whose schools took part in the study (Appendix 3). My senior supervisor contacted them and asked for their permission to conduct the study in their schools after she had explained the focus of the study to them. The science teachers involved in the observations and interviews were also asked to sign the consent form (Appendix 4). The teachers signed two copies of the consent form. They kept one and the researcher also took a copy. The consent form explained the study and its focus to the teachers. The teachers were assured of the confidentiality of the data gathered. To ensure confidentiality and anonymity, all names and identifying details in any verbal, written or published reports were code-named. The recordings made are being stored in locked premises only accessible to the researcher. At the end of the project all recorded data will be destroyed after 5 years as stipulated by the ethics committee.

The first page of the online survey was a consent page. It contained the information about the project, contact details of the researcher and the supervisors of the project, the university's ethics committee as well as the estimated time it will take teachers to respond to the items. Respondents needed to agree to be part of the study before they could access the items in the questionnaire. It was made explicit that agreeing to move to the next page from the first page meant consent has been given.

Summary of the chapter

The selection of appropriate methodological design for this study was informed by the research questions and the aim of the research (Fraenkel et al., 2012; Gray, 2009). The aims of the research were to gather enough data in order to predict New Zealand's science teachers' perceptions of their understanding of TPACK as well as to investigate how science teachers adapted their use of technology and the characteristics of their TPACK in different contexts. The aims of the research fit into the pragmatists' worldview of knowledge being socially and independently constructed (Gray, 2009). Therefore the pragmatists' design of mixed methods approach which comprised quantitative and qualitative aspects was used for the study.

The quantitative aspect of the study was achieved through an online survey which was sent to all the various science teacher associations in New Zealand for onward submission to their members. The data generated from the survey were analysed to find the mean responses for each of the TPACK constructs. Correlation and regression analyses were also performed to identify how the constructs correlated with TPCK and with each other as well as to find out which of the constructs was the major predictor of TPCK. Interviews and observations of teaching episodes constituted the methods for the qualitative part of this study. Six teachers who were regular users of technology in their teaching were purposively selected to be the cases for this study. They were interviewed on their uses of technology in their teaching and their teaching episodes were observed to find out how they used technology in two different classes.

CHAPTER 4

RESULTS

This chapter reports the analyses of the survey, the quantitative part of the research, conducted through online questionnaires on science teachers' TPACK. The results from the case studies that form the qualitative aspect of this research including the collation and analyses of the findings from the interviews and the classroom observations are also presented.

Quantitative results

The quantitative results emanated from data generated from a nationwide survey in which New Zealand's science teachers' perceptions of their knowledge on the constructs of TPACK was solicited through an online questionnaire. From literature, New Zealand science teachers' TPACK has not been measured yet and therefore the results of this survey contribute to a clearer knowledge base of the perception of science teachers' knowledge and use of ICT. This part of this study sought to provide data to answer the first two research questions: science teachers' levels of awareness of their TPACK and how these constructs relate to each other. Science teachers' mean scores and standard deviations for the various constructs of TPACK as well as the correlations and multiple regression results are provided below.

The science teachers who responded to this survey were asked to indicate how often they used ICT tools to facilitate their teaching and the learning of their students. These items were derived from Blanchard et al. (2011) *Science Learning Activity Types* which indicate the various activities science teachers undertake and the technological tools they can use to facilitate the performance of those activities. Out of 102 respondents, four teachers indicated that they did not use ICT in their teaching and therefore did not respond to this item. The responses of these four teachers were ultimately deleted since they were outliers when the assumptions for multiple regression were tested. The teachers were asked to rate their usage of ICT to perform certain functions on a scale of 'never' (0% of the time); 'rarely' (10% of the time); 'occasionally' (30% of the time); 'sometimes' (50% of the time); 'frequently' (70% of the time) and 'every time' (> 90% of the time). Again, the responses were ranked in a Likert scale format with 'never'=1; 'rarely'=2; 'occasionally'=3; 'sometimes'=4; 'frequently'=5 and 'every time' = 6 and the mean scores for the teachers calculated. The results of the remaining 98 teachers' responses are summarized in Table 13.

There was a greater use of ICT with regards to the preparation of lessons by teachers as compared to how they used ICT for other activities. The majority of the teachers used ICT to search for information for their lessons with none of these 98 teachers indicating that they 'never' or 'rarely' used ICT to help their lesson preparations. The mean score for the responses on how often teachers used ICT in their lesson preparation was 5.0 with a standard deviation of 0.8. This showed that teachers on average used ICT 70% of the time to help them prepare their lessons. Again, there seemed to be a general consensus on the use of ICT to facilitate lesson preparation since there was not a greater spread in the responses as indicated by a relatively small standard deviation when compared to the other statements. Similar results were seen for presentation of content to students through ICT tools though in this instance there was one teacher who reported that he/she 'rarely' used ICT to present content material to students. The mean score for this item was 4.9 which was very close to the value for 'frequently' and thus teachers do this activity 70% of the time although with a standard deviation of 0.9, there was a greater spread of responses.

Very few (10) teachers were not using ICT tools to explore, demonstrate or elaborate the concepts they have been teaching during the time of this research. The teachers who were using ICT to explore concepts were ranked close to using it 'frequently' to perform such acts as depicted by their mean score of 4.6. There seemed to be a wide variability among the teachers when it came to the use of ICT tools to explore, demonstrate or elaborate concepts as depicted by a standard deviation of 0.9, which was relatively large. Again, most of the teachers were using ICT tools to help their students to view images and objects which facilitated the understanding of the concepts they were teaching. The only activity which was not being done most often by teachers was allowing students to discuss issues through ICT.

Table 13: Teachers use of ICT in their teaching and student learning processes

Statements	Responses							
	Never Freq. (%)	Rarely Freq. (%)	Occasionally Freq. (%)	Sometimes Freq. (%)	Frequently Freq. (%)	Every time Freq. (%)	Total Freq. (%)	Mean (S.D)
Preparation of lesson	-	-	8 (8.2)	9 (9.2)	56 (57.1)	25 (25.5)	98 (100)	5.0 (0.8)
Presentation or delivering of content		1 (1.0)	8 (8.2)	19 (19.4)	46 (46.9)	24 (24.5)	98 (100)	4.9 (0.9)
Explore, demonstrate or elaborate a concept	1 (1.0)	2 (2.0)	7 (7.1)	25 (25.5)	51 (52.0)	12 (12.2)	98 (100)	4.6 (0.9)
To allow students to discuss issues	18 (18.4)	27 (27.6)	17 (17.3)	19 (19.4)	13 (13.3)	4 (4.1)	98 (100)	2.9 (1.5)
To allow students view images or objects	- -	7 (7.1)	15 (15.3)	27 (27.6)	38 (38.8)	11 (11.2)	98 (100)	4.3 (1.1)

Science teachers' TPACK

The first research question sought to identify New Zealand high school science teachers' perception of their understanding of the various constructs of the TPACK framework. When asked to rate their own understanding of the various constructs of TPACK on a five-point (strongly disagree-strongly agree) Likert scale, New Zealand high school science teachers demonstrated a very high level of understanding of the various constructs of the TPACK framework as can be seen in Table 14.

Science teachers in this survey scored high means for all of the various constructs with their lowest mean score being 3.7 for the Technological Knowledge construct. Teachers' high mean scores indicated that they agreed to most of the items on the various constructs and therefore possessed high awareness of their knowledge of the constructs of TPACK. The evidence points to the fact that the teachers had more knowledge in the 'traditional' content and pedagogy constructs.

Table 14: Science teachers' mean scores on the constructs of TPACK

Constructs	Mean scores	Standard Deviations
Technological Knowledge	3.7	0.7
Pedagogical Knowledge	4.4	0.5
Content Knowledge	4.5	0.6
Pedagogical Content Knowledge	4.3	0.5
Technological Content Knowledge	4.2	0.6
Technological Pedagogical Knowledge	4.1	0.7
Technological Pedagogical Content Knowledge	4.2	0.6

(N=98)

Mean scores of teachers' responses on each item were calculated to ascertain how they responded to the items under each construct. This was done to identify if there were specific items which needed attention. This could lead to targeted professional development programmes as well provide a clue to what areas teacher education programmes should target. Table 15 presents teachers' response patterns for the items of the TK construct. Teachers' responses to the items of TK revealed that they were confident and comfortable when it came to installing a new computer program they would like to use on their computer. Aside this item, the teachers had mean scores which were less than 4.0 for all the other items under this construct. The lowest mean score was for the item "I have had sufficient opportunities to work with a range of technologies". If teachers have not had sufficient opportunities to work with technology, then their technological skills will definitely be limited and thus it was not surprising that their mean score for TK was generally low as compared to the other constructs of the TPACK framework.

Table 15: Mean scores for Technological Knowledge items

TK Items	Mean	Std. Dev.
I know how to solve my own technical problems.	3.6	0.9
I keep up with important new technologies.	3.7	0.9
I know about a lot of different technologies.	3.6	0.8
I have the technical skills I need to use technologies.	3.8	0.9
I have had sufficient opportunities to work with a range of technologies.	3.4	1.0
I can learn to use new software easily on my own.	3.9	1.0
I can install a new program that I would like to use.	4.4	0.8

Mean score for the construct (3.7)

Science teachers in New Zealand demonstrated high levels of knowledge in the items under Pedagogical Knowledge. The teachers had a mean score of 4.0 and above for all the items as can be seen in Table 16.

Table 16: Teachers' mean scores for the items under Pedagogical Knowledge

Items	Mean	Std. Dev
I know how to assess student performance in a classroom.	4.4	0.6
I can adapt my teaching based upon what students currently understand or do not understand.	4.5	0.5
I can adapt my teaching style to cater for diverse learners.	4.2	0.8
I can use a wide range of teaching approaches in a classroom	4.3	0.7

setting.		
I can use different assessment tools and techniques.	4.3	0.6
I know how to organize and maintain classroom management.	4.4	0.7
I can determine the strategy best suited for the lessons I teach.	4.4	0.6
I am able to prepare lesson plans for the various topics I teach.	4.6	0.5

Mean score for the construct (4.4)

Table 17 summarizes the results for teachers' mean scores for the items of Content Knowledge construct.

Table 17: Teachers mean scores for Content Knowledge items

Items	Mean	Std. Dev.
I have sufficient knowledge about the subject I teach.	4.6	0.6
I have various ways and strategies of developing my understanding of the subject I teach.	4.6	0.5
I have a deep and wide understanding of the subject that I teach.	4.4	0.7
I can comfortably plan the scope and sequence of concepts that need to be taught within my class.	4.5	0.6
I know about various examples of how my subject matter applies in the real world.	4.5	0.6
I can use a scientific way of thinking.	4.6	0.5
I have good understanding of the Nature of Science.	4.5	0.6
I follow up-to-date resources and developments in my subject area	4.3	0.7

Mean score for the construct (4.5)

Teachers agreed to all the items under CK and so had high mean scores with the lowest mean score being 4.3. Teachers responded that they have a good understanding of Nature of Science which is one of the strands of science in the New Zealand curriculum.

New Zealand teachers seemed to have confidence in their abilities when it came to the content they taught.

Teachers demonstrated high understanding of items under PCK with mean scores of 4.0 and above. Table 18 presents teachers' mean scores for the various items of the Pedagogical Content Knowledge construct.

Table 18: Teachers' mean scores for Pedagogical Content Knowledge items

Items	Mean	Std. Dev
I can select effective teaching approaches to guide student thinking and learning in my subject matter.	4.3	0.6
I can produce lesson plans with a good understanding of the topic in my subject matter.	4.5	0.6
I can anticipate likely student misconceptions within a particular topic.	4.3	0.6
I can assist students in identifying connections between various concepts in my subject matter.	4.4	0.6
I can distinguish between correct and incorrect problem solving attempts by students within my class.	4.3	0.6
I am familiar with common student understandings and misconceptions in my subject matter.	4.3	0.6
I am able to meet the objectives described in my lesson plans.	4.4	0.5
I explicitly target aspects of the Nature of Science when teaching.	4.0	0.8

Mean score for the construct (4.3)

Teachers' responses indicated that they considered they were able to execute the blend between their pedagogical and content knowledge areas effectively. The lowest mean score under this construct was for the item 'I explicitly target aspects of the Nature of Science when teaching'. Though the score of 4.0 which translated as 'agreed', the standard deviation of 0.8 was relatively larger as compared to that of the other items under the same construct. This indicated a wide variability when it came to the response of this item. Nonetheless, it is heart-warming that science teachers are explicitly targeting the Nature of Science in their teaching.

The science teachers had a mean score of 4.0 and above for all but one item under TCK. They seemed to agree that they were aware of how the affordances of technology influence the content and vice versa. The mean scores for the items under TCK are summarized in Table 19.

Table 19: Teachers' mean scores for Technological Content Knowledge items

Items	Mean	Std. Dev.
I know about technologies that I can use for teaching specific concepts in my subject matter.	4.1	0.8
I know how my subject matter can be represented by the application of technology.	4.1	0.7
I know about technologies that I can use for enhancing the understanding of specific concepts in my subject matter.	4.1	0.7
I can use technological representations (i.e. multimedia, visual demonstrations, etc.) to demonstrate specific concepts in my subject matter.	4.5	0.6
I can use various types of technologies to deliver the content of my subject matter.	4.3	0.7
I can use technology to make students observe phenomenon that would otherwise be difficult to observe in my subject matter.	4.5	0.6
I can use technology to create and manipulate models of scientific phenomenon (e.g. animations, modelling, etc.).	3.9	1.0

Mean score for the construct (4.2)

The teachers were positive that they were aware of technologies that they could use for effective teaching of specific concepts they teach. Teachers seemed not so sure about whether they were able to use technology to create and manipulate models of scientific phenomenon. Teachers scored a mean of 3.9 for this item which was below the 'agreed' threshold of 4.0. The spread for the response to this item seemed to be very wide since the standard deviation (1.0) for the item was the biggest when compared to other items under the same construct. There was a general belief, however, among the teachers that they were capable of using technology to demonstrate the content they taught. In the course of their teaching, science teachers indicated that they were able to use technology to assist students to observe scientific phenomenon that otherwise would be difficult to observe in real life.

Although New Zealand science teachers were not decisive about their ability to effectively manage a technology-rich classroom as well as use technology to assess student learning, they agreed that they were able to undertake all the other activities that form part of Technological Pedagogical Knowledge construct. Table 20 summarizes teachers mean scores for the items of TPK.

Table 20: Teachers' mean scores for items of Technological Pedagogical Knowledge

Items	Mean	Std. Dev.
I can choose technologies that enhance the teaching approaches for a lesson.	4.2	0.6
I can choose technologies that enhance students’ learning of a concept.	4.3	0.6
I can choose technologies that are appropriate for my teaching.	4.3	0.5
I can apply technologies to different teaching activities.	4.2	0.6
I can effectively manage a technology-rich classroom.	3.9	0.9
I can use technology to help assess student learning.	3.9	0.8
I can use technology to actively engage students in teaching and learning.	4.3	0.7

Mean score for the construct (4.1)

Teachers were confident that they were able to select appropriate technologies that helped to enhance their teaching approaches as well as students’ learning. Teachers were also confident that they could select technologies that were appropriate for their teaching and choose different technologies to undertake different teaching activities. Again, there was an agreement from the teachers that they were able to use technology to actively engage students in the teaching and learning process.

In the Technological Pedagogical Content Knowledge construct, science teachers agreed with all but one item that made up this construct. Teachers indicated that they were capable of combining the content they taught with technology and pedagogy as well as select appropriate technologies to enhance the subject matter, their teaching approaches and students' learning. Table 21 presents teachers' mean scores for the various items of TPCK construct.

Table 21: Teachers' mean scores for Technological Pedagogical Content Knowledge items

Items	Mean	Std. Dev.
I can teach lessons that appropriately combine my subject matter, technologies, and teaching approaches.	4.3	0.6
I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.	4.3	0.6
I can use strategies that combine content, technologies, and teaching approaches in my classroom.	4.3	0.6
I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school.	3.9	0.9
I can choose technologies that enhance the understanding of the content for a lesson.	4.3	0.5
I am able to find and use online materials that effectively demonstrate a specific scientific principle.	4.6	0.5
I can use technology to facilitate scientific inquiry in the classroom.	4.2	0.7
I am able to use technology to create effective representations of content that departs from textbook approaches.	4.2	0.7

Mean score for the construct (4.2)

It can be seen from Table 21 that, teachers were undecided when it came to their ability to provide leadership in helping other teachers in their schools to coordinate the use of content, technologies and teaching approaches. It seemed that though teachers combined technologies, teaching approaches and the content they taught, in general, they were not confident to lead and direct other teachers to perform such functions.

Further exploration of the data to determine if teachers' teaching experience affected their mean scores of the various constructs was undertaken. Teachers' teaching experiences after registration as teachers were categorized into six groups: still in pre-registration period; less than one year; between 1-2 years; between 3-5 years; between 6-10 years and above 10 years. The mean scores of teachers of varying teaching experience are presented in Table 22.

Table 22: Mean scores of teachers with different teaching experiences

Teaching experience	No. of respondents	Mean scores and standard deviation for the various constructs						
		TK	PK	CK	PCK	TCK	TPK	TPCK
Pre-registration	8	3.3 (0.7)	4.1 (0.3)	4.2 (0.4)	3.8 (0.5)	3.7 (0.6)	3.9 (0.4)	3.9 (0.3)
Less than 1 year	4	3.7 (1.2)	4.0 (0.2)	4.1 (0.3)	4.0 (0.2)	4.1 (0.2)	3.9 (0.7)	3.9 (0.8)
1-2 years	3	4.3 (0.6)	4.1 (0.7)	4.5 (0.5)	4.3 (0.5)	4.7 (0.5)	4.1 (0.5)	4.5 (0.5)
3-5 years	7	3.6 (0.8)	4.1 (0.5)	4.7 (0.2)	4.2 (0.2)	4.3 (0.4)	4.0 (0.2)	3.9 (0.1)
6-10 years	14	3.9 (0.4)	4.1 (0.5)	4.3 (0.4)	4.2 (0.4)	4.2 (0.6)	3.9 (0.6)	4.1 (0.5)
Above 10 years	62	3.8 (0.7)	4.6 (0.5)	4.6 (0.4)	4.5 (0.5)	4.3 (0.6)	4.2 (0.6)	4.3 (0.5)

The Standard deviation is presented in parenthesis ().

With the exception of teachers who were in their second year of teaching after registration who had a mean score of 4.3, all the other teachers had a mean score lower than 4.0 for Technological Knowledge. The lowest mean score for this construct was registered by teachers who were still in their pre-registration period. These teachers recently graduated from their teacher education training and one would have expected that they would have more technological skills than those teachers who completed their teacher education a long time ago. However, this points to the fact that the pre-registration teachers probably did not have much technological training during their teacher education programmes.

All the teachers had a mean score of more than 4.0 for both Content Knowledge and Pedagogical Knowledge. This was not surprising since teacher education programmes focussed so much on these constructs; consequently teachers try as much as possible to be well informed in these areas. Teachers who were still in their pre-registration period were the only group of teachers who had a mean score less than 4.0 for Pedagogical Content Knowledge and Technological Content Knowledge.

There were mixed results for Technological Pedagogical Knowledge and Technological Pedagogical Content Knowledge. Teachers in pre-registration period, those who had taught for less than one year after registration as well as those who had taught for between 6-10 years had a mean score of 3.9 for TPK whilst the other groups of teachers had a mean score of 4.0 and above for this construct. On TPCK, all the teachers except those in pre-registration period and those who had taught for less than one year after registration had a mean score of 4.0 and above.

Correlation among the TPACK constructs

The second research question sought to determine how the various constructs of the TPACK framework correlated with each other. The Pearson's correlation coefficient was used for this analysis. There were no statistically significant correlations between Technological Knowledge (TK) and Pedagogical Knowledge (PK); Technological Knowledge (TK) and Content Knowledge (CK); Technological Knowledge and Pedagogical Content Knowledge (PCK). Table 23 summarizes the correlation results.

There were significant correlations between TK and TCK, TPK and TPCK. Pedagogical Knowledge (PK) correlated with all the other constructs aside TK with its strongest being with PCK.

Table 23: Correlation results for the TPACK constructs

	TK	PK	CK	PCK	TCK	TPK	TPCK
TK	-	.135	.255	.287	.567**	.451**	.455**
PK		-	.660**	.740**	.475**	.663**	.573**
CK			-	.770**	522**	.599**	.498**
P CK				-	.583**	.649**	.563**
T CK					-	.768**	.710**
TPK						-	.819**
TPCK							-

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

Content Knowledge strongly correlated with PCK and PK with other positive significant correlation with TCK, TPK and TPCK. Pedagogical Content Knowledge (PCK) correlated significantly with all the constructs of TPACK framework but TK. TCK and TPK both correlated with all the constructs of the framework while TPCK correlated with all the other constructs.

The strongest correlation was between TPK and TPCK followed by CK and PCK. TK did not correlate significantly with CK or PK as depicted in the TPACK Venn diagram, but there was a correlation between PK and CK which was contrary to the depiction of these constructs in the TPACK framework. There was a correlation between each basic construct (content, pedagogy and technology) and the intersection construct, TPCK. The correlations were followed with regression to determine how each of the constructs predicts the intersection construct TPCK.

Regression analysis

Since TPCK is the intersection of the contributing constructs, in order to identify which independent variable was the largest predictor of TPCK, when all the other variables have been taken into account, a standard multiple regression was performed. Technological

Pedagogical Content Knowledge (TPCK) was the dependent variable and Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) were the independent variables. This could help teacher educators and professional development organizers to know which construct to focus on in their programmes. The analysis was conducted with SPSS version 19.

The various assumptions underlying multiple regression were examined. The correlations between the independent variables and the dependent variable were above 0.3 and thus were acceptable for the regression analysis (Pallant, 2005; Tabachnick & Fidell, 2007). Moreover, there were not very high correlations ($r > 0.9$) (Field, 2009) between the independent variables. For further evaluation to check multicollinearity, which indicates a perfect linear relationship between two or more of the independent variables, the tolerance and variance inflation factor (VIF) values were examined. All the tolerance values were above 0.1 and the VIF values were less than 10, thus the data set did not indicate multicollinearity (Field, 2009; Pallant, 2005; Tabachnick & Fidell, 2007).

The Mahalanobis distance was used to check for outliers. Mahalanobis distance "is the distance of a case from the centroid of the remaining cases where the centroid is the point created at the intersection of the means of all the variables" (Tabachnick & Fidell, 2007, p. 74). It reveals cases that lie at a distance from the other cases and such cases are considered outliers. Mahalanobis distance is evaluated using chi square distribution. "Mahalanobis distance is distributed as a chi-square (X^2) variable, with degrees of freedom equal to the number of independent variables" (Tabachnick & Fidell, 2007, p. 166). In order to detect which cases are multivariate outliers, the critical X^2 value of the number of degree of freedom of the independent variables are compared with the Mahalanobis distance of the cases (Tabachnick & Fidell, 2007). Any case whose Mahalanobis distance value is greater than the critical X^2 is considered an outlier. Tabachnick and Fidell (2007) have produced a table of critical X^2 values which researchers can compare their Mahalanobis distance values with. This study had six (6) degrees of freedom and therefore had X^2 of 22.458 as calculated Tabachnick and Fidell (2007). The data cases of the study were compared with this critical X^2 value. Four cases with critical values higher than what was prescribed by Tabachnick and Fidell (2007) were detected. These were deemed to be outliers. The cases with the outliers were scrutinized again and it was realized that the cases were the four respondents who reported that they did not use technology in their teaching and since this research was more or less concerned about knowledge on technology use in teaching, these cases were deleted. Another calculation of the Mahalanobis distance after deletion produced one outlier whose critical value was lower than the recommended threshold and therefore it was maintained to form part of the study.

Normality of the data set was checked with the Normal Probability Plot and the Scatterplot of the Standardized Residuals. The Normality Probability Plot produced a fairly straight diagonal plot which indicated that the points did not deviate from normality. Again, the scatterplot produced a rectangular shaped distribution of the residuals with most points concentrated around the zero (0). This indicated that the data was fairly normally distributed. SPSS produces unusual cases in a table called Casewise Diagnostics for standard multiple regression. Pallant (2005) alerted that the Casewise Diagnostics table has information on cases that have values above 3.0 or below -3.0 as their standardized residuals and that in a normally distributed data, such cases should not be more than 1% of the total cases. In order to check if such cases are having effect on the results, one should have a look at the Cook's distance value. If the Cook's distance is more than 1, then there is cause for concern (Field, 2009; Pallant, 2005; Tabachnick & Fidell, 2007). Though the Casewise Diagnostics produced a case with standardized residual above 3 (in this case it was 5.496), the Cook's distance produced a maximum value of 0.49. Thus, though the standardized residual is above 3, the maximum Cook's distance value was less than 1 and therefore this case can be included in the regression.

The standard multiple regression with the six independent predictors (TK, CK, PK, PCK, TCK and TPK) to predict TPCK revealed that the six constructs accounted for 67.4% of the variance (Adjusted R^2= 0.674, $F (6, 91) = 34.456$, $p < .001$). The adjusted R^2 was reported because Tabachnick and Fidell (2007) recommended that the R square tends to overestimate its true value in the population when sample size is small and that the adjusted R square corrects the value of R square and thus produces a better predictor of the true population value. Thus the overall multiple regression was statistically significant. The summary of the model can be seen in Table 24.

Table 24: A model summary for the multiple regression

Model	R	R^2	Adjusted R^2
	.833	.694	.674

It can be seen from Table 25, a summary of the multiple regression analysis, that Technological Pedagogical Knowledge (TPK) made the largest unique contribution to the development of TPCK. The beta value for this construct was 0.607. Although the overall multiple regression was significant, it was seen that only TPK ($p < .001$) made a statistically significant unique contribution to teachers' TPCK. Thus, TPK made the largest contribution to teachers TPCK when the variances of TK, PK, CK, PCK and TCK are controlled for. The full SPSS output for the regression analysis can be found in Appendix 8.

To further determine if any of the other variables did make a significant contribution to the model and to confirm the outcome of the multiple regression analysis, a statistical (stepwise) regression was performed on the variables.

Table 25: Summary of multiple regression analysis for constructs predicting TPCK

Model	B (unstandardized coefficient)	Standard Error	Beta (standardized coefficient)
Constant	0.73	0.34	
Technological Knowledge	.062	.054	.083
Pedagogical Knowledge	.114	.102	.109
Content Knowledge	-.062	.113	-.051
Pedagogical Content Knowledge	.006	.116	.005
Technological Content Knowledge	.157	.093	.169
Technological Pedagogical Knowledge	.578	.103	.607***

***P < .001

The stepwise regression was not chosen first because of its characteristic of entering or deleting variables based on statistical criteria which therefore make any little difference have an impact on any of the predictors. Again, the stepwise regression was not conducted first because in regression analysis, several independent variables considered together tend to produce a much bigger R^2 than when they are considered singularly and separately (Tabachnick & Fidell, 2007). The stepwise method was chosen because the procedure begins without any particular predictor but rather adds the predictors as and when they meet the criteria (Tabachnick & Fidell, 2007). It also removes the least contributing independent variable anytime a predictor is added to the equation thereby removing any non-contributing predictors (Field, 2009).

The prediction model for the stepwise regression had two of the six predictors and was reached in two steps with no variable being removed. The model was statistically significant, F (2, 97) = 104.012, p < .001 and accounted for 68% of the variance of TPCK (R^2 =.686, Adjusted R^2 = .680). This result revealed that TPK and TCK were the primary predictors of New Zealand high school science teachers' TPCK. Though it came to light from the standard multiple regression that the TPK construct was the largest predictor of TPCK, the stepwise regression has shown that TCK also did contribute significantly to TPCK if all the other constructs are excluded from the model. Again the combined effect of the two predictors (TPK and TCK) raised the variance of TPCK accounted for by the predictors from 67% to 68%. Table 26 and Table 27 present the model summary and the regression results for the stepwise regression performed.

Table 26: Model summary for stepwise regression

Model	R	R^2	Adjusted R^2
1	.819	.670	.667
2	.829	.686	.680

Table 27: Stepwise regression results for TPCK

Model	B (unstandardized coefficient)	Standard Error	Beta (standardized coefficient)
Constant	0.84	0.24	
Technological Pedagogical Knowledge	0.63	0.08	0.67***
Technological Content Knowledge	0.18	0.08	0.19*

*p< 0.05; ***p<0.001

Technological Content Knowledge did not make any significant contribution to the model during the standard regression because of the nature of that procedure. In standard regression, all the predictors enter the model at the same time and independently; and that other variables are capable of whittling down the unique contribution of a particular variable (Tabachnick & Fidell, 2007).

Summary of the quantitative results

Teachers in this study revealed that they used ICT to facilitate their lesson preparation more than any other activity. They used ICT tools to search for information, content material and videos to facilitate their students' understanding of science concepts. The analysis of the survey data has brought to fore how New Zealand science teachers perceive their understanding of the various constructs of the TPACK framework. The responses of the teachers showed that they agreed with most of the items under the various constructs which when translated indicated that they had high opinion of themselves when it came to the constructs of the TPACK framework. The only construct that did not receive high rating was Technological Knowledge. The teachers felt that their Technological Knowledge was limited as compared to the other constructs of the TPACK framework.

The results have shown that the constructs of TPACK as far as New Zealand science teachers are concerned are highly correlated. All the six constructs correlated with TPCK. There were correlations between the various constructs with the exception of Technological Knowledge (TK) and Pedagogical Knowledge (PK); Technological Knowledge (TK) and Content Knowledge (CK); Technological Knowledge and Pedagogical Content Knowledge (PCK). The regression analyses that followed the correlations revealed that New Zealand science teachers' TPCK was predicted by their TPK and TCK.

Qualitative results

This section presents the case studies of the six teachers who were the unit of analysis in the case studies. Each teacher responded to a questionnaire, interviewed and their teaching episodes observed.

Case studies' settings

Six science teachers from two schools were the subjects of the case studies. The teachers selected were identified by the University of Canterbury Education Plus science advisor as using technology frequently in their lessons. The six science teachers in these case studies were interviewed, observed during teaching episodes and responded to a TPACK questionnaire which was a printed copy of the questionnaire used for the online survey. The interviews were semi-structured in nature and the questions covered areas such as their training in the use of technology to teach, how they teach with technology, the role ICT plays in their teaching and the context(s) that influence how they use technology. As noted in the earlier chapters, the use of technology in this study refers to digital technologies and ICT therefore ICT and technology were used interchangeably.

The six science teachers came from two schools situated in the south island Canterbury region of New Zealand. The schools have been labelled as School 'A' and School 'B' for the purpose of this study and were classified as decile eight and seven respectively. This will conceal their identities as agreed with the schools before the study took effect. School 'A' has a student population of approximately 2600 and School 'B' 960 students at the time of the study. Both schools are co-educational, public schools that pride themselves with the multicultural nature of their students.

Similarities between the schools

Teachers in each school had a laptop for their teaching and every classroom was fitted with a data projector. There were designated separate computer rooms and digital microscopes in each school. Both schools had a ‘Bring Your Own Device’ (BYOD) class where students were allowed to bring any technological device of their choice to assist their learning. The schools did not ask for specific devices to be brought but rather have left that decision to the students and their parents. Consequently, there were different devices ranging from handheld digital devices like iPods and smart phones to relatively larger ones like netbooks and laptops.

Both schools used Moodle as their Learning Management System (LMS). This system helped as a reference tool for students by providing overviews of the units of work, learning objectives, assignments, notes, homework and student projects using specific Moodle links for each subject. Teachers had reading materials for students on the LMS as well. Students were able to log on to the LMS from their homes. There were ICT committees in both schools which were in charge of making decisions with regards to the use of ICT tools in teaching and learning. The ICT committees were made up of teachers of the schools. The teachers who participated in this research pointed out that they were able to send their views to the committee through the departmental representative.

Most of the classrooms in which the observations occurred served simultaneously as classrooms and science laboratories. Only one classroom in School ‘B’ was purely a classroom with only desks and tables. The other classrooms in both schools had science equipment and tools. So the students in these classes undertake their science activities right in their classrooms. Both schools had relatively small class sizes. The largest class in which observation occurred had 25 students and the smallest had 16 students.

Differences between the schools

School ‘A’ was a decile 8 south island urban school. The school had netbooks and iPods which students were able to use. However students were able to use these devices only when a teacher had booked for them to be used in their lesson. Teachers had to book a set of netbooks or iPods in advance if they thought that students would need them for a lesson. The school had a Smartboard located in the Mathematics department as well as video conferencing facilities which the science teachers can use if the need arises.

School ‘B’ was a decile 7 south island urban area school. The school had document cameras for viewing objects. It also had a Hyper Interactive Teaching Technology (HITT) which is used as both an assessment and diagnostic tool in class. The HITT was a drill and practice-like software which contained questions on the various topics that teachers were teaching. Students were often asked to respond to the questions during classes using the HITT clickers. Students’ responses appeared on the bottom of the screen in a bar chart format through which teachers were able to see the number of students selecting a particular option. This technique provided instant feedback to the teachers so they were able to make informed decisions on the topics they had taught or were yet to teach based on students’ responses. The schools that took part in this study were very well resourced in terms of technological facilities and the students had ready access to digital tools and the internet.

In the next section, I discuss each teacher as a case with means of their scores on the various constructs of the TPACK framework, narrative report of the interviews and a description of their use of technology in their classrooms as seen during the observations of their teaching episodes. Cases of teachers in School ‘A’ are presented before those of School ‘B’. A summary of all the cases are presented to conclude the qualitative section.

Susan’s case: “It [ICT] just helps make lessons more interesting.”

Susan was a teacher in School ‘A’ who was teaching biology in years 11-13 and science in years 9-10. She was aged between 41-45 years at the time of the study and had been in the teaching profession for 20 years. I observed her teaching four times in her Year 10 science class and three times in her Year 13 biology class (See Table 12) and interviewed her in the classroom during a teaching break.

Teacher education and training to teach with ICT

Susan reflected that she had no ICT training during her initial teacher education programme. This, she argued, was because she had her education to become a teacher "a long time ago." During this time ICT was not popular and technology not too advanced. Though the school she teaches in has been organizing professional development programmes in ICT for teachers, the focus has not been on how to use such tools to teach. The professional development programmes introduced the teachers to the available technology and software, particularly the use of the Moodle, the school's learning management system, she noted. Susan therefore learned how to use ICT to teach through "word of mouth or trying things out for myself", through trial and error and reflection. She sought to "up skill" herself through what she termed the "odd course here and there." She emphasised that the knowledge she has when it comes to teaching with technology is through "just trying things out" for herself.

Aside from trying things out on her own, Susan admitted that she has replicated and emulated what some of her colleagues have been doing with technology after she had witnessed what they have done in their classes. She does not only learn from her colleagues but her students as well. She admitted that she has used technological devices after observing how some students were using such devices.

Susan felt confident in teaching with ICT when she was observed though she may not have had any 'formal' training. She did not feel handicapped or said she felt so. She however pointed out that it is "a challenge for me to try and to find something that might …help the students or make it more enjoyable." Thus, she needed to find out what digital activities, videos, simulations and software are available and how best she could incorporate such technologies into her practice for effective teaching.

Susan responded to a questionnaire on her knowledge of the constructs of technological pedagogical content knowledge framework. On a 'strongly disagree' to 'strongly agree' five-point Likert scale, Susan's mean scores for the various constructs of the TPACK framework can be seen in Table 28. The mean scores depicted how Susan rated her abilities when teaching with technology. She had mean scores above 4.0 for all the constructs on the TPACK framework. Her least value was a mean of 4.1 which she scored on the Technological Knowledge construct. A further analysis of her responses with regards to the 'Technological Knowledge' construct revealed that she 'agreed' or 'strongly agreed' with all but two of the statements. She 'disagreed' with the statement "I know how to solve my own technical problems."

Table 28: Susan's mean scores on each of the constructs on the TPACK framework

Constructs	Mean
Technological Knowledge	4.1
Pedagogical Knowledge	5.0
Content Knowledge	5.0
Pedagogical Content Knowledge	4.7
Technological Content Knowledge	4.6
Technological Pedagogical Knowledge	4.9
Technological Pedagogical Content Knowledge	5.0

The mean scores were derived from the score on each of the statements that made up each construct (See Appendix 5) .The responses were rated as 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=strongly disagree.

This seemed to suggest that though she has the skills to use technology, she does not know how to solve any technical problems that may arise. This was not surprising since her school has technical personnel who fix the school's technological problems.

However when asked if she had technical skills to use technologies, she did not 'disagree nor agree'. She stated in the interview that she learns how to use technology through trying things. This is because she has had no formal training in using technology to teach. She was cautious in responding that she has the skills needed to use technologies. This was because she could use some technologies easily without any difficulty, whereas she needed more professional learning for other technologies in order for her to use them effectively. Susan has strong belief in her abilities for teaching science effectively with technology as brought out by her responses to the items on the TPACK questionnaire.

Teaching with technology

Susan highlighted that she has been using ICT in her teaching for the past 12 years and rated her ICT use for teaching as being better than an intermediate user but not an expert. In an attempt to find out how often she used ICT in her teaching and her students' learning processes, she was asked to rank how often she did certain activities with ICT tools to facilitate teaching. Susan opined that she used ICT 'sometimes' (50% of the time) to prepare (e.g. search for information online) her lessons. She used ICT to make presentations and deliver content to her students 'every time' (> 90% of the time); she 'frequently' (70% of the time) used ICT to explore, demonstrate or elaborate a concept when she's teaching. Though she 'rarely' (10% of the time) used ICT to allow students to discuss issues through interactive whiteboard or online discussion forums, she 'frequently' used ICT to allow the students to view images or objects.

Technology has made her teaching fun as she described during the interview:

> I think it's made it more fun actually. So – oh there's so much more I can do. You know, I sort of think back to the days before YouTube and Google images, what did I do, you know, to try and make it interesting and fun?

She added that technology has not only made her teaching fun but it has added variety and depth to her teaching. After 20 years of teaching, she still has a passion for teaching due to technology.

> I think my teaching's become more enjoyable – even after 20years; I'm still really enjoying it.

The considerations that affected her use of a particular ICT tool were what her students preferred to use in the classroom; ease of use of the tool and the learning objectives of a topic. She stressed that students' technological preferences affected how she used technology in her teaching. She maintained that she had monitored her students and had come to the realization that her students "really like the use of small, handheld devices". Thus, she tried as much as possible to use what her students liked in her teaching. I noticed that she mostly booked the school's iPods for her lessons. It did seem that she preferred using the iPods in her teaching to the Netbooks.

Susan believed in the use of technology that worked during her teaching. She explained that she just makes sure it's all working beforehand.

> So if I'm going to show them something off YouTube, or there's a program on there that they might use on the netbooks, I check it out first, to make sure it's gonna work and it's not gonna shut down or it's not gonna do something crazy silly.

She does this because she reasoned that if she were going to ask students to perform an experiment, she would normally perform the experiment first to make sure that the experiment really worked. To her, it's the same thing with technology. She needs to make sure that the technology will work to perfection and result in the desired outcome.

Thus, though she tried things out, she made sure that whatever she was going to use actually worked and helped achieve the intended learning objectives and goals. To her, the main focus of using technology in her teaching was how best she could achieve the learning objectives and how best the students would be able to understand the concept(s) she was going to teach.

Susan contended that technology has not changed her lesson structure; she thought that technology had taken over some aspects of her teaching when she stated that "my lesson structure's fairly the same as it's always been" but conceded that there were aspects of her old teaching strategy that have been improved through the use of technology. For example, if she were to give a quiz in the past, she would have given it orally or written it on the board. However, she stated:

> Now it tends to be that it's on the screen or they have a netbook when they come in…it's still a quiz and it's still the same thing I'm doing. It's just that the ICT tool is slotted in there to run the quiz rather than me writing on the board.

She therefore accentuated that she is just using ICT tools to achieve the learning objectives or just to help the students understand a concept or an idea better.

The Roles of ICT in Susan's Teaching

"There's so much I can do" is how Susan put the role of technology in her teaching. She wondered how her teaching had been before the advent of digital technologies. "I sort of think back to the days before YouTube and Google images, what did I do?" She reckoned technology had made the search for information "instant and more enjoyable." This she illustrated by saying that if a student asked her how certain things worked and she did not know, she would probably reply:

> Oh, I don't know, let's just pop it into YouTube and see if we can find a little video to show what's going on and we can put it straight up on the screen.

Technology is therefore being used by Susan as an additional tool to aid her teaching.

For Susan, technology had endless possibilities for use in the classroom. She used it for "all sort of things." She stated that her use of digital technologies in teaching included:

> Taking photos, making movies to explain a learning objective. It could be simple research, an online quiz activity, sharing stuff on Google Docs.

She was convinced that technology improved students' understanding of concepts. This was because it focused them (students) and engaged them in what they were doing. This in turn, she believed led to an increased student interest in the concepts being studied.

Contextual use of technology

Susan used technology mostly with her year 10 group though her year 11 science extension class also received a lot of instruction through technology. She noted that the year 11 class “are a clever class and they just enlighten me to what I can do.” Thus, she tries to learn how to use technology from these students. This was in agreement with what Susan said when asked how she gained knowledge about how to use ICT in her teaching. She did indicate that she tried things out, learnt from colleagues and students.

When it came to her year 10 class, she used technology to keep them focussed and interested in science. She argued that most of the students in the year 10 class would not go on to study science therefore her idea was to use technology to motivate them to do science. An observation in her classes proved that she indeed allowed the year 10s to use more technology for their learning as compared to the year 13s. Students were asked to gather their own information in an inquiry model of learning through digital technologies and put such information together in the year 10 class. This made the lessons very student directed and centred. Susan believed the students became more motivated and interested in science when they are engaged with technology.

In the year 10 class I witnessed that the students were engaged in science projects. Students had to search for their own information, take pictures and videos of themselves, and collect different data for their projects. They were given choices about how they collected and presented the data or information. The finished projects were sent to Susan to be uploaded on the class’ Moodle space/site.

With the year 13 class however, she used technology mostly for presenting information and to elaborate on concepts. This made the lessons in her senior class very teacher directed. She asserted that she could not allow the seniors (year 13) to go and collect data, search for information and do all the things the juniors were doing because there was not enough time to cover all the content material required before they write their examinations and this lack of time prevented such activities in senior classes. Thus, she tried to deliver as much content as possible to the year 13 students. This is because this group of students had an external examination at the end of the year and she believed she could cover the content more effectively through more conventional teaching methods. Susan seemed to be focused on meeting the curriculum demands when it came to the senior class. She wanted to make sure that the seniors had covered enough content before they sat their examination. She therefore thought that she could deliver more content if she took charge of the teaching and learning process and provided the specific information the seniors needed in a short time. She thought the students might not find the specific information they needed and even if they did, it would take them a lot of time to get the accurate and targeted information. Given the amount of content to be covered at year 13, she considered the most effective way to assist students, was if she prepared and provided the needed information for them. Thus, she searched and prepared the information the students needed to know, looked for diagrams and videos that will help the students rather than allowing the students to do such searches themselves. She needed to direct the teaching and learning process in order to meet the curriculum demands

The students also expected her to do this. The next section presents the report on the observations of Susan's teaching episodes. Susan's uses of technology in her teaching in the two classes she was observed are presented.

Observation results for Susan

Susan was observed in two different classes: year 10 science and year 13 Biology classes. Four observations were conducted in the year 10 class and three were conducted in the year 13 class. The year 10 was a general science class whilst the year 13 was a biology class. The observations were conducted with the help of a checklist. The results of the observations have been summarized in Table 29.

In Susan's year 10 class, she was teaching a topic called 'Hazards'. She started the lesson by indicating to the students what they will be doing over the next couple of weeks. This she did by presenting the information to the students through her laptop and the class projector. The topic was going to be taught in a project format. Students were asked to form groups of their choice for the project. She explained the project to the students; gave the directions and asked the students to start the project. After this, she allowed the students to take charge of their learning process. The students recorded the activities they were doing with digital tools such as iPods and netbooks. These iPods and netbooks had already been booked and brought to the class by Susan.

In the course of the project, Susan demonstrated a concept to the students through a video she had downloaded from the internet. The video explained the concept of the project the students were undertaking and she played it from her laptop through the class projector to the students in the class.

The photos, videos and measurements made by the students were saved and a copy sent to the teacher as back up. Students returned and worked with the data in the subsequent lessons. Each group was expected to present its work to the whole class at the end of the project. The students chose how to gather data and present their work.

Table 29: Observation Responses depicting how Susan used Technology in her teaching

How teacher used technology	Year10 Science	Year 13 Biology	Technology used
To present content knowledge to students		✓✓✓	PowerPoint
To use ICT tools to allow students to examine/observe pictures, diagrams etc.		✓✓	PowerPoint
To let students gather information /conduct an inquiry	✓✓✓	✓	Internet

To support students generate data using digital devices	✓✓		iPods
To allow students put together collected data	✓✓		iPods, netbooks, laptops, internet
To demonstrate a concept through video	✓✓		YouTube, projector
To allow Students to present their work	✓	✓✓	Year 13- PowerPoint Year 10- iPods, netbooks, laptops
To explain or elaborate on a scientific concept		✓	PowerPoint
As a management tool	✓		PowerPoint
To explore science content through simulations			
To allow students take a quiz			
To allow students discuss opposing viewpoints			
To allow students review a test			
To let students recognize patterns, describe relationships and discrepancies			
To engage students in discussion			

A tick (✓) represents how many times the correspondent action was undertaken. There were seven observations in all: three in year 10 and four in year 13.

Each group made something unique and the presentation came in PowerPoint format, videos, and still pictures with voice overs. Students collaborated and cooperated with each other during the various lessons. The final work was again sent to the teacher for uploading to their class Moodle space/site.

The year 13 class was being taught mutation when the observations in their class started. Susan used her laptop and the projector to present the content knowledge to these students. Students were asked to search for information on the internet using the class set of netbooks only once during the observation period. Pictures, images and diagrams were presented through the projector by Susan as a means to elaborate and explain concepts to the students. Most of the students had made PowerPoint presentations about an assignment Susan had given to them whilst a small number decided to read from a sheet of paper to their colleagues when they were asked to present a previous given assignment.

Summary of Susan's profile

Susan was a very confident teacher who believed in her teaching abilities. She has a very positive opinion about her knowledge and skills for teaching. Having taught for over 20 years, it was expected that she would be a very confident teacher. She underestimated her ability to teach using a range of technologies which was probably due to the fact that she was being cautious since she had not had any formal training on how to use technology to teach during her initial teacher education programme. Moreover, she insisted that she had not undertaken any professional development that had really targeted how to teach with technology. Instead she learned how to teach with technology by herself, through observing and talking with colleagues, through trial and error and from the students themselves, showing her openness and willingness to learn new ways of doing things. Interestingly, she was very confident in her use of technology during her teaching.

Though she highlighted that technology made her teaching more fun and enjoyable, my observations revealed that she used technology in different ways during teaching. She seemed to use technology depending on the objectives of the lesson and her perception about the relative need to engage her students in interesting ways. In her junior classes, she enabled the students to engage with technology, allowed them to make choices and which thereby led to the students taking control of their own learning. In the senior class however, she directed what was to be learnt and took charge of the teaching and learning process.

The next section presents the profile of the second teacher who took part in this case study in School 'A' and in like manner, his interview responses, observation summaries and responses on the TPACK questionnaire have been presented.

Colin's profile: "I get more satisfaction from seeing the students learn in a creative way."

Colin was a teacher in School 'A' who was aged between 20-25 years and taught science in years 9-10 and physics in years 11-13. During the term of the study he was teaching science in two year 10 classes and physics in years 12 and 13. Colin was a relatively new teacher who was in the second year of teaching after being registered as a teacher during the course of this research. The observation of Colin's teaching episodes occurred in one of his year 10 science and his year 12 physics classes. There were four observations conducted in the year 10 science and three in the year 12 physics classes. The year 10 science class was a 'Bring Your Own Device'(BYOD) class in which the students were allowed to bring any technological device of their choice to the class. There were different devices ranging from handheld iPods and phones to large devices like netbooks and laptops. Students were allowed to search for information, take notes, pictures and videos with their devices in class.

Teacher education and training to teach with ICT

Colin completed his teacher education about three years prior to this study. When asked if he had any ICT training during his teacher education programme, he remarked:

> Yes we did. At the College of Education we had… one whole class was devoted to, basically ICT and developing ICT skills. So we'd learn there about things like Web 2.0 tools, and yeah, using My Portfolios in the classroom.

This implies that Colin had training in ICT during his initial teacher education programme. He argued that most of the content of the ICT course he took during his teacher education programme was focussed on delivering general knowledge and skills about technology. He revealed that there were a few times where there was information on how to use particular tools to teach. He noted that the course lecturers "did go into quite a bit of depth about how you can use a programme in your teaching." Thus, it seems the bulk of his ICT training was focused on how the preservice teachers could develop their general ICT skills.

Besides the ICT training he received during his teacher education programme, Colin mentioned that the school he teaches in also provided some form of ICT professional development for the staff.

> At the school we do, basically a bit of professional development, and we [have] done a little bit of ICT in that. Most of it there hasn't been much point. Most of its usually just when we change a computer program, like a database, we need to learn a new database... but in terms of the ICT for teaching, not so much.

He believed most of his professional learning in ICT was not specifically geared towards the use of ICT in the teaching and learning process. Rather, the professional development programmes in ICT were just to let teachers learn how to use new administrative tools. For example, he reported that the teachers were trained in how to use the school's administrative tool called 'Kamar' when they switched from the old one which was called MUSAC.

Colin's perception on his knowledge on the constructs of the technological pedagogical content knowledge framework was sought with the help of a five-point Likert scale with 'strongly disagree' to 'strongly agree' as the responses. His mean scores for the various constructs of the TPACK framework can be seen in Table 30.

Analysis of Colin's response pattern revealed that he 'agreed' or 'strongly agreed' to the statements making up the various constructs which confirmed his strong belief in his abilities. As a relatively new teacher, it was not out of place that his mean scores for 'Pedagogical Knowledge' and 'Pedagogical Content Knowledge' were smaller when compared to the other constructs.

Table 30: Colin's mean scores on each of the constructs on the TPACK framework

Constructs	Mean
Technological Knowledge	4.8
Pedagogical Knowledge	4.5
Content Knowledge	4.9
Pedagogical Content Knowledge	4.5
Technological Content Knowledge	4.8
Technological Pedagogical Knowledge	4.9
Technological Pedagogical Content Knowledge	4.9

The mean scores were derived from the score on each of the statements that made up each construct (See Appendix 5). The responses were rated as 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=strongly disagree.

His mean scores on some of the constructs of TPACK reflected his recent training and therefore were not surprising.

Colin pointed out that he determined the educational qualities of a technological device through trial and error. He believed that one cannot really just see a device and think that device will be brilliant for teaching. Such knowledge he reiterated comes from trial and error and comes with prolong use of devices. Since he had ICT training in his teacher education programme and had such high mean scores for 'Technological Content Knowledge', 'Technological Pedagogical Knowledge' and 'Technological Pedagogical Content Knowledge' constructs on the TPACK framework, it was surprising that he indicated he could not determine the educational qualities of a device without trialling it first.

Teaching with technology

Colin insisted that he has been using ICT in his teaching since he started teaching. He claimed that:

> The whole time I've been teaching, I've been using some form of ICT, whether it's just a simple PowerPoint, or YouTube videos or something, something like that….I've always tried to use a few applets.

He rated his ability to use ICT in teaching as 'better than an intermediate but not quite an expert yet. When asked how he used ICT in his teaching and students' learning processes, Colin noted that he 'frequently'(70% of the time) used ICT to prepare his lessons. The preparation encompassed the use of ICT to search for information online for his lessons. He declared that he used ICT 'frequently' to present or deliver the content he wanted to teach. This he did through PowerPoint or any other presentational software. Through simulations and animations, Colin 'frequently' explored, demonstrated or elaborated a concept to his students. He 'occasionally' (30% of the time) used ICT to allow students to discuss issues through online discussion forums. He also used ICT albeit 'frequently' to allow students to view images or objects.

In selecting a technological tool to use in his lesson, Colin will "try and think about sort of key activities which will…engage the students or make them think deeper" and select the appropriate technology to achieve that. He also added that time as well as convenience affected his decision to select a technological tool to use in his teaching. He reasoned that he did not want the situation where students will take a long time to use a technology for an activity and end up not learning much. He quickly added that though time and convenience do affect his selection of a technological device,

> Engaging the students is the key point. So if you can find something that's gonna engage the students and make them think, that's the main part of it.

Roles ICT plays in his Teaching

Colin asserted that ICT plays a big part in his lessons. Though he conceded that it takes a long time for him to make resources and to think about how he was going to teach using ICT, he believed it was worth the trouble since the outcome was always better than teaching without ICT. He insisted that he got more satisfaction from seeing students learn in a creative way and that ICT helps students to learn in "an inclusive environment where they're engaged in the work and they are switched on." He further reiterated that ICT has shifted teaching from a position where it was the teacher doing all the work to where students work and collaborate with each other. Therefore he allowed students to use ICT so that they (students) can take charge of their own learning and talk among themselves, share ideas and collaborate.

Colin further emphasized that ICT provided an opportunity for him to demonstrate a concept with ease. For example, a difficult to perform demonstration can be made easy through ICT. To him ICT "helps to deliver [content] and put it into a contextual situation." He cited an example as a teacher may try to demonstrate a satellite orbiting another object with a ball and another object and that it might be easier for students to understand if the teacher could find an applet which showed the orbiting of an object by a satellite. Thus, ICT enabled him to make abstract concepts real and helped students to appreciate the concepts being taught with ease. He reasoned that through ICT teachers can show and make the concepts students are learning relevant in real life.

Contextual use of ICT

The observation of the teaching episodes of Colin was done in two separate classes. When asked which of his classes he used ICT more often to teach, he admitted that "it would probably be the juniors". He accentuated that:

> A lot of the students now are comfortable with technology and so at a junior level I find it's quite good to have the technology, and it just basically makes them feel like home.

Because the juniors were accustomed to using technology and have them in their homes, he used technology to make his students feel at home i.e. to see school as more or less an extension of their homes.

He argued that ICT helped the juniors to be engaged in the teaching and learning process. It helped to get the junior students interested in coming to school. When asked if ICT cannot help engage the senior students, Colin agreed that ICT can help the seniors to be engaged in their learning but that he thought the junior students need the 'engagingness' at a younger level. He said that:

> School these days ...is seen – to be quite boring, um, which is how I think some of them see it. As – you know, there's a lot of exciting things they can do at [home] – they can play computer games and video games which are really exciting. Coming to school I think for them is sort of old-fashioned and more boring, and so if we can use ICT for those younger classes um and keep them engaged until they get to a senior level, um, I think that's, that's pretty key.

In his quest to 'engage' the juniors, he allowed them to take charge of their learning. He gave the junior students the opportunity to work with their technological devices. The junior students were allowed to search for information on the internet, put the collected information together and made presentations through the use of technological devices. He believed that when it came to the juniors "it's more of keeping them excited and keeping them having fun in science." Colin claimed that the senior students are "better off at managing themselves….and it's more about picking effective tools to use." Thus, in the senior class he takes charge of the teaching and learning process whilst in the junior classes he becomes more of a facilitator. He also postulated that the senior students have National Certificate of Educational Achievement (NCEA) to sit and that they will write the examination with pen and paper "so no matter what their ICT skill is, they need to be able to do the old way as well." When he was asked why he was not using ICT more in the seniors if ICT can help in the understanding of concepts, Colin stressed that "if there was a good applet out there, if there's something that demonstrated a concept really well to them, that's definitely worth using." He will use ICT to help his senior students better understand a concept. To him, the “junior classes need ICT, whereas the senior classes, it’s a nice touch to basically finish off [their] conceptual understanding.”

Colin used ICT to help his junior students get interested and engaged in science. Therefore, he allowed the students to take charge of their learning. The teaching and learning process in the junior class was very much student centred and directed as was witnessed during the observations. The students had the freedom to search for their own information, manage the information and present it in any format of their choice. When it came to the senior students, Colin was very much in charge of the teaching and learning process. He used PowerPoint presentation and led the teaching. Students in the senior class were very passive in the process.

Observations made in Colin’s classes

The observations for Colin were conducted in two of his classes: a year 10 science class and a year 12 Physics class. Four observations were conducted in his year 10 class and three in the year 12 class. There were a maximum of 25 students in the year 10 class and 22 in the year 12 class during the period of the observations. The year 10 class was a ‘bring your own device’ (BYOD) class whereby students were allowed to bring any technological device of their choice to the class. Colin explained that the school does not place restrictions on what device a student can bring. Students in this class can use their devices to take notes, search for information and make presentations during lessons. A summary of the observations can be seen in Table 31.

Colin was teaching ‘climate change’ in the year 10 class during the observations. He told the students the topic was going to be treated in a project manner and put the students into groups. At the beginning of the lesson, he gave out the instructions about the project. The instructions included the scoring rubrics, what was expecting of the students and how they could present their work. He further gave the students a few internet links from which they could get information for their project.

The students worked collaboratively at the task given and shared the responsibilities. Some of the students searched for information about the topic, others wrote down the needed information and others put the gathered information together. Students were seen critiquing each other's information before the whole group accepted it. There were instances where Colin was called in to act as an arbiter on the validity of some information. Students used different technological devices to undertake their project. Each student had his or her own device. It was also noticed that students in different groups shared information, ideas and technological skills. Students who were struggling with technological skills were helped by their group members or members of a different group.

The students then put their information together and each group presented their work to the whole class. The presentations came in different forms including videos made with movie maker software. Students who made their presentation in this format had pictures explaining their concepts put together in a video form with one student narrating the events to explain the concepts.

Others videoed themselves while explaining the concepts of climate change and their project in general. Some students used animations to present their work. There was one group that made a PowerPoint presentation and manually explained their work.

In the year 12 Physics class, Colin presented the content to be learned to the students through PowerPoint presentations with diagrams to elaborate the concept he was teaching. Colin had quiz projected on the board for the students to respond to. After the responses, he then reviewed the questions with the students.

It was seen that Colin allowed the students in the year 10 science class to take charge of their learning. He gave the year 10 students the opportunity to use a lot of ICT tools in their learning.

Table 31: An observation responses depicting how Colin used technology in his teaching

How teacher used technology	Year 10 Science	Year 12 Physics	Technology used
To present content knowledge to students		✓✓✓	PowerPoint, laptop, projector
To use ICT tools allow students to examine/observe pictures, diagrams etc.		✓	PowerPoint
To let students gather information /conduct an inquiry	✓✓✓		Internet, netbooks, iPhones, iPods, laptops
To support students generate data using digital devices	✓✓✓		Netbooks, laptops, iPods, Tablets, phones
To allow students put together collected data			
To demonstrate a concept through video			
To allow students to present their work	✓		Videos, PowerPoint, Netbooks, laptops
To explain or elaborate on a scientific concept		✓	Laptop, PowerPoint
As a management tool to present information to students	✓		Projector, laptop
To explore science content through simulations			
To allow students take a quiz		✓✓	Laptop, PowerPoint
To allow students discuss opposing viewpoints			
To allow students review a test		✓	Laptop, PowerPoint
To let students recognize patterns, describe relationships and discrepancies			
To engage students in discussion			

A tick (✓) represents how many times the correspondent action was undertaken. There were seven observations in all: three in year 10 and four in year 12.

This probably has led to the students being able to search for their own information, build up collaboration and connectedness.

Teaching and learning in this class was very much student directed and centred. Students were the architects of their own learning. In the senior class however Colin led the teaching and learning process. He came to class with his prepared notes and presented the learning matter to the students. Though he used ICT, it was used to help him deliver and explain the content to the students.

Colin maintained that he used ICT to help engage the junior students in the lesson and science in general. To him the juniors needed such engagement. He noted that the focus for the seniors, as far as he was concerned, was to develop conceptual understanding and thus he can do that without much ICT. His teaching and use of ICT in the senior class was very much teacher directed and centred.

Summary of Colin's profile

Colin's perceptions of his abilities as far as the constructs on the TPACK framework was concerned aligned with what was witnessed in his classes. His relatively high scores on the technology and content related constructs of TPACK could be attributed to the fact that he is a recent graduate. He did his teacher education programme in an era where technology had become common place and therefore had training in how to use such technologies to teach during his initial teacher education programme. His confidence in the content knowledge could also be attributed to the same reason i.e. he is a recent graduate. It was evident during the observations that he planned and made technology play a big part in his teaching albeit to different degrees in the two levels he teaches. He stated during the interviews that he used technology more often in the junior levels. To him, the juniors needed technology more because the use of technology helped them to be engaged in the teaching and learning process. He thought that the senior students were old enough to manage themselves. Their external examinations drove him to find the right tools for teaching conceptual understanding to senior students as seen during the observations his teaching in the seniors' class. He took charge of the teaching and learning process with the seniors. He made the content matter into presentations and presented them to the students. He led the discussions and students asked questions.

The interviews, observation summaries and the means for the various constructs on the TPACK framework which together formed the case for the third teacher in School 'A' has been presented in the next section.

Janet's profile: "I think it [ICT] puts them [students] in charge of their own learning."

Janet was an elderly teacher with vast teaching experience who has taught in different schools. In her 41st year of teaching, Janet currently teaches science in years 9-10 and chemistry in years 11-13 in School 'A'. The observations for this study were conducted in Janet's year 10 science and year 12 Chemistry classes. There were four observations in the year 10 class and three in the year 12 Chemistry class.

Teacher education and training to teach with ICT

Janet contended that ICT did not really exist when she was being educated as a teacher. She therefore claimed that she learned how to use ICT in her teaching through people she has worked with over the years. "Basically I suppose I've just got tips and ideas from various people that I've worked with and been on the odd course, but never really had a lot of formal instruction" was how she described how she has learned to use ICT. She had a "bit" of formal education in computing and other ICT when she was on a study leave in 1996. She reported that it was during that time that she got to know email.

In order to improve upon her knowledge in the use of ICT in teaching, Janet posited that she deliberately attended sessions on how to use ICT in teaching at conferences. She has also participated in ICT related professional development programmes. Yet, Janet insisted that the bulk of her knowledge about teaching with ICT came from reading and listening to other people.

An attempt was made to gauge Janet's perception of her knowledge with regards to the constructs of the TPACK framework. This was done through the use of a five-point Likert scale with responses ranging from 'strongly disagree' to 'strongly agree'. Janet's responses to the items on the various constructs on the TPACK framework were scored and the mean scores provided in Table 32.

Janet scored mean values of 4.0 and above for 'Technological Knowledge', 'Pedagogical Knowledge', 'Technological Content Knowledge' and 'Technological Pedagogical Knowledge'. As can be seen from Table 32, she had a high score for 'Pedagogical Knowledge' and most of the constructs that are technology related. The only technology related construct that she had a mean score less than 4.0 was 'Technological Pedagogical Content Knowledge'. She had a score of 3.9 for this construct. A critical and further analysis of the items that formed this construct was therefore conducted. She agreed with all the items except one.

She 'Neither agreed nor disagreed' with the statement "I am able to use technology to create effective representations of content that departs from textbook approaches." This implied that Janet could not emphatically say whether her use of technology in teaching departs from conventional textbook approaches. A neutral position presupposes, to a large extent, her inability to perform the action the particular item was referring to which therefore implies that she cannot create representations with technology that depart from a typical textbook instruction.

Table 32: Janet’s mean scores on each of the constructs on the TPACK framework

Constructs	Mean
Technological Knowledge	4.7
Pedagogical Knowledge	4.0
Content Knowledge	3.6
Pedagogical Content Knowledge	3.5
Technological Content Knowledge	4.0
Technological Pedagogical Knowledge	4.0
Technological Pedagogical Content Knowledge	3.9

The mean scores were derived from the score on each of the statements that made up each construct(See Appendix 5) .The responses were rated as 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=strongly disagree.

Janet had a mean score of 3.6 for ‘Content Knowledge’ and 3.5 for ‘Pedagogical Content Knowledge’. A further analysis revealed that she disagreed with the statement “I have good understanding of the Nature of Science” under the ‘Content Knowledge’ construct. This resulted in a low mean score for the whole construct. The Nature of Science strand is a very important strand in the New Zealand Curriculum and one which is relatively new to teachers. It is compulsory for all students from Year One to Year 10. This strand talks about the importance of scientific processes, seeks to introduce students to how science is carried out and emphasises investigations and communication in science. The focus of this strand is to help students to understand the way scientific knowledge is developed and how science relates to their lives and the everyday context of wider society (Ministry of Education, 2007). Thus, science teachers should be able to understand the Nature of Science before they can teach their students. Unfortunately, Janet conceded that she does not have a very good understanding of this strand although she teaches in a class where Nature of Science is a compulsory subject.

On the 'Pedagogical Content Knowledge' construct, a review of Janet's responses revealed that she disagreed with the statements "I can distinguish between correct and incorrect problem solving attempts by students within my class" and "I explicitly target aspects of the Nature of Science when teaching." Her response to these items seemed to have lowered her score in this construct. Since she agreed that she does not have a good understanding of Nature of Science, it was not surprising that her teaching did not target aspects of that strand. However, having taught for so many years, it was very surprising that she felt that she cannot distinguish between students correct and incorrect problem solving attempts.

Teaching with technology

Janet's first experience with technology in teaching was in 1990 during which the school she was teaching in at that time had standalone computers. She remarked that those computers were networked and she did use them a lot. Although she seemed to have had an encounter with computers quite early, she still rated her skills to teach with ICT as better than an immediate but would not consider herself as an expert. In her teaching, she used ICT 'every time' (> 90% of the time) to prepare her lessons by searching for information on the internet, videos, animations and simulations for her students. She 'rarely' (10% of the time) delivered the content to be learned to students through presentation software. Through animations, simulations and videos she 'frequently' (70% of the time) explored, demonstrated or elaborated concepts to be learned to her students. She 'rarely' discussed issues through interactive white boards or online discussion forums with the students. In the course of her teaching, she 'frequently' used ICT to allow students to view images or objects through animations and digital images.

“What do I want them to do; how can I engage them; and what tool do I have that will do this and engage them”? These are the questions Janet asks herself before selecting a technological tool to use in her lesson. She explained that teacher-centred activities are boring so she was always thinking “how can I make this more engaging and also get the kids to get the required or bring to mind the required information”? She has therefore found the solution to these questions through technology. She posited that technology has allowed her to put her students in charge of their own learning.

Janet claimed that teaching with ICT was easy. To her, “just with the internet and your own computer, the teacher’s computer, you can seize the moment more...easily than you can without it”. She explained that with technology it was easy to get current information and students can relate with such current information with ease.

She insisted that ICT has made her lessons more interesting to her students thereby culminating in her taking a personal delight in teaching with ICT. She emphasised that it makes her teaching better. “It’s better for the kids, it’s better for me” is how she captured teaching with ICT.

Roles ICT plays in her Teaching

Technology played an integral part of Janet’s teaching and she reckoned the influence of ICT on her teaching was huge. She upheld that:

> Before ICT it was probably very much text-books, much harder to make the learning student-centred I think. It’s definitely possible, sure. Um, but things like a 10-year-old textbook are not nearly as engaging as up-to-date information out of the internet. So I think the impact has been huge.

To her ICT provided opportunities to make her teaching student-centred. Though she agreed that it was possible to make teaching student-centred without ICT, she underscored that the advancement of ICT has made it easier to present a student-centred content to students. Janet accentuated that ICT has shifted her role as an epitome of knowledge to a facilitator.

> So I'm not a person out front delivering the stuff. It's allowed me to put the students in charge of their own learning.

She asserted that ICT takes the focus and tension off from her and thereby not making her to "be the sage on stage so much." She believed her role is to guide the students to search and make meaning out of the appropriate information. She demonstrated this in her year 10 class where the students were making a project on earthquakes. She allowed the students to search for their own information and make meaning out of the retrieved information. In her senior class however, she was pretty much in charge and directed student learning.

She further contended that with ICT "it's easier for them (students) to work cooperatively" and to create a better and more productive atmosphere in class. She stressed that ICT has "made it easier to make learning relevant" because she can easily link students learning to real life events through ICT. It seemed important to her that students need not learn things abstractly anymore but they could be provided with real life events of the concepts they are learning.

Contextual use of ICT

Since Janet teaches in both junior and senior classes, she was asked in which of the two levels she uses ICT the most. "I use ICT a lot with my year 10s, and quiet a lot" was her reply. She attributed this to the fact that the juniors were not so focussed on examinations. She reasoned that the use of ICT in teaching takes a lot of time and she cannot lose anytime with the seniors who have examinations to write. She explained that her use of ICT in the junior classes was to foster inquiry learning whereby the students take charge of their own learning. She alerted that though she was behind in terms of what she has to teach as far as the year 10s were concerned because of her frequent use of ICT, "it doesn't really matter" because they will catch up. However she accentuated that she can't be behind with her senior classes.

> You have to think more carefully before you put them [seniors] in charge of their own learning. I have to make sure that I've got the resources there that will support the learning that they actually need, whereas with my year 10s, I can perhaps be… allow a little bit more time for them to do their own research and, and to find resources – you know, like websites or whatever that are appropriate.

She explained that the seniors were expected to cover certain amounts of content knowledge before they will be adequately prepared for their examinations. Therefore she could not allow them to take charge of their own learning through the use of ICT. She believed it was her duty to find the appropriate resources that seniors needed for effective learning. "Basically I'm trying to feed stuff into their heads" is how she described her teaching when it comes to the senior classes.

Observations made in Janet's classes

Janet's teaching episodes were observed in her year 10 and 12 classes with four observations conducted in the year 10 science class and three in the year 12 chemistry class. A summary of the observations conducted in Janet's classes can be found in Table 33. Twenty-nine students were in the year 10 class during the course of the observations and the year 12 class had 23 students.

Janet was teaching 'chemical equilibrium' in the year 12 class and all the lessons took place in the classroom. In the first lesson, Janet booked for a set of netbooks to be used by the students. Most of the students had one netbook but few students shared the netbooks with their friends. In the beginning of the lesson Janet played a video from her laptop to the whole class. It was a YouTube video of 'equilibrium song'. She then asked the students to log onto the school's Moodle space/site to watch a video she had uploaded for the students. Janet explained the concepts as students watched the video which had been uploaded on the Moodle space/site.

Janet continued teaching the concept ‘equilibrium’ during the second day of observations. She presented the content knowledge to the students through her PowerPoint presentation with intermittent questions, students responded to the questions and if students had any issues they also asked Janet. This lesson was very much teacher directed. The use of any form of ICT was done by Janet. The third lesson followed a similar trend with Janet leading the teaching by presenting the information she wanted the students to know. She then asked the students to undertake some experiments on ‘equilibrium’. Although Janet was not expecting the students to come to class because they were writing examinations, Janet was still able to teach them when they unexpectedly came to class. This was possible because Janet had already uploaded the lesson material on the class’ Moodle space therefore she just asked the students to log on to their Moodle site.

In the year 10 class, Janet taught two different topics in the course of the observation. The first teaching episode observed was on the topic ‘reactions’ which was about the effect of a catalyst on a reaction. Janet took the students through how various catalysts affect the rate of a reaction. She led the discussion through a PowerPoint presentation. Students asked questions and responded to Janet’s questions as well. This lesson was very teacher directed in terms of the content delivery and use of ICT tools.

She concluded the topic on ‘reactions’ and started a new project during the second observation. Janet brought in netbooks for this lesson. In this lesson, students watched videos on the effect of different catalysts on rates of reaction. There were YouTube videos played directly from the internet by Janet and there were other videos she had uploaded to the class’ Moodle space/site. She then presented the information about the new project to the students. The project was “earth science research’ based. Students were to explain to a foreigner why New Zealand has more earthquakes than Australia.

Janet gave out the task sheet of the project to the students as a group by presenting it through her laptop first and later gave out printed copies to each student. The task sheet contained instructions to the project, questions for students to think about and internet links for information. Students were to present their work in a form of a pamphlet and also upload it to their wikispaces. The questions served as a guideline to the students. Janet made the project such that in the students' quest to answer each question, they will ultimately be able to answer the main question. Students started the project by searching for information on the internet through their netbooks. Most students were seen searching for information from different websites other than what Janet provided to them. Students downloaded and saved the information they needed for the project.

On the second day of the project, Janet moved the class to one of the school's computer rooms because she wanted every student to have a computer to work with. This was because there were not enough netbooks so some students had to share. Students continued to search for their information. In the course of the class, I noticed that some students had started putting their information together and had started to develop their pamphlet. Even though each student had a computer to work with, students collaborated and helped each other. They shared information and critiqued each other's information.

Students who were more proficient in the use of computers were seen teaching their peers how to use the computer to develop their pamphlets. This was interesting since each student was supposed to present a separate work. One would have thought they would be competing among themselves yet they decided to cooperate and collaborate. The students in this class were used to sharing information and working collaboratively and it seemed technology offered more opportunity to collaborate. Janet also encouraged them to share information and help each other.

Table 33: An observation responses depicting how Janet used technology in her teaching

How teacher used technology	Year 10 Science	Year 12 Chemistry	Technology used
To present content knowledge to students	✓	✓✓	PowerPoint, laptop, projector
To allow students to examine/observe pictures, diagrams etc.			PowerPoint
To let students gather information /conduct an inquiry	✓✓✓		Internet, netbooks, Desktop
To support students generate data using digital devices	✓✓		Desktop
To allow students put together collected data			
To demonstrate a concept through video	✓	✓	Laptop, projector, Netbooks
To allow Students to present their work			
To explain or elaborate on a scientific concept			Laptop, PowerPoint
As a management tool to present information to students	✓		Projector, laptop
To explore science content through simulations	✓		Netbooks
To allow students take a quiz			
To allow students discuss opposing viewpoints			
To allow students review a test			
To let students recognize patterns, describe relationships and discrepancies		✓	Laptop, Projector
To engage students in discussion		✓	Laptop, PowerPoint

A tick (✓) represents how many times the correspondent action was undertaken. There were seven observations in all: three in year 10 and four in year 12.

Janet insisted that the purpose of the project was not only for the students to know why New Zealand has so many earthquakes but also to improve their communication skills in line with the Nature of Science aspect of the New Zealand curriculum. She believed a scientist should be able to explain his scientific ideas to other people. This forms part of the Nature of Science aspect of the curriculum yet Janet reported in the questionnaire that she does not target nature of Science aspects when teaching.

Summary of Janet's profile

Having been educated as a teacher in an era where technology was not so advanced, Janet has taught herself how to use ICT to teach. She has made conscious efforts to learn how to use technology to teach. This she did by reading, attending conferences, participating in ICT related professional developments and learning from other teachers. This was confirmed by the observations that Janet used ICT in teaching frequently. It was not surprising that she maintained that she used technology almost every time in her teaching. Her mean scores for the various constructs on the TPACK framework showed that she was really into technology since she had relatively high scores on constructs related with technology although her score for TPCK (3.9) was the second lowest of all the six interviewees.

She had relatively low scores on 'Content Knowledge' and 'Pedagogical Content Knowledge'. This was attributed to the fact that she had little understanding of the Nature of Science and how to specifically teach aspects of the Nature of Science. The Nature of Science strand is relatively new in the New Zealand curriculum. Though the Ministry of Education and other stakeholders in education are undertaking professional development on the Nature of Science aspect of the curriculum, it seems Janet is one of the teachers who is still not so clear about how to teach that strand.

Janet claimed that she used ICT to facilitate student-centred teaching. This was evident only in her junior science class. She allowed students in the junior class to take charge of their learning through project work and online searches using various ICT tools. When it came to her senior classes, she took charge of the teaching and learning process. This, she contended, was because she believed she was better placed to provide the senior students with what she thought would benefit them in their external examinations. She believed ICT could foster student engagement, make learning relevant and facilitate cooperative learning, but only acted on this belief with her junior classes. Technology therefore played a major role in her teaching.

Again, although Janet responded that she rarely delivered content to be learned to students through presentation software in the questionnaire, it was observed that she used PowerPoint more often in her senior class. Indeed, she did not use much of presentation software in her class. There seemed therefore that her use of ICT was very much context dependent as noted by her in during the interview that she delivers the content to the senior class because of the focus on external examinations.

The cases of teachers in School ‘B’ are presented in the next section. The presentation followed no particular order.

Case studies in School ‘B’

The following section reports the cases of the three teachers from School ‘B’. Two biology teachers and one physics teacher participated in the research from this school. Each teacher was interviewed, observed during teaching episodes and responded to a TPACK questionnaire. A total of 23 (Table 12) observations were conducted in School ‘B’ with each teacher’s teaching episodes being watched four times in two separate classes with the exception of Elliot whose teaching was observed three times in his Year 12 class.

Elliot’s profile: “It’s keeping the students engaged.”

Elliot teaches science and biology in School ‘B’, was in the second year of teaching during the time of this research and is aged between 31-35 years. Elliot worked in a research institution prior to becoming a teacher. He also did relief teaching and taught outdoor education for over seven years. Elliot’s teaching was observed four times in his year 10 class and three times in the year 12 biology class (See Table 12). He was the only teacher who was observed seven times in School ‘B’ because his year 12 class went for a field experience programme so he was one short of observation as compared to the other two teachers in the school.

Teacher education and training to teach with ICT

Elliot had a course on ICT during his teacher education programme which gave him some background about available ICT to facilitate teaching. He asserted that the ICT course was more or less an avenue where students including him were told of the available tools they can use in their teaching without necessarily being taught how to use such technology in teaching. He specified that the knowledge he has when it comes to using ICT to make presentations came from his research background. He acknowledged that he was taught how to use ICT to teach during his biology curriculum class at the university. The ICT component of his biology curriculum course provided good examples of technological tools available to teachers and how best those tools can be applied and used in teaching. He explained how he has been using technology in his teaching and indicated that:

> It’s been a lot of playing around with what’s the better way to get them to start using technology, especially in terms of using Moodle or wikis or those kinds of things. So I’ve tried two or three different classes, systems with different classes and it’s just seeing, what are the things they actually do in that they actually help-so mostly trial and error.

He further reiterated that he has not had professional development with regards to the use of technology in teaching. He mentioned that the closest professional development he had was when he participated in a BIO LIVE conference. This is a biennial national biology teachers’ conference. He explained that there were sessions on ICT in biology during that conference though they were not directly geared towards how to use such technology to teach. Elliot therefore believed that he learned how to use technology in his teaching basically from trying things out.

To further ascertain his knowledge on how to teach with technology, his views on his knowledge on the constructs of the technological pedagogical content knowledge (TPACK) framework were sought. On a ‘strongly disagree’ to ‘strongly agree’ five-point Likert scale, Elliot’s mean scores for the various constructs of the TPACK framework can be seen in Table 34. Elliot scored a mean of 4.0 and above for Technological Knowledge, Pedagogical Knowledge, Content Knowledge and Technological Pedagogical Knowledge with his strongest being in the area of Content Knowledge which he had a mean score of 4.4. He therefore had a high opinion about his skills in these areas. His lowest scores were means of 3.5, 3.6 and 3.8 for Technological Pedagogical Content Knowledge, Technological Content Knowledge and Pedagogical Content Knowledge respectively.

It was seen on further analysis of his responses that he ‘neither agreed nor disagreed’ with some of the items under Technological Pedagogical Content Knowledge construct. These items were; “I can teach lessons that appropriately combine my subject matter, technologies, and teaching approaches”; “I can use strategies that combine content, technologies, and teaching approaches in my classroom”; “I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school”; and “I can use technology to facilitate scientific inquiry in the classroom”. The responses he gave to these items signified that he was not too sure about his abilities to perform these tasks and thus questions his own knowledge on these items. Though he would not agree that he cannot perform these acts, he could not emphatically say he can do them either.

On Technological Content Knowledge construct, Elliot agreed to all the items except two. He ‘neither agreed nor disagreed’ when asked if he knew about technologies that he can use to enhance the understanding of specific concepts.

Table 34: Elliot's mean scores on each of the constructs on the TPACK framework

Constructs	Mean
Technological Knowledge	4.0
Pedagogical Knowledge	4.3
Content Knowledge	4.4
Pedagogical Content Knowledge	3.8
Technological Content Knowledge	3.6
Technological Pedagogical Knowledge	4.0
Technological Pedagogical Content Knowledge	3.5

The mean scores were derived from the score on each of the statements that made up each construct (See Appendix 5). The responses were rated as 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=strongly disagree.

He disagreed that he could use technology to create and manipulate models of scientific phenomenon. These two items lowered Elliot's score for this construct and thus yielded a low mean score for him. Therefore Elliot acknowledged that he was not sure whether he really knew technologies that he could use to help his students understand concepts. Moreover, he highlighted the fact that he was not able to manipulate scientific phenomenon with technology. Elliot's position on these two items was backed up by his interview comments that he learned how to use technology to teach through trial and error and added that he had not had enough training on how to use technology to teach. As well as his personal intuitions to guide him in selecting tools to use, he also used technologies based on other teachers' recommendations and commented that "other teachers say this works really well if you run this experiment and there's a couple of tools that you can use."

A detailed analysis of the items under Pedagogical Content Knowledge construct which he had a mean score of 3.8, revealed that he 'neither agreed nor disagreed' when he was asked whether he can anticipate likely student misconceptions within a particular topic. He gave the same response when asked if he was familiar with common student understandings and misconceptions in the subjects he teaches. The responses to these items highlighted the fact that Elliot seemed to be cautious when it came to issues with students' misconceptions of concepts. It is best if the teacher knows the misconceptions of the students so that he can direct his teaching to the elimination of those misconceptions. However, it is difficult for one to know all the misconceptions different students may have about a concept. Therefore it looked as if Elliot was being cautious about his abilities in that regard since he is a relatively new teacher.

On a whole his awareness levels of the various TPACK constructs were positive though not all the constructs had very strong means. He had a relatively low score for TPCK as compared to the other teachers who took part in the observation. Elliot seemed to be very modest when it comes to his teaching abilities. Though he does not lack confidence he seemed to have a very unassuming personality. It may be due to the fact that he has just recently registered as a teacher.

Teaching with technology

Since Elliot registered as a professional teacher quite recently (2 years ago), he started teaching with ICT right from the onset and rated his ability to teach with technology as one of an intermediate user. He therefore has not had to modify his teaching to incorporate ICT because he started teaching with ICT.

Elliot opined that he used ICT 'every time' to help him prepare for his lessons and 'sometimes' (50% of the time) to deliver the content material he wanted to teach to his students. He further reiterated that he 'frequently' (70% of the time) used ICT to explore, demonstrate or elaborate a concept through animations or simulations to the students; 'occasionally' (30% of the time) he allowed the students to discuss issues through ICT tools and ‘frequently’ allowed the students to view digital images or objects. These were the ways he used ICT in his teaching and to enhance students’ learning.

To select the appropriate technological tool for teaching Elliot hypothesized that he put himself in the shoes of students and asked himself if such tools would help him in his own learning. He therefore selected ICT tools for his students if those tools could help increase his learning.

> I guess I try – mostly I try and think about what kind of things would’ve, would help me in my learning. That’s the way I usually approach it. So if it’s something I think would help me to understand the concept better or to walk through, then it’s something that I wanna try, and that’s often where a lot of it comes from.

In this way he believed he chose the appropriate technology for his students. The use of technology in his teaching was to help students to continue to learn outside of the classroom as well as be self-reliant when it came to their learning.

> A lot of what I’ve been trying to do in the last time is I want them to be able to recognise that learning should be happening outside the classroom as well. So a lot of the tools I’m trying to use are ones – so they recognise that they can access these whenever they want. So as opposed to always having to ask me for something, so which means it can only be done in a classroom, if they have a question or something at home, they have sources that they can use to start answering that, and so that they’re engaging in learning all the time as opposed to only in our class, when they’re in with me.

Elliot was determined to use technology to help students to become lifelong learners and did not restrict learning to the classroom or only what he provided during presentations. He also actively looked for tools that encouraged continuous learning for his students. Elliot alerted that he also selected tools to help engage students as well as add value to the content he wanted to teach.

Elliot regularly appraised his own teaching in order to identify ways in which he could use technology to be more effective. He often asked himself if a tool contributed to students' understanding; did it engage them more or did it add anything to the course after each lesson? He stated that if the tool did not meet any of these criteria then he would not use it again. Moreover, he would not use a tool that had software problems or problems when implementing it in the classroom or one that wasted a lot of time to use. In selecting new tools to use in his teaching, he relied on tools that other colleagues had used and recommended as useful. He further looked at the tool to find out if it would help him deliver the information he wanted the students to have.

The Roles of ICT in Elliot's Teaching

Technology played a big role in Elliot's teaching because of its ability to keep students engaged as well as present a visual representation of concepts he wanted to teach to students. He reasoned that technology should be able to go beyond just helping to give out mere information to students. Thus, the important thing for him was that technology provided the opportunity for students to be interactively engaged and interested in their learning rather than just sitting and listening to the teacher. He stated that the biggest reason for using technology in his teaching was that:

> ICT offers another option to have them interact with their learning more and so give them a chance to engage more in their learning but also maybe to take a bit more responsibility, which is what we're trying to do in terms of them developing some of their own resources, and learning more about where to find the information if they want it, so as opposed to just asking me what the answer is, what it is, is giving them skills in terms of being able to find the information themselves.

Elliot emphasised that his end goal was to help the students learn technological skills which will help in their own learning. He enjoyed the affordances of ICT for providing different approaches to deliver content material which are very different from the traditional teaching approaches.

He described the myriad ways in which he has been using technology in his teaching including the use of PowerPoint presentations mixed with animations and videos to emphasize certain points. Sometimes he used the schools' learning management system for students to submit information or to post information to them; to collect homework as well as run activities on websites outside of the classroom. There were times when he used a lot of video tools such as digital microscopes and video i.e. he downloaded the videos that he could use as demonstrations from YouTube and other online resources to supplement what he expected students to see. He reasoned that the videos made it easier to "demonstrate things and make sure everybody's actually seeing it, as opposed to having 20 people crowd around me trying to dissect something." In order to get immediate feedback and find out whether students actually understood what's happening, Elliot used his school's Hyper Interactive Teaching Technology a lot. This to him was a very good formative assessment tool.

Thus, technology played an active role in Elliot's teaching and classroom practices. It made his teaching more meaningful and engaging, provided the opportunity for him to present and receive assignments from students as well as an avenue to provide feedback on assessments.

Contextual use of technology

Teaching two different levels within the school may demand that different approaches are used to teach these different groups. Therefore, Elliot was asked which groups of students he normally used ICT with in his teaching. He explained that he used technology with both levels to varying degrees. When it came to the seniors, he restricted himself to the school's LMS. He put notes and assignments on the LMS so that his senior students could access them as they required. However, he acknowledged that he often had more opportunities to use technology in the junior classes. "In terms of trying lots of different, more interactive tools and online things, I'd say I do it with my juniors more than the seniors."

To justify why he used technology more often in the junior levels, Elliot posited that:

> I think because we have a bit more freedom in terms of the curriculum at the junior level, and there's not the restrictions [sic] that NCEA places on some of them.

Since the juniors did not have any external examinations at the end of the year, he had the freedom to experiment with technology. He complained that the curriculum for the seniors was very broad and as a teacher he needed to cover enough of the content material the curriculum stipulates thus he cannot try out different technologies in interactive ways. He articulated that he can lose teaching time by spending more time with the juniors trying out a new technology but cannot do that with the seniors because any time lost would ultimately affect their preparations for the NCEA.

> In – with the year 10 junior class, you tend to have a little bit more flexible, flexibility in terms of how much time you have to teach the content, whereas with the senior classes, if you lose a couple of classes trying a new tool or trying something different, it's gonna have more of an impact on their overall learning, cos you don't have as much extra time.

Thus in his quest to cover all the necessary content before his seniors sat their examinations, Elliot restricted how much he "played with different technology" in the senior classes. He believed that due to time restrictions and the curriculum demands at the senior level, he could not try out new things. Therefore he imagined that if he was aware of the effectiveness of a tool, he would not hesitate to use it in the senior classes. Elliot seemed concerned about the fact that a new technology may not work or not yield the desired outcome when he tried it out with the seniors. Again, due to time factor he preferred giving content material through using technology to the seniors rather than allowing the students to search for the information themselves. Thus even if he tried something new with the seniors, it tended to be tools that they would use outside of the classroom for example, uploading reading material on the school's Moodle space/site for the students. Elliot therefore used technology interactively and tried new things in the junior classes whereas in the seniors he was restricted to using technology to deliver content material.

Observation of Elliot's teaching

There were seven teaching episodes that I witnessed in Elliot's classes: three in his year 10 science class and four in year 12 biology class. Using the checklist, what was occurring in each of the teaching episodes was recorded. The results are summarized in the Table 35. During the course of the observation, Elliot taught 'Test of nutrients' and 'Digestion' in the year 10 class and 'Gas exchange and circulation in exercise' in the year 12 biology class.

In the year 10 class, Elliot was teaching the last lesson on the topic 'Test of nutrients' when he was observed. He presented information he uploaded to the class' Moodle space/site to the whole class and explained the concepts to the students. After the presentation, the students responded to and reviewed answers to questions which Elliot had downloaded from the 'Brain Pop' website. Students were very vocal and expressed their opinions and defended their choices during the quiz time.

Elliot taught the topic 'Digestion' during the next two teaching episodes. In the first of these two lessons, Elliot concentrated on the digestive system with the 'teeth' as the topic under discussion. He taught the students the various types of teeth in mammals. This lesson was very much teacher directed with Elliot presenting information to students through PowerPoint presentations with diagrams and pictures of the various types of teeth.

During the third teaching episode, Elliot taught the year 10 class 'digestion' whereby he presented content information with diagrams and pictures to the students through a PowerPoint presentation. He also explained the concepts to the students through the use of animations and videos which he played through his laptop and projected to the whole class.

Table 35: An observation responses depicting how Elliot used technology in his teaching

How Elliot used technology	Year 10 Science	Year 12 Biology	Technology used
To present content knowledge to students	✓✓	✓✓	PowerPoint
To use ICT tools to allow students to examine/observe pictures, diagrams etc.	✓✓		PowerPoint
To let students gather information /conduct an inquiry	✓		Internet
To support students generate data using digital devices			
To allow students put together collected data	✓		Moodle
To demonstrate a concept through video	✓	✓	YouTube, Laptop, projector
To allow Students to present their work			
To explain or elaborate on a scientific concept	✓		PowerPoint
As a management tool	✓		Moodle
To explore science content through simulations			
To allow students take a quiz	✓	✓	Year 10: Brain pop website, projector, laptop Year 12: HITT clickers
To allow students discuss opposing viewpoints			
To allow students review a test	✓	✓	Year 10:Brain pop website, projector, laptop Year 12: HITT clickers
To let students recognize patterns, describe relationships and discrepancies			
To engage students in discussion		✓	Projector, Laptop

A tick (✓) represents how many times the correspondent action was undertaken. There were seven observations in all: three in year 10 and four in year 12.

Though Elliot used different technological tools to help students understand the concepts he was teaching, he was the only one who was using technology. The students were very passive recipients of the affordances of technology and did not take any active role in the use of the technology in that lesson.

The students were taken to one of the computer laboratories during the fourth teaching episode. Elliot wanted the students to start a 'science project' in anticipation for the national science fair. Students selected research topics of interest to them and stated research questions which would help them answer the research topic. Elliot went round and discussed students' topics with them. The students used the internet to search for information about their projects and uploaded the information on to their wikispaces. They also filled in their learning journals which were located on the school's LMS. In this lesson, the students actively used technology. They searched for their own information, decided which information to store and they saved such information.

The topic for the year 12 biology class during the observations was 'gas exchange and circulation in exercise'. In the first lesson, Elliot presented content information with pictures and diagrams to explain the concepts he was teaching to students through PowerPoint. He later led the class to discuss a graph he projected to the students. Students discussed the concepts the graph depicted based on the probing questions that he used. During the second teaching episode, Elliot wanted the students to have a visual representation of what he was teaching so he demonstrated the concept through a YouTube video which was projected to the whole class. He later presented the content information to the students through a PowerPoint presentation.

Elliot revised the content he taught to the students during the third teaching episode. He did this through the Hyper Interactive Teaching Technology (HITT) clickers which presented questions to which students responded through a remotely connected clicker. Each student's answer to the "multiple response" questions can be detected and students' responses were grouped based on the number who selected a particular option. Elliot used this technology to assess students understanding of the concepts he taught over the previous two lessons. He discussed and reviewed students' responses after each question with the whole class. He made students justify why they selected particular options and if that option was the wrong answer, he explained to the students why that option was a wrong choice.

Summary of Elliot's profile

During the research Elliot came across as a calm, unassuming person who was cautious about his abilities probably due to the fact he was a relatively new teacher. The observations confirmed the assertion that he made during the interview that he used technology differently with the different levels. During the last teaching episode in the year 10 class Elliot had started a project with the students which required the use of technology by the students. There was no sign of such use of technology in the senior class.

Although Elliot remarked that he had a course on ICT during his initial teacher education, he reiterated that it was more about exposing him to the tools that were available. He however acknowledged that the 'ICT in biology' curriculum course during his initial teacher education programme at university helped him to understand how he can teach with technology. He had relatively low mean scores in Technological Pedagogical Content Knowledge, Technological Content Knowledge and Pedagogical Content when his knowledge on the TPACK constructs was gauged. He emphasized that technology provided the opportunity to students to be interactively engaged and interested in their learning rather than just sitting and listening to the teacher.

Ben's case: "They [ICT] make it [teaching] more exciting."

This section presents the case of Ben who is a physics and science teacher in School 'B'. He was aged between 31-35 years and in his fifth year of teaching after registration though he did two years of teaching prior to registration. Ben had a very assertive personality and exhibited high level of confidence in his teaching. He was strict yet friendly with his students. The observations of the teaching episodes took place in his year 9 science class and year 12 physics class. The year 9 science was a BYOD (bring your own device) class where students brought into the classroom their personal technological devices. Each class was observed four times for during the course of the study.

Teacher education and training to teach with technology

Ben stressed that he had been using computers before he came into teaching and thus brought his computer knowledge to teaching. He emphasized that his knowledge to teach with technology did not come from his teacher education programme since there was not any course like that when he did his teacher education programme.

> I think I've always used computers a fair bit with ah, just Microsoft products and things like that, for presentations. Um, so I had that background as well before coming into teaching

He had been to ICT related courses, workshops and seminars which introduced him to packages like MS- EXCEL, MS-WORD and Moodle. He pointed out that the ICT courses he has participated in were generally focussed on general skills' development but not necessarily geared towards providing skills that could be used to teach.

He highlighted that his school has started a fortnightly professional development programme which is not specifically geared towards using ICT to teach but has ICT components. This led him to suggest that the bulk of his knowledge with regards to teaching with technology came from the skills he had acquired before he entered into the teaching profession.

Ben's knowledge in each of the constructs of the TPACK framework was solicited with the help of a TPACK questionnaire. The questionnaire used in this study was a five-point

Likert scale with responses ranging from 'strongly disagree' to 'strongly agree'. The mean scores of Ben in each of the constructs can be seen in Table 36.

Table 36: Ben's mean scores on each of the constructs on the TPACK framework

Constructs	Mean
Technological Knowledge	4.5
Pedagogical Knowledge	4.1
Content Knowledge	4.0
Pedagogical Content Knowledge	4.1
Technological Content Knowledge	4.6
Technological Pedagogical Knowledge	4.8
Technological Pedagogical Content Knowledge	4.5

The mean scores were derived from the score on each of the statements that made up each construct (See Appendix 5). The responses were rated as 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=strongly disagree.

Ben had a mean score of 4.0 and above for all the constructs. These scores indicate that Ben was a very confident teacher and felt comfortable with using technology as a teaching tool to address the demands of the content. A further analysis was conducted to find out how he responded to the items making up the constructs (Content Knowledge, Pedagogical Knowledge and Pedagogical Content Knowledge) where he had comparatively low mean scores. On 'Content Knowledge', Ben agreed and strongly agreed to all the items except one. He neither agreed nor disagreed when asked if he follows up-to-date resources and developments in the subjects he teaches. Ben seemed to indicate that he followed content developments and applied these in his teaching subjects up to a certain level.

Under 'Pedagogical Knowledge' Ben could not give a definite response as to whether he can adapt his teaching style to cater for diverse learners in his class. He neither agreed nor disagreed when asked if he adapts his teaching to suit diverse learners. Though in general he had a high score for ‘Pedagogical Knowledge’, for effective learning to take place teachers should be able to modify their teaching and adapt to meet the needs of their learners. Pedagogical Content Knowledge is the intersection between ‘Pedagogical Knowledge’ and ‘Content Knowledge’ from the TPACK framework. Thus, it is plausible for a person to have a low score in this construct if he has low scores in the contributing constructs. Under this construct, Ben could not tell whether he explicitly targets aspects of the Nature of Science in his teaching. Having been introduced recently to the Nature of Science, most teachers are not so sure about what constitutes the nature of science and how to teach it explicitly. By neither agreeing nor disagreeing, Ben seemed to be non-committal when it came to that item. He was cautious and his response depicted that he does not always target aspects of Nature of Science in his teaching.

Teaching with technology

Ben pointed out that he has been teaching with ICT to varying degrees since he started teaching and therefore rated his ability to use technology to teach as better than an intermediate but not quite an expert yet.

> There’s, you know, I’ve always used the projector, so I’ve always used some extent of ICT, and now I’m looking to move more into, an e-learning environment where I can give the student, students the work digitally and they can do that work and access that work inside and outside of the classroom, which I think is the true advantage.

He seemed very confident when teaching with technology and was able to seamlessly blend technology with his teaching approach. This could be due to the fact he has been teaching with technology for a while and probably has become used to it.

Ben claimed that he ‘frequently’ (70% of the time) used ICT to assist him to prepare for his lessons by searching on the web for information and material that could help in his lessons. When it came to the presentation or delivering of content material to students, Ben stated that he ‘frequently’ relied on ICT through PowerPoint and other presentation software.

He highlighted that he used ICT ‘frequently’ as well to explore, demonstrate or elaborate a concept through animations and simulations to students. Though he used ICT ‘sometimes’ (50% of the time) to allow students to discuss issues through online discussion forums, he ‘frequently’ used ICT to allow the students to view images or objects. Thus, Ben used ICT often and frequently to enhance his teaching and students learning processes.

In this era of plethora of technological devices and advances, one must be able to select the appropriate technology and be willing to adapt it if teaching is to be effective. Ben explained the basic strategies he used to select technological tools for his teaching.

> You can obviously sit there and view the whole thing and trial it. Um, that’s one way. Ah obviously there – it comes with colleagues’ recommendations or recommendations through authors and other people that are using it. Um, and more and more I’m actually getting the students to go out and find things and add them to our learning environment. So if they find it that means that their interest is already – and they can be in there and therefore it could be good for my learning if I can tune it to what we’re actually discussing at the time.

Ben’s approach in selecting the appropriate tool starts with trial and error where he just tries out a new tool to find out how effective it will be. He also relied on the recommendations of his colleagues and what other users have said about a particular tool. He acknowledged the fact that the students also have the ability to select tools that might be useful. He believed that using tools that the students have identified and are already using was a good way to select a tool since in such situations the initiative was coming from the students and therefore they were already interested in them.

Though he would accept the recommendations of colleagues or try things out on his own, he had specific things he looked out for when selecting a tool. His criteria were based on what the tool can help the students do in their learning. Ben emphasized that he looked for tools that can encourage student collaboration, as well as allow students to prepare and present their documents.

> I'm looking to go through kind of icloud systems, so collaborative systems where they can work on a document together. So if it can work collaboratively, then it's good. If they can prepare their work on it and present their work on it, it's good.

He further reiterated that a technological tool for teaching should have internet connectivity abilities, should allow users to edit their documents as well as have a relatively easy to read screen size.

Aside from looking at the qualities of the tools before he selected them, he was always guided by what he wanted to achieve at the end of the lesson. He reported that selecting a tool to use in his teaching depended on the activity he wanted to do. He believed that the more engaging and interactive a tool was the better it was for teaching. When asked how different teaching with ICT was compared to teaching without ICT he said:

> I think it's just a very different way of facilitating learning. One, you are the fount of all knowledge and you're just spilling it upon the whiteboard as they all take it in, whether they're concentrating on it or not. And the other one it puts that on to them, and they're in control of their learning and you're there more as a support structure.

Technology helped him to teach without being at the centre of the teaching and learning process. He claimed when he used ICT to teach, the students became the centre of the teaching process and they took charge of their own learning.

Ben speculated that he was at a new level of teaching with technology after having used computers, projectors and other ICT tools in his teaching for a while.

> The big thing that I'm moving to now is more of e-learning, where you present the work for the students and they go and find the information and process the information on a more individual basis rather than a 'teacher tells the story' basis. And I think that's much more of a significant shift and requires a lot more thinking about how you set it up.

He claimed the use of ICT tools in his teaching had become a daily and normal practice and he was now moving into 'e-learning' with his students. In this, he was allowing the students to bring to class their own devices and search for their own information. He believed that with this the students would be able to continue learning even after school and thus learning will not be confined to the classroom. Ben summed up the benefits of teaching with technology as:

> Definitely access out of the class time, ah access to it. Um, definitely engaging and um being able to see a demonstration that's going to work every time.

Ben claimed that teaching with technology has become part of his daily routines as a teacher and that he will continue to teach with technology. He considered that technology made his teaching exciting and offered greater opportunities for him to teach collaboratively with his students.

The Roles of ICT in Ben's Teaching

Technology brings to Ben's teaching the assurances that whatever he wanted to demonstrate will work. He claimed that his animations always worked which made his teaching more exciting whereas some experiments failed to work at the last minute. Besides making his teaching exciting, he claimed technology gave him easier options to assess his students. Ben claimed that science comes with so many abstract and microscopic concepts which are difficult to demonstrate in the classroom if there were no technologies to assist you.

> There [are] so many things you can't see that we're trying to study in science, things on the subatomic levels, things on you know, you just can't set them up in a, in a timeframe of an hour in a school or have the time to actually set them up outside that hour. Um, and you can just put them on some sort of animation or and just have it instantaneous. So it's just the, the readiness of it.

Technology thus saves him time to manually prepare scientific demonstrations of phenomenon which may not even work during class time.

Ben has been using technology to teach because it added a new level of excitement to his teaching and made him more passionate which he claimed affected the students as well. He highlighted that technology has brought a higher level of engagement to his students, increased their collaborations and given them the ability to access their lessons outside the classroom. He further reiterated the connections technology brings between him and other people as well as the diversity of ways ICT can be used.

> Obviously higher engagement from students. Um, collegiality I think is important too, because I'm often helping other people and ah learning from others, so it gives us a reason to be talking around – cos there's so many different ways to use ICT, whereas there's only a few ways to do chalk and talk kind of teaching. And so I'm very interested, and ah, yeah I have lot greater and more in-depth relationships over the work that we're doing around it.

He was emphatic about the relationships he has built with others through regular discussions and conversations around ICT. Ben's use of technology in his teaching therefore stems from the fact that it makes him and his students excited about science as well as engaging them.

Contextual use of technology

Ben taught two different levels in the school- junior level science and senior level Physics- and therefore was asked to explain how he used technology in these different class levels. He upheld that he had a similar goal for the use of technology in these classes and therefore did not differentiate when it came to the use of technology. He claimed that the difference resulted due to the level and extent of content that was important for these classes. To him the goal for using technology in his teaching was to foster collaboration among the students which was the same for all the students at different levels.

> I don't differentiate too much. But potentially – actually no, I'm not going to say there's significant difference at all. The only differences really would be in the level of content that they're working towards, wanting to push collaborativeness in both.

> Wanting them to bring their ideas to the work that we're doing, rather than just having it teacher-led and so it's equal between both juniors and seniors.

He believed technology can help students to be active agents of their own learning and that is what he strives for when he teaches with technology. Observations conducted in Ben's classes confirmed that he did not use technology differently in his classes. The trend was the same for both senior and junior classes.

This is quite a deviation from the other teachers who took part in these observations; in that most of the teachers used technology differently at different levels. They attributed their practice to the fact that the seniors have NCEA to study towards and therefore they do not have the luxury of time to play with technology in the seniors as they would do in the junior classes.

Observation of Ben's teaching

Observations of Ben's teaching were conducted to find out how he used technology in his teaching. Four observations each took place in two of his classes-year 9 Science and year 12 Physics. The results of the observations are summarized in Table 37.

The year 9 Science class was a BYOD class (bring your own device) in which the students were allowed to bring any technological device of their choice into the classroom. In the course of the observations, Ben taught three different topics in the year 9 class. The observations started when he was already in the middle of the first topic. In the first and second observations, Ben was teaching the topic 'Laws of reflection' and had asked the students to continue on the task he had already given to them to work on during the previous lesson. Some of the students used their digital tools to search for information, others worked on their collected information on their devices and few of them were engaged in science experiments on the concepts under discussion. Students took photos of the experiments they were undertaking.

Atomic structure' was the concept being taught during the third observation of teaching episode in Ben's Year 9 Science class. Ben started the lesson with a projected MS-WORD document to the students. He explained the concepts to the students through the projected information. In order for the students to have further understanding of the concepts being taught, Ben played a 'YouTube' video and animations on the concepts to the students. He discussed the concepts being portrayed in the video as well as the animations with the students. The students were excited about the videos and expressed their views on the concepts being played out in the video and animation.

In the fourth lesson, Ben wanted to teach testing for selected gases. Ben explained the concepts to the students and gave out the instructions to them. Students were asked to form groups and assigned roles to each member. Students started the experiments and Ben realized that some of the students were not partaking in the experiments so he asked each group to record its members undertaking the experiments with their cameras.

In the year 12 Physics class, Ben was teaching the concept of 'Motion' to the students. In the first teaching episode, Ben was teaching the concept of 'projectile motion' to the students. Ben screened a 'YouTube' video of real life applications of the concepts he was teaching. The video had people undertaking actions that fell under the concept and had voice over explaining each of the stages of the concepts. The video was such that actions were slowed, marked and replayed so that the students took note of the salient points. After the concepts had been taught, he later asked the students to go onto their Moodle space/site because he had uploaded the marking rubrics and the correct answers to a test the students had previously undertaken. This made every student take part in the experiment so that he or she would be recorded on their phones and tablets. The students became very interested and engaged in the task.

Table 37: An observation responses depicting how Ben used technology in his teaching

How Ben used technology	Year 9 Science	Year 12 Physics	Technology used
To present content knowledge to students	✓	✓	PowerPoint
To use ICT tools to allow students to examine/observe pictures, diagrams etc.		✓	PowerPoint
To let students gather information /conduct an inquiry	✓✓	✓✓✓	Internet
To support students generate data using digital devices	✓✓✓	✓	Camera on Phones, laptops, internet
To allow students put together collected data	✓ ✓		Laptops, tablets
To demonstrate a concept through video	✓	✓✓	YouTube, Laptop, projector
To allow Students to present their work			
To explain or elaborate on a scientific concept			
As a management tool			
To explore science content through simulations/animations	✓	✓✓✓	Laptop, Projector
To allow students take a quiz	✓	✓	Year 9: HITT clickers Year 12: Moodle
To allow students discuss opposing viewpoints			
To allow students review a test		✓	Moodle
To let students recognize patterns, describe relationships and discrepancies		✓	Laptop, Projector
To engage students in discussion			Projector, Laptop
To work on tasks	✓✓	✓	Year 9: Laptops, Tablets Year 12: Moodle (Desktops)

A tick (✓) represents how many times the correspondent action was undertaken. There were eight observations in all: Four in year 9 Science and four in year 12 Physics.

He discussed the correct responses to the questions with the students. During the later stages of the lesson, Ben asked the students to search for more videos and/ or animations of the concepts that had been taught that day.

Ben continued teaching the concept of ‘projectile motion’ during the observation of the second teaching episode in the year 12 class. During this lesson Ben wanted the students to have a first-hand experience of ‘projectile motion’ so he took them to the school’s field for them to kick a rugby ball into the air. The students were asked to video record their friends as they kicked the rugby ball as well as to measure the distance the ball travelled. The students had a real life experience of projectile motion through this activity. Ben took the students back to the classroom and showed an animation on the concept to the students to give them further understanding. The students were asked to mark their own assignment which was on their LMS with the provided rubric.

Ben started a new concept ‘Wave motion’ during the third teaching episode. He played simulations and animations to explain the concepts he was teaching to the students. In order to bring out the differences between the different types of wave motion, he showed a simulation of the different types of waves to the students. He then allowed the students to discuss and describe how they saw each type. This led the students to discuss what they saw and Ben helped them to identify the concepts he wanted them to grasp. He then asked the students to search for more information on the concepts they had just learned on the internet.

The concept of wave motion was continued by Ben during the fourth teaching episode in the year 12 class. He presented and discussed content information with diagrams to the students through the laptop and projector. He showed and discussed a video demonstrating the concepts he was teaching to the students. Students were then asked to complete a task on the concept on their ‘Moodle’ space/site after which they were asked to search for more information including videos on the concepts they have been taught.

Summary of Ben's profile

Ben's use of technology in his teaching was extensive. It included the use of videos, simulations and animations related to the concepts he was teaching. He contended that he selected technological tools based on the content he wanted to teach. This showed in his lessons because I noticed that his videos targeted the concepts he was teaching. He therefore displayed a good level of Technological Content Knowledge. He did not allow the students to be just passive recipients of the information but rather encouraged them to express their views on the concepts shown in the videos. He was very confident in his use of technology and felt comfortable as well with the content matter he was teaching as seen in the high mean values on the questionnaire for the various TPACK constructs. He seemed to use technology similarly in the classes at both levels of classes he was teaching. He explained that he wanted to forge the same sense of collaboration in both senior and junior students. Moreover, he argued that he wanted the students to be active agents of their own learning and was trying to shy away from teacher centred teaching.

Sharon's profile: "I'd be lost without it."

This section looks at the case of the last teacher who took part in the case studies. Sharon, aged between 41-45 years, has been in the teaching profession for the past 10 years four of which she did as a provisionally registered teacher. She teaches Science in the junior classes and Biology in the senior classes in School 'B'. She was observed during teaching episodes in her year 9 Science class and year 13 Biology class with each class being watched four times as depicted in Table 12.

Teacher education and training to teach with ICT

When asked to describe the ICT training she had during her teacher education programme, Sharon stated that she had minimal experience with technology.

> Very, very small amount. I went through Teacher's College and I came in knowing probably nothing at all about ICT. I wouldn't have been able to use a PowerPoint

> probably. So I purposely took a couple of papers while I was there and that was very basic but it was just looking at things like how to put a PowerPoint together or how to make use of a database, spreadsheet, that sort of thing.

She complained that the basic ICT training she had whilst in school was not geared towards how to teach with technology. She was introduced to such tools in the general sense of learning about a tool. She highlighted that she was aware that her knowledge in ICT after teacher training was limited. She believed her use of ICT in the early stages of her teaching career was very poor and abysmal and that she has improved a great deal with the passage of time.

She asserted that she learned how to use technology for teaching during her development as a teacher. She believed her ICT knowledge related to teaching was gained through colleagues and what other people said worked for them.

> Um hands on. Yeah, I very much… you see people do other things or you hear about other people that do things and they say try this, it's easy.

Her colleagues encouraged her to use tools that had worked perfectly fine for them in their teaching and she had also had training on how to use other ICT tools from the school's IT manager. She also learned how to use the Moodle platform from the school's professional development programmes since ICT seemed to be the focus for their professional development in 2013. Moreover, she intentionally attended ICT related sessions when she went to conferences. Sharon seemed therefore to have learned how to use technology to teach from her own ingenuity, from colleagues and exhibited the willingness to learn from other people.

Sharon's knowledge on the constructs of the technological pedagogical content knowledge (TPACK) framework was sought. On a 'strongly disagree' to 'strongly agree' five-point Likert scale, Sharon's mean scores for the various constructs of the TPACK framework can be seen in Table 38. She scored a mean of 4.0 and above in all the constructs with the exception of ‘Technological Knowledge’ and ‘Technological Pedagogical Content Knowledge’ in which she had means of 3.9 and 3.8 respectively. Her mean scores on the ‘Technological Knowledge’ and ‘Technological Pedagogical Content Knowledge’ constructs were relatively low compared to the other constructs.

Table 38: Sharon’s mean scores on each of the constructs on the TPACK framework

Constructs	Mean
Technological Knowledge	3.9
Pedagogical Knowledge	5.0
Content Knowledge	4.6
Pedagogical Content Knowledge	4.4
Technological Content Knowledge	4.3
Technological Pedagogical Knowledge	4.2
Technological Pedagogical Content Knowledge	3.8

The mean scores were derived from the score on each of the statements that made up each construct (See Appendix 5). The responses were rated as 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=strongly disagree.

In contrast, during the course of the observations, Sharon demonstrated a high level of knowledge and skills in using technology to teach and, combined with the confidence and exuberance she used to teach with technology, I was expecting to see a high score on her assessment of her TPCK construct.

A further analysis conducted to find out how she responded to specific items under TPCK construct revealed that she ‘agreed’ to all the items except two -‘I can use technology to facilitate scientific inquiry in the classroom’ and ‘I am able to use technology to create effective representations of content that departs from textbook approaches’- which she ‘neither agreed nor disagreed’ to. It seems Sharon took a cautionary approach when responding to these items and probably underestimated her capabilities. She sought to indicate that she does not really know whether she possessed the knowledge the items sought to solicit.

On a whole, it could be seen that Sharon has a high perception of her knowledge when it came to the various constructs on the TPACK framework and thus believed in her abilities to teach with technology effectively. This was detected during the observations of her teaching episodes. She was very comfortable with the content she was teaching as well as the pedagogies and technologies she was using to deliver the content.

Teaching with technology

Sharon stated that she has been teaching with technology since she started teaching although at different levels and therefore rated her abilities to teach with technology as an intermediate. This was a very humble self-rating since she has been teaching with technology for almost 10 years and used a wide range of technological tools very effectively during the observations of her teaching episodes.

To foster her teaching and improve students' learning, Sharon mentioned that she used ICT 'every time' to facilitate her preparations for lessons and 'frequently' (70% of the time) to deliver or present the content to be learnt to the students through presentation tools. In order for her students to gain deeper understanding of concepts, she 'frequently' used ICT tools to explore, demonstrate or elaborate concepts through animations, simulations and videos. She also used ICT 'occasionally' (30% of the time) and 'sometimes' (50% of the time) to allow students to discuss issues through discussion forums and view images and objects through animations, digital images and microscopes respectively. These uses of technology by Sharon were meant to improve her teaching as well as student learning.

The effectiveness of a technological tool in teaching starts with one's ability to select the appropriate tool to use. Sharon claimed that she treated the use of technology as she would treat any other teaching strategy and question what that tool will add to her teaching.

> I'd probably look at it as like I'd look at any other sort of strategy, so it's like what do I want out of this? Is this going to help for literacy or something, for example? Um, you know, and why would it help, and you know, and that's how I usually approach it. So it's not necessarily that I'll go to technology – sometimes it's an engagement factor, so it's a, you know, whether it's making use of YouTube or something like that because it's an engagement, whereas other times it's, you know, I can make use of this through literacy or something like that.

She claimed that she was not moved to use a particular tool just for the sake of using technology but rather looked out for what that tool could add to her teaching and her students' learning. She highlighted that a lot of the tools she selected in her teaching were dependent on what she wanted to teach as well as the group of students she was teaching.

> A lot of it depends on what you're actually teaching and it depends on the group you're teaching obviously. I wouldn't approach it in a case of okay, I've got to make use of, you know, VoiceThread or whatever it happens to be, so I don't approach it – it's more a case of what do I want out of this?

In selecting her tools, she acknowledged that her colleagues also influenced her decisions. She articulated that during their group planning sessions for developing the term's programme, colleagues suggested tools that could help in the effective delivery of specific concepts.

> Pretty much a lot of it happens at the scheming end of things. We work a lot together, very collaborative, which is good because often people have knowledge of other tools that I don't know about and so we'll be talking through about where we want to get with particular areas and they'll say 'well, did you think about using this'?

In this school, there seemed to be a deliberate collective effort to the use of technology. Teachers encouraged one another to use technology and they were open about what was working in their classes and were willing to share experiences with their colleagues. This collaborative approach was supportive of each teacher's development and use of a wider range of tools. Schools may want to leverage this kind of sharing more deliberately.

Though she had had to modify her teaching to accommodate the use of technology, she considered it as a positive thing, as she stated that technology was “another great big set of tools” that she can make use of and this has made her feel as a new teacher anytime she used a new tool. She asserted that technology has given her a variety of options to choose from when it came to teaching students. It invigorated her and kept her interested in her teaching. To her, teaching and learning are always evolving and the onus lies on the teacher to keep up with new trends, which she acknowledged is difficult because of the rate of change of technology and content information. Sharon therefore theorised that she sees her role as being able to access the many different new ideas and bring them in a very comprehensible form to the students.

She emphasized that technology has brought new ways of engaging students in the course of teaching. She underscored the fact that students think differently and most of them would not sit down to read a textbook and thus she would rather direct the students to an online article rather than suggest a textbook to them.

Technology therefore permeates every aspect of her teaching and she relied on it to facilitate her teaching and students learning. It enhanced her teaching because it appealed to students and grabbed their attention. It has also eliminated the trouble of her drawing difficult diagrams and pictures to help explain abstract concepts.

> Certainly for some of those really um in-depth topics like genetics and all the rest, some of those animations and things like that, there’s no way I could do that. There’s no way I could teach to that level with me drawing things on the board or something along those, those lines. Yeah, it’s a great tool.

She asserted that technology has made teaching easy and difficult at the same time. She claimed that on the positive side there is so much information available to her as a teacher which will go a long way to make her teaching easier as well as improve students’ understanding. On the other hand, it is difficult for her to juggle the practicalities of the technology she would like to use in her teaching in the sense that sometimes a particular tool she would like to use may not be available to her at the time she may want to have it or whether her students would be able to have access to certain tools and materials she would like to use in their homes.

> They make it [teaching] easier, but it also makes it more difficult. More difficult in that often you're juggling ah the practicalities of it. It's not necessarily um the reasons why I'm using it, but the practicalities. Like I said before, it's things like can I get access to a computer lab? Do I have students that have access to everything at home?.... On the other hand, easier in that there's so much – I mean obviously I can put things together myself, but there is so much available to me as a teacher, so if I am looking at a new idea or what can we do for example um for the animals, ah body systems topic, I'm looking at case studies dealing with um living at high altitudes. That's what I'm working on this weekend. First place I'm going to call is YouTube, because I'm looking for some snazzy little clips out of, you know, usually something like BBC or something like that so I can grab the students, so they can see it in context. That's probably the first place I'll look. Um, and yeah, I'll, I'll jump online.

She went further to reveal that all is not always perfect with technology because sometimes things do go wrong. She explained that there are times the technology will fail to work at the very last minute.

> I mean I suppose on the negative side it's when you've got something all set up to go and something goes wrong and it's like ooh, I'm going to have Plan B. Um, so yes, I suppose there's always that side of it, cos that can be the frustration side of it and you know, so don't get me wrong, it's not always perfect.

Notwithstanding the occasional hitches associated with technology, she still believed technology was a very important component of her teaching and she will continue to use it.

The Roles of ICT in Sharon's Teaching

Sharon alerted that she "would be lost without" technology because she would not have been able to engage the students without technology as she is able to do now. Moreover, she underscored the fact that without technology she would not be able to get access to some of the information and materials she has now which could have affected the quality of her teaching.

Technology engages her as a teacher and makes her teaching clearer to students and succinctly described the role of technology in her teaching as:

> I think it's also – especially for some of the concepts - it's certainly made my teaching clearer, or at least the content clearer to the students, ah, which is a huge thing for some of those topics that we're looking at because they're so abstract. It's just something that I've done and that I do and, if I go off and talk to people at other schools or, at conference and you find out other people don't do it it's like oh I thought everyone did that. I just think it's, I think it enhances the students' understanding of the topic much better.

She claimed that technology has become part and parcel of her teaching to the extent that she thought every teacher was using technology in their teaching. Technology does not just enhance her teaching but helped to make abstract concepts clearer and understandable for students.

Though she emphasized that her teaching has changed, she was reluctant to attribute the change entirely to technology. She believed her other professional development programmes have had effects on her teaching as much as technology has had effect on her teaching.

> I've changed greatly how I've taught in that 10 years and I don't think that's necessarily just because of technology. I think it's also because um we have some fairly intensive PD on things like um teaching literacy, information literacy. I mean certainly when I first started teaching it was very, very, very teacher-directed and there's still a lot of things I do that are teacher directed now, but not as much so, in that we can have periods of time that is very much back on the student and I, yeah, I don't know if I could separate that out and say that's just because of technology. Certainly it does have an impact, okay - in particular things it has had an impact, but I don't know if I could say it was just purely because of that.

Technology therefore played an integral part of Sharon's teaching and she believed there was no way she could enjoy her teaching and to a large extent be an effective teacher without technology. She exhibited a high level of confidence when she was teaching with technology. It has seamlessly become part of her teaching strategies and she relied on it very much to make sure that her students understood the concepts she was teaching.

Contextual use of technology

Sharon's views on how she used technology to teach in the two different levels of classes she teaches were sought. Sharon believed she used technology at similar frequency in both levels but for different reasons depending on the topic she would be teaching. She added that she has been using technology in her junior classes in such a way for them to be engaged in their learning. Technology has helped the junior students in their science experiments and research whilst in the seniors she normally used animations which helped to increase and facilitate deeper understanding of the concepts by the students.

> Probably – yeah, probably for different reasons, like at the senior level it is, it is more about – yeah, it is the content and the processes that we're looking at and it's a case of the type of things that are available to get the concept across better than I can, or better than I feel I can as far as just, whereas the juniors, it's probably more as a strategy that – … I knew I was going to increase the engagement.

Her focus for using technology in her classes seemed to differ in the two levels. In the seniors, she used technology to increase students' understanding of the concepts by looking for tools such as animations and simulations that would bring out the meaning of the concepts to students by making the abstract concepts clearer and visible. In the juniors however, she sought to get the students engaged and interested in the teaching and learning process through the use of technology. However she highlighted that she did not use technology more frequently in one level than the other.

Sharon seemed to deviate from how the other teachers (except Ben) used technology in their two different levels. Most of the teachers accepted that they used technology frequently in their junior classes as compared to their senior classes because of the demands of the senior level curriculum. Sharon seemed not to be affected by any such demands. However, during the observation of her teaching episodes, I noted that she used technology in all the lessons in the senior class whereas in the junior class her use of technology was very minimal It could be due to the fact that the topics she was teaching at the junior class were not conducive to the use of technology since she asserted that the topic of the day determined whether she will use technology or not, or that because Biology is her speciality, she was more motivated to include digital objects to illustrate concepts and was more familiar with these as compared to the physics related topic she was teaching in Year 9. It seemed reasonable that teachers put more effort into adjusting teaching to include technology when they are more familiar and excited by the content.

Observation of Sharon's teaching

After the interview and the responses from the questionnaire, Sharon's teaching episodes were observed to find out how she incorporated technology into her teaching. The observations were conducted in two of her classes: year 9 Science and year 13 Biology. Each class was watched four times and what was occurring in the classes as far as the use of technology was concerned was recorded with the help of a checklist. In the course of the observations, Sharon taught the concepts of 'Density' and 'Light' in the year 9 Science class and 'Genetics' to the year 13 Biology class. The summary for the observations can be found in Table 39 below.

In the first teaching episode I witnessed in the year 9 class, Sharon taught the concept of density to the students. She explained the concept to the students through projected information she had on the class' Moodle space/site after which she showed a video to the students to deepen their understanding. In the second teaching episode, she continued with the concept of density and went further to demonstrate and explain the densities of different objects.

Table 39: An observation responses depicting how Sharon used technology in his teaching

How Sharon used technology	Year 9 Science	Year 13 Biology	Technology used
To present content knowledge to students	✓✓✓	✓✓	Projector, laptop,
To use ICT tools to allow students to examine/observe pictures, diagrams etc.	✓	✓✓	Projector, laptop
To let students gather information /conduct an inquiry			
To support students generate data using digital devices			
To allow students put together collected data			
To demonstrate a concept through video	✓	✓	Laptop, projector
To allow Students to present their work			
To explain or elaborate on a scientific concept	✓		Laptop, projector
As a management tool			
To explore science content through simulations/animations	✓	✓✓✓	Laptop, Projector
To allow students take a quiz		✓	HITT clickers
To allow students discuss opposing viewpoints			
To allow students review a test	✓	✓	Year 9: Moodle Year 13: HITT
To let students recognize patterns, describe relationships and discrepancies			Laptop, Projector
To engage students in discussion		✓	Laptop, Projector
To work on tasks			

A tick (✓) represents how many times the correspondent action was undertaken. There were eight observations in all: Four in year 9 Science and four in year 13 Biology.

She did the explanation through the content information she had uploaded to the class' Moodle space/site. Students were asked to respond tasks she had uploaded on the class Moodle space/site.

Sharon was teaching 'properties of Light' during the third teaching episode in the year 9 Science class. This class was very hands-on and thus minimal use of ICT occurred. The students were engaged in the 'practical' aspect of science where they were taking measurements, making observations among other things. After Sharon explained the concepts to the students through the laptop and projector, she asked the students to form groups so that they can perform the experiment in groups. They were investigating how shadows form as part of the properties of light. Each student was noticed participating in the experiment and Sharon went around helping students who needed a little bit of guidance.

An interesting thing occurred at the end of the lesson when Sharon decided to give the students homework. Some of the students had not brought their homework diary so they decided to use their phones to write down the home work. During the fourth teaching episode Sharon continued the concept of the properties of light and projected different diagrams to explain the concept to the students. A digital experiment as well as animation was shown to the students to explain the concepts to them.

In the year 13 Biology class, 'Genetics' was the broad topic when the observations of Sharon started. During the observation of the first teaching episode, she was teaching the concept of 'Operon theory/condition'. She presented information to the students and led them to discuss the concepts of the topic she was teaching. She later asked the students to respond to test items through the Hyper Interactive Teaching Technology (HITT) "clickers" and reviewed the items with the students when they finished responding. She went through their responses with them and highlighted where certain options were incorrect.

In the second teaching episode, Sharon dealt with the concept of gene expression and she started with a presentation on the concepts to the students. She had diagrams and pictures to elaborate on the concepts she was teaching. The presentation formed the main medium of explaining the concept to the students. To further the students' understanding of the concepts she played animations of the concepts she was teaching.

Sharon's aim for the third teaching episode was to demonstrate the effects of mutation in humans. She chose to teach this by showing videos of people living with certain genetic defects. The video explained the conditions of the people and how they realized they had such conditions and how they are coping with the disease. This made the students very attentive and quite subdued since the videos helped the students to see the real life effects of what they were studying. Sharon explained the concept to the students after the video and later showed animation and simulations of how the genes interacted and mutated. The students were then asked to read the notes on the concepts on their Moodle space/site.

She continued teaching the effects of mutation during the fourth teaching episode. During this class, she presented content information mainly through the projector and laptop as PowerPoint slides to the students. The presentation had diagrams and pictures to help improve students' understanding of the concepts being taught.

Summary of Sharon's profile

The observation of the teaching episodes revealed that Sharon used technology frequently in the senior classes as compared to the juniors. However, in both levels her use of technology was teacher-directed and centred. Thus, it was found that she used technology frequently with her senior classes though she remarked during the interview that she used technology similarly in both levels. It should be noted however that she did indicate that her use of technology was dependent on the topics she wanted to teach; therefore it could be that she thought the topics that were being taught at the junior level during the period of the observations could be taught effectively using other methods. Sharon showed that she was strategically choosing appropriate pedagogy related to content.

Her use of technology was mostly to foster further understanding of the concepts she was teaching which made her seem as if she was always in charge of the teaching and learning process. In these ways, she searched for the tools and information she thought were interesting to the students and thus made the students appear to be mere passive recipients of the content knowledge. She was able to able to use technology to capture their attention and improve students' interest in what she was teaching. She seemed confident and knew what she was doing with each application of technological tools.

Summary of the case studies

Six teachers were asked to respond to a TPACK survey, interviewed and observations of their teaching episodes conducted. The aim of the case studies was to find out how these teachers perceived their knowledge levels of the various TPACK constructs; how they learnt how to use technology to teach; how they teach with technology; role technology plays in their teaching; contexts that affect their use of technology; and to observe their actual practices of using technology to teach.

The teachers who took part in the observations demonstrated high level of awareness of the various TPACK constructs as demonstrated by their mean scores in the Table 40. The teachers had high mean scores on all the constructs of the TPACK framework indicating that they are aware of the constructs and therefore do possess TPACK for their teaching. These teachers were purposively selected due to their use of technology and it was therefore not surprising that they had high means on the constructs of the TPACK framework. The small standard deviations indicate that the responses were close to the mean and that these teachers responded similarly to most of the items on the various constructs.

Table 40: Observed teachers' mean scores on the TPACK constructs

Constructs	Mean scores	Standard deviation
Technological Knowledge	4.4	0.4
Pedagogical Knowledge	4.5	0.4
Content Knowledge	4.4	0.5
Pedagogical Content Knowledge	4.2	0.5
Technological Content Knowledge	4.3	0.5
Technological Pedagogical Knowledge	4.5	0.4
Technological Pedagogical Content Knowledge	4.3	0.6

There seemed to be a general consensus among the teachers that they acquired their knowledge to teach with technology mostly by themselves. They did not receive much knowledge on how to teach with technology during their initial teacher education programmes but this was highly dependent on when they trained to be a teacher.

More recent graduates indicated the inclusion of ICT in their initial teacher education programme. The teachers indicated that they learned from each other and shared experiences on what worked.

The teachers indicated that they taught with technology because it engaged the students, helped to facilitate students' understanding of the concepts taught and brought abstract concepts to life. A summary of how the teachers used technology in their teaching and learning processes can be found in Table 41. Technology played an integral part of these teachers' teaching because they believed it helped them to be effective. They asserted that it brought higher student engagement, facilitated better student understanding of concepts and provided avenues for students out of classroom and continuous learning.

Table 41: Frequency of observed teachers' use of ICT in their teaching and students' learning processes

Statements	Never	Rarely	Occasionally	Sometimes	Frequently	Every time
	Responses					
Preparation of lessons (e.g. search for information online etc)				1	2	3
Presentation or delivering of content (through PowerPoint or any other presentation software)		1		1	3	1
Explore, demonstrate or elaborate a concept (e.g. through animations, simulations etc)					6	
To allow students to discuss issues through interactive white board, online discussion forums, blog, etc)		2	3	1		
To allow students view images or objects (animations, digital images, microscopes etc)				1	5	

The six teachers in the case studies indicated that they regularly used technology to support the teaching and the learning of their students. All the teachers used ICT tools frequently to explore, elaborate or demonstrate a concept to students to further their understanding. Though their use of ICT tools to facilitate students’ discussion through forums was not encouraging, they made sure ICT featured predominantly when it came to the preparation of their lessons. Again, the teachers frequently allowed their students to observe images through ICT tools and most of them regularly used presentational software to deliver content material to student. They asserted that it brought higher student engagement, facilitated better student understanding of concepts and provided avenues for students’ out of classroom and continuous learning.

The observations of the teaching episodes confirmed the TPACK survey indicators as shown in Table 40 and further revealed that most of the teachers used ICT to facilitate inquiry and self-mediated learning in the junior levels. In the senior levels, however, the teachers mostly used ICT to deliver content material to facilitate the understanding of concepts through animations, videos and simulations.

These case studies will be compared with the quantitative findings from the TPACK surveys in the discussion chapter. That is, how representative were the case study teachers, or were they indeed ahead of the national colleagues in terms of their understanding and use of ICT?

CHAPTER 5

DISCUSSION

This chapter takes a critical look at the results of the research and compares them to findings in the literature. As already explained at the definition of terms section, TPCK is used to refer to the centre of the framework and TPACK is used to refer to the whole framework. The three research questions that guided the research and the discussion are:

1. What are New Zealand science teachers' perceptions of their understanding of the constructs of the TPACK framework?
2. How do these constructs correlate with each other?
3. How do teachers' adapt the use of technology in their classrooms?

New Zealand science teachers TPACK

The science teachers who responded to the online survey in this study rated their knowledge in the various constructs of Technological Pedagogical Content Knowledge (TPACK) framework very highly with the exception of Technological Knowledge (TK) as shown in Table 14. The mean for TK was the lowest and fell below the 'agreed' point of 4.0 but it was higher than the 'neutral' point of 3.0. The low score in TK could be due to the fact that majority of the respondents were trained as teachers at a time technology was not so advanced and that technology did not explicitly form part of teacher education programmes since they have been teaching for more than 10 years (See 'Participants' section). Although the teachers had a low score for TK, they had high mean scores for all the other technology related constructs (Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological Pedagogical Content Knowledge (TPCK)). Thus they believed they were able to incorporate technology effectively in their teaching.

Ratings of the teachers from the online survey on constructs of Pedagogical Knowledge (PK), Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) as can be seen in Table 14 seemed to suggest that the science teachers were more familiar and most experienced with constructs associated with traditional teaching strategies. This is not surprising and could be due to the fact that traditionally teacher education programmes have focussed on CK and PK as noted by Archambault and Crippen (2009) when they found that online educators in the US scored high means on the constructs of CK and PK. Archambault and Crippen (2009) proffered possible reasons for the high scores of teachers on the constructs of CK and PK. They noted that teachers may have been well prepared by their initial teacher education programme in terms of their content knowledge and pedagogical skills. This could be true for New Zealand since high school science teachers mostly have a science related degree before they enrol for their teaching qualification.

However, the findings from this study contradict Graham et al. (2009) who found that science teachers who had high score on TPCK also had a high level of TK. The science teachers in the current study rated their TPCK as high even though they did not have a comparatively high TK (Table 14). The data in this study indicated that though teachers identified that their TK was relatively low as compared to the other constructs on the TPACK framework, the teachers were still confident that they were able to teach effectively with technology or they were confident teaching with limited TK. Thus, it seems teachers in this study did not need to be 'expert' technology users before they could incorporate technology in their teaching.

There was evidence from this study that teachers' TCK and PCK development increases with teaching experience. As can be seen in Table 22, recently graduated teachers had the lowest score for these constructs. This goes to depict that the training of these teachers did not provide them with these constructs. This finding was not surprising since most teacher education programmes teach content, pedagogy and technology differently and in isolation to preservice teachers. The recently graduated teachers in this study therefore needed practice and experience to develop these constructs (TCK and PCK).

Correlation among TPACK constructs

There was a statistically significant positive correlation between each basic construct (content, pedagogy and technology) and the intersection construct TPCK (Table 23) just as Chai et al. (2010) found among Singaporean teachers and Archambault and Crippen (2009) among online educators in the U.S. This result agrees with the TPACK framework as developed by Mishra and Koehler (2006) where TPCK is the intersection of CK, TK and PK. If these constructs blend to form TPCK, then it stands to reason that they should correlate with it. There were positive correlations which were statistically significant between the second level intersecting constructs (PCK, TCK, and TPK) and TPCK. The strongest of these correlations was between TPK and TPCK, followed by TCK and then PCK. Archambault and Crippen (2009) also found a similar correlation pattern between TPCK and the second level intersecting constructs (PCK, TCK and TPK). Pamuk et al. (2013) found correlations between TPCK and PCK, TPK and TCK. However, they indicated that while TCK had the strongest correlation with TPCK, PCK had the weakest correlation.

In this study, all the six constructs (TK, CK, PK, PCK, TCK and TPK) had statistically significant positive correlations with TPCK. The strongest was with TPK, followed by TCK, PK, PCK, CK and the lowest was with TK. The evidence from this study, which is consonant with Archambault and Crippen (2009), shows a stronger relationship between the second level intersecting constructs especially TPK and TCK and TPCK as compared to the relationship between the basic constructs (TK, CK, PK) and TPCK.

Since Shulman (1987) bemoaned the act of treating teachers' content and pedagogical knowledge as mutually exclusive entities and indicated that teaching begins with teachers' ideas of the concepts to be learned and how to teach those concepts and propagated the idea of PCK, it stands to reason why teacher educators have tried to link pedagogy and content in the training of teachers. Thus, teachers have been trained to see the link between their content and pedagogical knowledge (McEwan & Bull, 1991). Therefore, although there is no direct link between PK and CK in the TPACK framework, this study found a significant correlation between them (Table 23). Archambault and Crippen (2009) also found a significant correlation between PK and CK and suggested that most teachers believe their content and pedagogical knowledge are linked such that it is very difficult to delineate them in their study. This outcome seemed to justify the claim that "the relationship between content and pedagogy is more complex, the boundaries between them more porous-in fact, that they leak into and through each other" (McEwan & Bull, 1991, p. 498). In this study, no correlation was found between TK and either CK or PK and as noted by Archambault and Crippen (2009). Thus, the data from this study (Table 23) identified a separate domain for TK, CK and PK as predicted by the TPACK framework.

Both PK and CK correlated strongly with PCK and this was expected since PCK is an intersection between PK and CK (Table 23). There was no correlation between TK and PCK which was understandable because in the TPACK framework TK does not contribute to PCK. All the basic constructs (TK, PK, and CK) had statistically significantly positive correlations with TCK and TPK. TK had the strongest relationship with TCK followed by CK and when it came to TPK, PK had the strongest relationship followed by CK. The correlation between PK and TCK as well as CK and TPK were surprising since in both scenarios the two constructs involved did not interact in the TPACK framework. This suggests teachers' difficulty to delineate their CK from PK as noted by Archambault and Crippen (2009). Teachers probably responded to items under PK and CK along the same lines. This is because there is a porous boundary that exists between content and pedagogy (McEwan & Bull, 1991) which therefore makes separating them in practice difficult.

The correlations between some of the constructs as seen in this study, e.g. CK and PK; PK and TCK; and CK and TPK even though they are not supposed to share any relationship based on TPACK framework, confirmed the notion that it is very difficult to delineate the constructs of TPACK in their practice (Archambault & Barnett, 2010) and that trying to tease out the various constructs will be an analytic act rather than a practical one (Mishra & Koehler, 2006). The findings of this study however provided some insight into the behaviour of the constructs. The unexpected correlations involved constructs that had either content or pedagogy embedded in them. This was probably because of the difficulty teachers find to separate content and pedagogical knowledge as indicated by Archambault and Crippen (2009). Since there was a high correlation between content and pedagogical knowledge, it stands to reason that these would correlate whenever one appears. Thus, there was a correlation between CK and TPK because of the presence of content and pedagogical knowledge. This claim is supported by the fact that there was no correlation between TK and PCK. This is because teachers were able to delineate technological knowledge from that of content or pedagogical knowledge and thus there were no correlations between TK and CK as well as TK and PK. The correlations found in this study confirm the interrelatedness of the constructs in the TPACK framework and why these constructs should not be treated in isolation. The correlations have also revealed the complexity of the constructs of TPACK framework as noted by (Graham, 2011).

More insight on the complexity of the constructs of the TPACK framework was derived from the qualitative aspect of the study. Teachers' demonstration of the characteristics of TPACK in their teaching depicted the complex interrelationships between and among the constructs of the TPACK framework. The observations of teachers' teaching episodes showed how these constructs are linked in teaching and learning. Teachers seamlessly combined technology, pedagogy and content throughout their teaching. From Sharon playing a 'YouTube' video to introduce the lesson to Colin allowing the students to use their devices to search for information or Elliot using the HITT to assess students' learning, teachers combined the constructs of TPACK in a very interrelated manner. Ben indicated that the use of technology has become part and parcel of his teaching.

> I think I have always taught with ICT, to some extent. For me there's – and I, and I always will, I'll always use these things, projectors and computers and those sorts of things to display and ah show ideas…..that's all just part of teaching for me.

This therefore means that teasing out the various constructs of TPACK in practice will be an arduous if not impossible act (Mishra & Koehler, 2006).

Prediction of the contributions of the various constructs to TPACK

The regression analyses indicated that TPK and TCK were the significant contributors to TPCK (Table 25, Table 27 and Figure 3). These constructs accounted for over 60% of the variance in TPCK. Although TPK was the single largest contributor, the stepwise regression indicated that TCK also made a significant contribution to the variance in the model. The evidence seen in this study replicates the findings of Pamuk et al. (2013) and Horzum (2013) who also found that TCK and TPK had strongest effect on TPCK. Although Pamuk et al. (2013) found TCK as the biggest contributor to TPCK, the research in this thesis rather found TPK to be the strongest predictor of TPCK. Pamuk et al. (2013) did not find any direct effect of TK, PK and CK on TPCK just as this study found. Horzum (2013) did not indicate which of the two constructs made the largest single contribution to TPCK. He however noted that TK made contributions to TPACK during the post course analysis albeit very modest as compared to TCK and TPK. Again, the findings of Chai et al. (2011) also supported the idea that TPK was the strongest predictor of TPCK.

However, Chai et al. (2011) found that CK and TK made a significant contribution to TPCK after their participants had undergone some instruction in ICT course. This is contrary to the findings of this study whereby TK, CK and PK did not make any statistically significant contribution to TPCK according to the survey. Although Chai et al. (2010) also found that TK, PK and CK did make significant contributions to TPCK their study did not include the second level intersecting constructs (CK, TPK and PCK). They just focussed on the foundation constructs (TK, CK, and PK) of TPCK.

The evidence from this study suggests that the development of TPACK should be looked at from a blended approach where all the constructs are treated together (Koehler & Mishra, 2005; Mishra & Koehler, 2006) rather than in isolation. Since there was a correlation between all the three basic constructs (TK, CK and PK) and TPK as well as TCK, it can be argued that all the three constructs contribute indirectly to TPCK. This is because in order to develop TPK and TCK, one needs to develop TK, PK and CK. It is these constructs that blend and merge to form TPACK (Koehler & Mishra, 2005, 2008; Mishra & Koehler, 2006). Thus, TPACK is a conceptual framework whose development rests on the contributing constructs. The evidence also suggests that the development of TPACK does not rest solely on one of any of the contributing constructs.

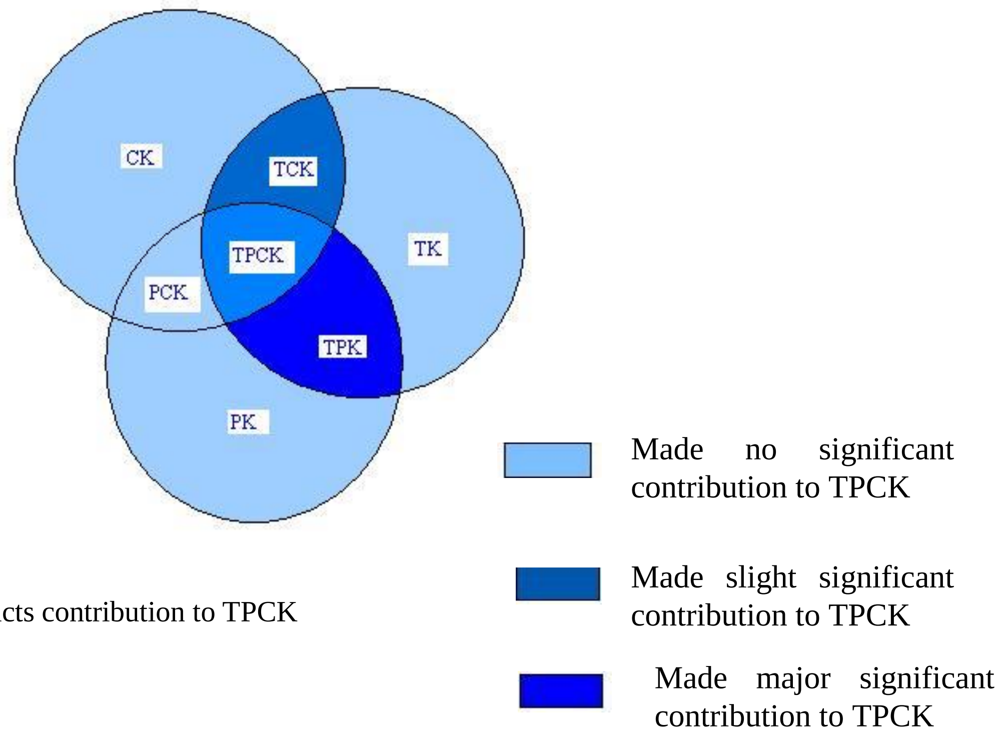

Figure 3: Constructs contribution to TPCK

Teachers' adaptation of technology in classrooms

Teachers are expected to repurpose technology to suit their own and their students' needs (Kereluik et al., 2011) if technology is to be effective for teaching. One of the aims of this research was to find out how teachers used technology in their classrooms. The observations and interviews provided additional evidence to the TPACK survey data about the teachers' TPACK levels. The six teachers in the case studies had high mean scores on the constructs of TPACK framework (Table 40). A comparison of the mean scores of the observed teachers and the scores of the online national survey can be seen in Appendix 9.

The teachers who participated in the observations had higher scores than the national teachers on most of the constructs that were measured. The higher mean scores of the teachers in the case studies justified their selection for this research as the idea was to find teachers who had high technological knowledge and who used technology more often in their classrooms.

The teachers in the case studies opined that technology was an integral part of their teaching because it made access to information easier and concepts clearer to teach and learn. Table 41 presents the frequency and variety of use of technology, by the case study teachers in this study, to facilitate teaching and learning in their classrooms. They asserted that it brought higher student engagement, facilitated better student understanding of concepts and provided avenues for students out of classroom and continuous learning.

The six teachers in the case studies remarked that they regularly used technology to support their teaching and the learning of their students. All the teachers used ICT tools frequently to explore, elaborate or demonstrate a concept to students to further their understanding. The teachers relied heavily on technology to search for information when it came to the preparation of their lessons. Janet was of the view that with technology it was easier for her to get access to current information which text books may not provide. The teachers frequently allowed their students to observe images using ICT tools and Ben explained that it was because of the subatomic nature of science concepts which students find difficult to imagine without any visual representations. Technology therefore provided sources of content: animations, simulations and images that teachers showed to students to facilitate the understanding of specific concepts. Technology creates endless possibilities for learning according to Susan. Sharon noted she would find teaching difficult without technology and Janet was of the view that with technology she was able to seize the moment in her teaching.

For example, at the end of one observation in Janet's Year 10 class her Year 13 Chemistry entered the class to the surprise of Janet. She asked the students why they have come to the class since she thought that the students were writing examinations. The students indicated that they had no examination at that time. Janet then asked the students to sit down and directed the students to their Moodle site where Janet had already uploaded the next lesson. She taught the students through the uploaded content material on the Moodle site as if she knew the students were coming for class at that time. Sharon noted that the use of technology has become part of her teaching to the extent that she cannot distinguish technology from her teaching. Moreover, she realized that every teacher was not necessarily using technology in their teaching as she was doing.

> I can't think how I'd put it. I suppose I don't really – I don't really necessarily think about it in that sort of – it's just something that I've done [laughs] and that I do um and, and, and if I go off and talk to people at other schools or, you know, at conference and you find out other people don't do it it's like oh I thought everyone did that [laughs]. So I don't know how to put it.

There was a consensus among the teachers that they used technology to engage their students in the teaching and learning process. Elliot noted that technology offered students the opportunity to engage in their learning and that he inculcated in the students with the ability to search for their own information. Colin reiterated that technology provided an inclusive environment whereby students were engaged. The teachers in the case studies were unanimous that technology shifted the focus of teaching from the teacher to the students. However, it was seen that teachers' use of technology differed from one level of students to the other. They were influenced by the content context. Teachers used technology to foster inquiry and student centred approaches in the junior classes but switched to a more teacher directed approach in the senior classes. Teachers' TPACK levels, *advancing, exploring, adapting, accepting* and *recognising,* (Niess, 2012; Niess et al., 2009; Niess et al., 2010) were therefore depicted based on how they used technology in the two levels they were observed as well as their responses during the interview.

At the *recognizing* level teachers considered technology as a low level tool for learning the subject matter and did not use technology to foster student-centred teaching; teachers who did not consistently consider how technology might influence and support their teaching although they use technology, are at the *accepting* level; at the *adapting* level, teachers incorporated technology in their teaching but only allowed students to use technology for low-level thinking activities which were very much teacher directed; teachers were more ready to allow students to explore with technology through student centred approaches and demonstrate different ways of teaching the concepts with technology at the *exploring* level; when teachers purposefully encouraged students to use technology and willingly used technology to develop the content ideas then they are at the *advancing* level (Niess, 2012; Niess et al., 2009; Niess et al., 2010).

Teachers TPACK levels in junior classes

Three of the teachers, Colin, Janet and Susan, were identified to have demonstrated characteristics of *exploring* TPACK level in their year 10 classes. Ben, Sharon and Elliot depicted *adapting* TPACK level in their junior classes. At the *exploring* TPACK level, Niess

(2012) indicated that teachers exhibit traits of allowing their students to explore with technology through student-centred teaching approaches. Colin, Janet and Susan demonstrated student centred approaches in their year 10 classes when their teaching episodes were watched. They consciously and actively made students use of technology an integral part of their teaching the year 10 classes. The students in the year 10 classes of these teachers were in charge of their own learning for some units of work. They searched for their own information and constructed their knowledge. The teachers served as facilitators in these classes as noted by Janet.

> I'm not a person out front delivering the stuff. It's allowed me to put the students in charge of their own learning.

Susan noted that she used this approach because the students become motivated and engaged when they are put in charge of their own learning. Colin claimed that the use of technology in the year 10 was to help the students to become interested in science by indicating that:

> A lot of the students now are comfortable with technology and so at a junior level I find it's quite good to have the technology, and it just basically makes them feel like home.... As – you know, there's a lot of exciting things they can do at [home] – they can play computer games and video games which are really exciting. Coming to school I think for them is sort of old-fashioned and more boring, and so if we can use ICT for those younger classes um and keep them engaged.

These teachers therefore engaged in project based teaching in the year 10 classes. Students were required to search for their own information, arranged the information and present them in a format of their choice. The teachers guided and facilitated student learning without being the centre of teaching.

Although Ben's year 10 class was a BYOD class, he was more in charge of the students' learning as compared to the other teachers in the *exploring* level. He used more of animations and video clips to help students' understanding of concepts. Ben used small group activities through which students used technology to perform certain activities. This was in agreement with Niess et al. (2010) findings that teachers at the *adapting* TPACK level were seen using small group teacher-directed activities with technology.

Sharon and Elliot used minimal amount of technology in their year 10 classes. These teachers were aware of the importance of technology in their teaching as noted by Sharon:

> I think it's also – especially for some of the concepts - it's certainly made my teaching clearer, or at least the content clearer to the students, ah, which is a huge thing for some of those topics that we're looking at because they're so abstract.

Elliot also added that:

> ICT offers another option to have them interact with their learning more and so give them a chance to engage more in their learning.

However, their uses of technology as witnessed during their teaching episodes were minimal. This could be due to the topics they were teaching at the time of the observations. Elliot showed signs of student-centred use of technology during the observation of his last teaching episodes. He had started a new topic in which he allowed the students to search for their own information for a topic of their choice. Thus, Sharon and Elliot's use of technology in the junior classes fell within the *adapting* level of TPACK since their teaching with technology in those classes were much teacher-directed although the teachers had made the choice to use technology in the teaching of their science lessons (Niess, 2012).

Teachers TPACK levels in senior classes

At the senior level, Ben and Sharon depicted *adapting* TPACK level whereas Colin, Janet, Susan and Elliot demonstrated *accepting* TPACK level. The teachers used technology to facilitate student conceptual understanding at the senior level. The teachers' aimed at improving the understanding of the concepts they were teaching by using technology to present information and simulations to the students.

Ben maintained similar uses of technology between the juniors and seniors. He used technology to foster his teaching and student learning through teacher-directed approaches.

Students' searching for information was limited to videos to help their understanding of already taught concepts. Sharon's use of technology in her senior classes was not very much different from how she used it with the juniors. In her seniors, technology was an integral part of her teaching. She used videos to explain and elaborate on the concepts she was teaching. Ben's and Sharon's use of technology were teacher-directed and served as a means to help students understand the concepts the teachers were teaching. Although she did not use technology frequently in the junior classes as compared to the senior class during the period of the observations, Sharon's use of technology in the junior class was still teacher-directed. Both Ben and Sharon indicated in their interviews that they did not use technology differently in the different classes they teach and this was found to be accurate during the observations of teaching episodes in their classes. Ben and Sharon's use of technology in the senior classes fell under the *adapting* level of TPACK. This is due to the fact that their use of technology in their teaching was teacher-directed and they only allowed students to use technology for low-level thinking activities as noted by (Niess, 2012; Niess et al., 2009; Niess et al., 2010).

The teachers (Colin, Janet, Susan and Elliot) who demonstrated *accepting* TPACK level at the junior classes indicated that they were aware that they used technology differently in their junior classes as compared to their senior classes. They proffered reasons as to why they used technology differently in their classes. Colin indicated that the seniors have examinations to write so his duty was to find resources that could help him teach the content the students needed to learn.

> If there was a good applet out there, if there's something that demonstrated a concept really well to them, that's definitely worth using.

Colin further went on to declare that the:

> Junior classes need ICT, whereas the senior classes, it's a nice touch to basically finish off [their] conceptual understanding.

Susan noted that she kept her year 10s motivated with technology.

> A lot of those students won’t go on in science after this year, or if they go on, it’ll be one more year and that’ll be it, because they’ve, you know, just their ability and keeping motivation up. You know, we’ve gotta get through the whole year in science.

Elliot attributed the difference in his use of technology to the restrictions the external examinations the seniors have to write bring on teachers and the demands of the curriculum at the senior level.

> I think because we have a bit more freedom in terms of the curriculum at the junior level, and there’s not the restrictions that NCEA places on some of them... with the year 10 junior class, you tend to have a little bit more flexible, flexibility in terms of how much time you have to teach the content, whereas with the senior classes, if you lose a couple of classes trying a new tool or trying something different, it’s gonna have more of an impact on their overall learning, ‘caus you don’t have as much extra time.

Janet gave similar explanations with regards to why she used technology differently in her classes. She explained:

> You have to think more carefully before you put them [seniors] in charge of their own learning. I have to make sure that I’ve got the resources there that will support the learning that they actually need, whereas with my year 10s, I can perhaps be… allow a little bit more time for them to do their own research and, and to find resources – you know, like websites or whatever that are appropriate.

These teachers therefore relied on teacher-directed approaches in order to teach the content material. They channelled their efforts into making the students learn the concepts through traditional teaching approaches and used technology to further enhance students’ conceptual understanding of the taught concepts. The teachers’ use of technology in the senior classes was similar to what Niess et al. (2010) noted of teachers who demonstrated *accepting* TPACK level in their study. They indicated that teachers at *accepting* level were more concerned about teaching content knowledge to students through traditional teaching methods. Similar observations were made in the classes of most of the teachers in the current study. The teachers in this current study felt that they had to teach the content to the senior students. They were more interested in 'delivering' the content to the students which Janet puts it as "basically ... trying to feed stuff into their heads."

The evidence from this study has confirmed that for these teachers, TPACK was not static but shifted (Niess, 2012; Niess et al., 2010). The teachers used technology, and were able to justify their use through different philosophies applied to the different classes they were teaching. The teachers' TPACK approaches were affected by the content and academic level of their students as well as the teachers' perceptions of what they thought students needed to know. Colin noted that the examinations for the seniors are pen and paper based "so no matter what their ICT skill is, they need to be able to do the old way as well." The teachers also used technology based on what they thought students expected of them. Although Janet wanted her senior students to be engaged, she realized that some of the students expected her to teach differently. She explained:

> That class that you've just been in, they're not as engaged in, in technology as we might think students are. I mean they're, they're okay, but there's a lot of kids in this class – I think it's mostly girls – who think that they should be writing heaps of notes in books and things like that.

The observations in the study lend empirical evidence to the claim that context influences teachers' TPACK levels and development as well as their use of technology in general (Koehler & Mishra, 2009; Mishra & Koehler, 2006; Niess et al., 2010). Again, the teachers who were part of the observations in this study have shown that TPACK is not fixed but is rather a "dynamic, fluid process, rather than as a static view of teachers having or not having TPACK" (Niess, 2012, p. 7) and that it is influenced by the content context.

Transformative nature of TPACK

This thesis did not set out to find out the nature of TPACK knowledge although a review of the nature of TPACK knowledge was done. However, the results from the observed and interviewed teachers have brought to the fore the transformative nature of TPACK knowledge. The transformative view however sees TPACK as a unique body of knowledge required for effective teaching with technology (Angeli & Valanides, 2009; Graham, 2011). The transformative view of TPACK advocates that technology, pedagogy and content knowledge are unexpressed resources for a teacher and they become useful for effective teaching only when they are transformed into TPACK.

The teachers who were observed showed that they possessed TPACK albeit to different levels and draw upon their TPACK depending on the context. Janet noted that "What do I want them to do; how can I engage them; and what tool do I have that will do this and engage them"? are the questions that come to mind when she is preparing her lessons. This means that she does not prepare the lesson and then search for technological device that can help her deliver the content. She therefore has a transformed knowledge from which she depends upon to teach with technology. Sharon also indicated that she treated the use of technology as she would treat any other teaching strategy and question what that tool will add to her teaching.

> I'd probably look at it as like I'd look at any other sort of strategy, so it's like what do I want out of this? Is this going to help for literacy or something, for example? Um, you know, and why would it help, and you know, and that's how I usually approach it.

As noted by Sharon, the use of technology has become another teaching strategy just like demonstration, inquiry or lecture method. She therefore uses the approach that is best suited for the content as well as her students. This therefore indicates that she has a transformed knowledge which she draws upon to teach with technology.

Summary of the discussion

The discussion has revealed that New Zealand science teachers in general have a very high opinion of themselves with respect to the various constructs of TPACK framework. They scored mean scores of 4.0 and above for the various constructs except TK. Teachers' TCK and PCK were found to develop with practice and experience since their training did not provide them with the characteristics of these constructs. Positive significant correlations were found between the six constructs and TPCK. The regression analysis revealed that TPK and TCK made significant contributions to TPCK.

Science teachers' TPACK levels were found to shift and change in practice depending on context as noted by Niess (2012). The case studies provide specific examples of these shifts. These show that in science classes observed, teachers' TPACK levels shifted due to the curriculum and content demands. In classes where the students were not focussed on external examinations, teachers exhibited characteristics of higher levels of TPACK but shifted to apparent lower levels of TPACK in senior classes who were focussed on examinations. Since this was relatively consistent for all six cases, it is likely that most science teachers in New Zealand use technology similarly to the teachers exemplified in the cases. Especially so given that these teachers scored highly on average, relative to the national teacher data, on the TPACK questionnaire, the cases illustrate how frequent users of technology in the teaching process appropriate the affordances of technology to foster science teaching and learning in New Zealand.

Although the influence of contextual factors has been speculated to affect TPACK in the literature, previously there has not been documented empirical evidence to support this speculation. This research therefore provides new empirical evidence to support the claim that contextual factors indeed affect science teachers' TPACK in practice.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This is the concluding chapter of the thesis. It presents the summary of the research including the design used, limitations and findings as well as the conclusions drawn from the results and how they may affect educational practice and ends with recommendations and areas for future research.

Summary of the research

Summary of research design

The aim of this research was to gauge New Zealand's high school science teachers' perceptions of their understanding of TPACK and its related constructs as well as find out how science teachers used technology in different contexts in order to describe their TPACK. The study used a mixed methods approach (Creswell, 2008; Yin, 2009) whereby quantitative data was generated from a large national sample as well as qualitative, in-depth observations and interviews to ascertain the actual practices of cases of science teachers and their use of technology in their classrooms. Quantitative and qualitative data were collected, analysed and triangulated to help provide a comprehensive analysis of the topic under discussion (Creswell, 2008; Creswell & Plano Clark, 2011).

The quantitative aspect of the study was achieved through the use of an online survey to collect data to identify teachers' perceptions of their understanding of the various constructs of the TPACK framework whereas the qualitative part employed case studies in which direct observations of events as well as interviews of teachers in several teaching contexts were used to yield deeper understanding of a phenomenon (Cohen et al., 2007; Merriam, 1998; Sarantakos, 2005, 2013; Yin, 2009). Means and standard deviations for the various constructs of the TPACK were calculated for the quantitative data. Multiple correlation analyses were conducted to identify how the various constructs of the TPACK framework correlated to each other. Regression analyses brought to the fore which constructs were the major predictors of TPCK. Information gathered from participants through the interviews and observations were clustered into themes and analysed thematically through narrative analysis.

Limitations of the study

Since no human endeavour is perfect, especially research, this study also had its limitations. The use of the survey was useful to gather a large amount of data but inherently, was not able to provide answers to in-depth or probing questions nor could this survey seek clarifications and determine the conditions or contexts related to how the participants responded to the questionnaire items (Sarantakos, 2013). Moreover, surveys are not able to account for under or over self-estimations of capabilities. In order to minimize the effects of these weaknesses on the study, a large sample was used to provide sufficient data to describe teacher perceptions "on average" as well as other (interview and observations) data collected. The questionnaire for the survey was piloted before it was used for the actual study. The items on the questionnaire were taken through a rigorous factor analysis procedure to ensure their validity. In addition, the subscales of the questionnaire all had Cronbach alpha coefficients of 0.7 and above. The interviews and observations of six teachers as specific cases, helped to throw more light on the issues noted in the questionnaire. Thus, there was an element of triangulating the data to make sure that the best possible combination of methods was used to answer the research questions and to provide in-depth nuances to expand the descriptions relative to teachers' backgrounds.

Although the survey items were taken through rigorous validation process, it should be noted that the items were limited to the description of the various constructs. The context within which respondents were going to be was not captured by the items. Thus, the survey could not account for the various contextual factors that could influence teachers' responses.

Again, the outcome of the case studies should be interpreted with caution since the participants were selected purposively. The teachers selected for the case studies could be considered as better users of technology than the average New Zealand science teacher. This was evident in the high mean score they had for technological knowledge as compared to the national average (See Appendix 9). Although generalizing from case studies is not desirable, the conditions under which these teachers were teaching were similar to most New Zealand schools which therefore mean that it will not be far-fetched to assume that what was found among these teachers could also pertain to other schools.

Moreover, since the research was time bound and could not go on for a long period, the topics that the teachers were teaching at the time of observations could impact on how they used technology. Thus, the timing of the observations is noted as a limitation of this study. The interview comments indicate their thoughts at the time, and there may have been other factors that they did not mention. Similarly the data are dependent on the level of self-awareness of the teachers and their ability to reflect on their teaching approaches and behaviours. However, it is assumed that since there were more than one observation the research captured what pertains in the classroom as much as possible, within the bounds of the contexts described.

Key findings of the study

The data and its analysis revealed that New Zealand's high school science teachers' in general had a high perception of their understanding of TPACK and its related constructs. Teachers in this study had high mean scores on all the constructs of TPACK indicating that they were able to perform, understand or know most of the activities indicated in the items of the questionnaire. On a five-point (strongly agree to strongly disagree) Likert scale, the teachers had mean scores of 4.0 and above, which translates into ‘agreed’, for all the constructs of TPACK framework.

The evidence from this study showed that there were statistically significant correlations between all the basic constructs (TK, CK and PK) and TPCK. The primary intersecting constructs (PCK, TCK and TPK) also correlated significantly with TPCK. There were varying correlations between the basic constructs and the primary intersecting constructs. The data also revealed correlations between PK and CK and also demonstrated how the primary intersecting constructs correlate among themselves. The evidence from this research has shown the relationships that exist among the various constructs of the TPACK framework. The analysis revealed that of all the constructs, TPK is the major predictor of TPCK although TCK also made significant contribution to TPCK (See Figure 3). The other constructs did not make any statistically significant contribution to the development of TPCK.

The teachers who were observed and interviewed demonstrated the characteristics of TPACK to varying degrees. The observations indicated that TPACK is not a static construct but can best be described as being dynamic, i.e. changes in use and application with context. The results of this research revealed that teachers’ TPACK is influenced by the level of students they teach and by implications the learning intentions and outcomes teachers had for students at each level. At the senior level, where the students were focused on examinations, teachers mostly demonstrated low levels of TPACK. On the contrary, the teachers switched to higher levels of TPACK at the junior level, where there was no immediate focus on examinations. Thus, this research has shown that teachers’ slide in and out of higher levels of TPACK to lower levels depending on the prevailing context. The context that influenced this study’s teachers’ TPACK characteristics was the perceived importance of content. The teachers wanted to focus on the content in the senior levels so that the students would be better prepared for their examinations. Students’ high stakes assessment therefore influenced how the teachers used technology in their teaching. The teachers felt that they were able to provide better learning experiences for the senior students by using technology for conveying content and that in some cases the use of technology hindered the amount of content they could cover within the school term (See Qualitative Results). They therefore resorted to minimal use of technology in order to cover a lot of content in the senior classes.

The results also revealed that teachers' use of technology in their teaching was mostly influenced by what their colleagues used. Teachers learned how to use new technology from their colleagues, tried new technology based on the recommendations of their colleagues as well as discussed among themselves what worked and did not work as far as their use of technology was concerned. The teachers who were participants in the case studies can be considered high users (or early adopters). Other teachers might aspire to being like them or there may be some way to bring other teachers up to this level through either peer mentoring processes or specific professional development that targets specific needs.

This research has brought to light how the characteristics of teachers' TPACK shift and change i.e. teachers' levels of TPACK has been found to be dynamic. The research has revealed that teachers shift their levels of TPACK to suit the contextual factors. In view of this, it will be appropriate that more emphasis is laid on the importance of context in the TPACK framework. Although the whole framework is embedded in context, researchers have not previously emphasised the significance of contextual factors on TPACK development, use and application.

Conclusion

It can be concluded based on the results of this study that New Zealand high school science teachers have high perceptions of their understanding of TPACK constructs. There were positive high correlations between TPCK and the other six constructs of the TPACK framework. TPK and TCK were found to be the major predictors of TPCK (See Table 27).

The regression analysis has shown that the intersecting constructs of TPK and TCK are the predictors of TPCK which therefore presupposes that there is a link between the various constructs of the TPACK framework and therefore TPACK development should have a holistic, blended and integrated nature rather than just treating each of the basic constructs in isolation (Harris et al., 2009; Koehler & Mishra, 2005). The issue of the intersecting constructs predicting TPCK has been noted previously (Horzum, 2013; Pamuk et al., 2013).

It can also be concluded that teachers' TPACK levels are affected when their teaching becomes assessment driven. Moreover, teachers' use of technology in their schools was motivated by what they thought students needed to learn. These two conclusions emphasise the fact that contextual factors have a major influence on teachers' use, application and development of TPACK (Koehler & Mishra, 2009; Niess et al., 2010).

Recommendations

The following recommendations are offered as a consequence of this research.

1. There should be an effort to dissuade teachers from making their teaching assessment driven since teachers indicated that their use of technology was influenced by the NCEA. Rather, they should be encouraged to focus on what and how students might learn what they need to know and do and therefore how technology can assist learning.
2. There are many teachers in the school system who trained at a time when the use of technology was less important. Therefore teachers should be offered professional learning on how to use technology to foster inquiry that would "cover" a large amount of content knowledge at the same time so that students' own expertise is leveraged.
3. There should be conscious leadership training for teachers on how to use and share their use and applications of technology to teach since teachers relied on

and valued their colleagues’ knowledge when it came to teaching with technology.

4. Initial teacher education programmes should incorporate the development of TPACK in their curriculum since it has the potential for focussing on more effective teaching with technology and provides a framework for teachers to reflect on what aspects they may need help with.
5. The development of teachers’ TPACK should be through an integrated approach where technology, pedagogy and content knowledge are treated together rather than in isolation with emphasis on the intersecting constructs as well.
6. Teacher education programmes should rigorously pursue the integration of technology in the teaching of their programmes since most teachers felt that their initial teacher education programmes did not prepare them well for teaching with technology.

Implications of the research on educational practice

This research has shown that TPACK is mostly affected by the primary intersecting constructs (TPK and TCK) and these constructs are derived from the three basic constructs (TK, CK, and PK). Thus, in order to develop TPACK one needs to have all the three basic constructs developed simultaneously in an integrated manner. The implication of this is that teacher education programmes should not teach these basic constructs in isolation. There should be a shift from teaching one technology course in isolation to teaching how to use technology to teach specific content (i.e. an infusion or embedded model using technology within all courses). Preservice teachers should not be taught the concepts of science separately from the possible pedagogies and technology they can use to teach those concepts but rather content could be learnt through the incorporation of technology.

Content, technological and pedagogical skills should therefore be taught and modelled together in an integrated manner. This approach will help to eliminate the phenomenon of treating technology as an "add-on" to treating technology, pedagogy and content in a more blended, integrated and connected way which takes into consideration the classroom contexts as suggested by Koehler and Mishra (2009). This study has revealed that the development of TPACK should be geared towards developing in teachers an integrated knowledge where the overlaps between the various constructs are not downplayed. Thus, there should be a paradigm shift in teacher education programmes from the practice of teaching preservice teachers about technology and paying little attention to learning to teach the subject with technology (Niess, 2001) and rather focus teaching students how to integrate technology, pedagogy and content for specific teaching contexts.

This research has shown that teachers' perception of the importance of content knowledge, with assessment in view, does affect teachers TPACK levels and applications of technology. This aspect of TPACK should be tackled during initial and on-going teacher education. It is impossible for teacher educators to foresee all the contexts that teachers might face. However, examples of possible practice (as exemplified by the case studies in this research) can show how teachers can use technology within a particular learning environment, yet potentially adapt and modify this use to another context. It will require conscious efforts by teacher educators to minimize the effect of school assessment on teachers' TPACK levels. This may help teachers to reach the *advancing level* of TPACK *(Niess, 2012)* as this level deals teachers consciously encouraging students to use technology and evaluating the effectiveness of the technology on students' learning.

In general, the teachers observed and interviewed indicated that they did not feel well prepared by their initial teacher education to teach with technology. This is in agreement with Grunwald and Associates (2010) assertion that it is myth for people to believe that teachers feel adequately prepared to teach with technology by their initial teacher education programme. In order to extenuate this myth, teacher education programmes should incorporate into their curriculum how they can consciously help preservice teachers to teach with technology. Such technology-rich curriculum should use TPACK as its guiding principle and should teach courses in an integrated manner instead of teaching just one technology oriented course focussed on technological skills.

This research showed that teachers' TPACK was affected by their desire to cover large amounts of content so that their students were well prepared for examinations. Thus, when these teachers taught senior sciences in New Zealand, their approaches and planning were driven by assessment demands. This contextual issue can therefore be tackled by teacher educators, curriculum developers and policy makers. As noted by Pamuk (2012) context-free teaching approaches are always bound to fail. Just informing preservice teachers that context does affect how they integrate technology without specific examples is not good enough. Rather preservice teachers should be made aware of the contexts that research has found to influence the use of technology in the classroom.

There is evidence from this study that teachers' use of technology is influenced by their colleagues. There seemed to be a collegial approach to the use of technology by teachers in these New Zealand schools. When the case study teachers tried a new tool out, it was based on the recommendations of another teacher. Professional learning programmes should therefore target groups of teachers in the same school instead of being individualized. This will enable teachers to provide leadership to their colleagues in terms of how to use technology.

Again, technology related professional development programmes should move away from enriching teachers' technological skills but rather emphasis should be laid on how teachers can appropriate the affordances of technology in their classroom practices. This is because effective teaching with technology does not just lie in advanced technological skills but rather how effectively teachers can appropriate the affordances of technology to meet their instructional goals as well as students' learning outcomes.

Suggestions for future research

This research revealed other areas of interest that research on TPACK could progress towards. There seems to be a belief that TPACK is a teacher knowledge construct i.e. something that teachers possess and therefore there has not been any research on the effect of teachers' TPACK on student learning. This is an area that should be researched. After all, improving student learning is the ultimate goal of teaching. More research is also needed to determine other contextual issues that affect teachers' TPACK in practice as well as the way in which the contributing components or constructs affect TPACK and how this varies in practice.

This research has shown how contextual factors influence teachers' TPACK levels and how the characteristics of TPACK shift and change depending on context. It is therefore appropriate that future surveys on TPACK stipulate the context within which they want respondents to supply responses to the items soliciting information on the various constructs. This will give the reader as well as the researcher a fair idea as to how the respondents were thinking when they responded to the survey items.

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APPENDICES

Appendix 1: Ethical approval letter for the research

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: 2012/02/ERHEC

16 March 2012

Kofi Owusu
School of Sciences & Physical Education
UNIVERSITY OF CANTERBURY

Dear Kofi

Thank you for providing the revised documents in support of your application to the Educational Research Human Ethics Committee. I am very pleased to inform you that your research proposal "Assessing New Zealand's science teachers' technological, pedagogical, content knowledge (TPACK)" has been granted ethical approval.

Please note that should circumstances relevant to this current application change you are required to reapply for ethical approval.

If you have any questions regarding this approval, please let me know.

We wish you well for your research.

Yours sincerely

pp L Griffioen

Nicola Surtees
Chair
Educational Research Human Ethics Committee

"Please note that Ethical Approval and/or Clearance relates only to the ethical elements of the relationship between the researcher, research participants and other stakeholders. The granting of approval or clearance by the Ethical Clearance Committee should not be interpreted as comment on the methodology, legality, value or any other matters relating to this research."

Appendix 2: Information sheets for the participants of the study

College of Education

School of Sciences and Physical Education

Tel: +64 3 343 9623, Fax: + 64 3 345 8131

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Information sheet for science teachers who will be interviewed and observed

Assessing New Zealand's Science Teachers' Technological, Pedagogical, Content Knowledge (TPACK)

I am a PhD student at the College of Education, University of Canterbury, New Zealand. I am conducting a study on the knowledge and perceptions behind science teachers' use of technology. The study seeks to find out how science teachers blend technology, content and pedagogical knowledge. Your experience and ideas will make an important contribution to this research.

If you decide to be part of this project, I will interview you about your experience of teaching with technology, how you obtained your technological know-how, what informs your use of a particular technology for a particular science topic, the technology available to you and the role technology plays in your teaching. I would also like to observe your teaching to see how you use technology in the teaching and learning process. There will be between four (4) to five (5) observations at different times suitable to you. I will take notes during the observations but will not record it with a tape recorder or video camera. I may look at some of your past teaching and learning materials.

The interview will take about 20- 30 minutes and will be tape recorded. You may request the recording to be stopped temporarily or permanently if at any time you feel uncomfortable. As the principal researcher, I will conduct and transcribe the interview. You will be provided with a copy of the interview transcript for review and approval. Your participation is voluntary and you have the right to withdraw from the project at any time. If you choose to withdraw, I will remove any of the information relating to you from the project, including any final publication, provided that this remains practically achievable. The research will not interfere with the normal teaching schedule.

It will be difficult to ensure your anonymity during the study since some members of your school community will know that you are being observed and interviewed. However, all information gathered will be treated in strictest confidence and your confidentiality will be ensured in all publications. All data gathered will be securely stored in password protected facilities in the University of Canterbury for five years following the study before being destroyed and any data that can identify you will not be given to any other researcher or agency. The results of the study may be submitted for publication to national or international journals or presented at educational conferences. You may at any time ask for additional information or results from the study.

If you would like more information or have any questions about the research, you can contact me or my supervisors Assoc. Prof. Lindsey Conner (lindsey.conner@canterbury.ac.nz) and Dr. Chris Astall (chris.astall@canterbury.ac.nz). If you have any concerns or complaints about this research, please contact The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz). If you are happy to take part please **sign the consent form and return it to me** in the envelope provided. Please retain this information sheet. Thank you for your consideration of this research project.

KOFI OWUSU (kofi.owusu@pg.canterbury.ac.nz) Office Phone: (03) 364 2987 etxn: 4322

Information Sheet for Principals

Assessing New Zealand's Science Teachers' Technological, Pedagogical, Content Knowledge (TPACK)

I am a PhD student at the College of Education, University of Canterbury, New Zealand. I am conducting a study on the knowledge and perceptions behind science teachers' use of technology. The study seeks to find out how science teachers blend technology, content and pedagogical knowledge. Thus, this study seeks to measure New Zealand's science teachers' understanding of Technological, Pedagogical, and Content Knowledge.

Science teachers' involvement in this project will include completing an online survey and if selected, interviewed before they teach and their classroom during teaching observed for 4-5 sessions. The interviews will focus on the teachers' perceptions of technology integration, their knowledge behind the use of technology in their classrooms, how they gained the knowledge on how to use technology in their teaching, what informs their use of particular technology as well as their preparation before they use technology in their lesson. The observations will focus on how teachers are using technology: whether teachers use technology to facilitate students' conceptual knowledge building, procedure knowledge building or as knowledge expression tool. I may look at some of school records like teachers' past teaching and learning materials.

The interviews will be tape recorded whiles notes will be taken during the observations. However, teachers may request the recording to be stopped if they feel uncomfortable being recorded during the interview. All participants will be provided with a copy of interview transcript for review and approval. As the principal researcher, I will conduct and transcribe all the interviews. Science teachers' participation in this project is completely voluntary and their informed consent will be sought. Participants may withdraw from the study any time. If they choose to withdraw, I will use my best endeavours to remove any of the information relating to them from the project, including any final publication, provided that this remains practically achievable.

It will be difficult to ensure the anonymity of participants during the study since some members of your school community will know that observations and interviews of colleagues are ongoing. However, all information gathered will be treated in strictest confidence and teachers' confidentiality will be ensured in all publications. All data will be securely stored in password protected facilities in the University of Canterbury for five years following the study before being destroyed and any data that can identify the participants will not be given to any other researcher or agency. The results of the study may be submitted for publication to national or international journals or presented at educational conferences. Participants may at any time ask for additional information or results from the study. If you would like more information or have any questions about the research, you can contact me or my supervisors Assoc. Prof. Lindsey Conner (lindsey.conner@canterbury.ac.nz) and Dr. Chris Astall (chris.astall@canterbury.ac.nz). If you have any concerns or complaints about this research, please contact The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz). If you are happy to take part you will need to **sign the consent form and return it to me** in the envelope provided. Please retain this information sheet. Thank you for your consideration of this research project.

KOFI OWUSU (kofi.owusu@pg.canterbury.ac.nz) Office Phone: (03) 364 2987 etxn: 43229.

Appendix 3: Consent form for principals

College of Education

School of Sciences and Physical Education
Tel: +64 3 343 9623, Fax: + 64 3 345 8131

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

School Principal's Consent Form

I understand the aims and purposes of the research study being undertaken by ***KOFI OWUSU.***

- The study has been explained to me and I understand the information that was given in the information sheet and I understand I can ask for more information at any time.
- Participation in this study by the science teacher is voluntary and he or she will have all questions answered to his or her satisfaction.
- The teacher is aware that he or she can withdraw from the study at any time without penalty and understands his or her involvement in the project.
- I understand that all information will be treated in strictest confidence; that it will be difficult to ensure the anonymity of participants during the study since some members of my school community will know that observations and interviews of colleagues are ongoing. However, all information gathered will be treated in strictest confidence and participants' confidentiality will be ensured in all publications and that no information that could identify them will be given to other researchers or agencies. I understand that all data from this research will be securely stored in password protected facilities and/or locked storage at the University of Canterbury for five years following the study before being destroyed.

- Within these restrictions, the findings may be submitted for publication to national or international journals or presented at educational conferences and that the results of the study can be made available to participants upon their request and participants can request additional information at any time.

- Interviews will be tape recorded and participants can ask that the recording to be stopped temporarily or permanently at any time and will be provided with a copy of the interview transcript to check for accuracy. Notes will be taken during the classroom observation.
- The study will be carried out as described in the information statement, a copy of which I have retained.
- I have read the information sheet and consent form. I allow you to conduct your study within this school.

Name: ____

Signed: ____

Date: ____

Appendix 4: Consent form for teachers

College of Education

School of Sciences and Physical Education
Tel: +64 3 343 9623, Fax: + 64 3 345 8131

Assessing New Zealand's Science Teachers' Technological, Pedagogical, Content Knowledge (TPACK***)***

Science Teachers' Consent Form

I understand the aims and purposes of the research study being undertaken by KOFI OWUSU.

- The study has been explained to me and I understand the information that was given to me on the information sheet.
- I am aware that my participation in this project is voluntary. I have had all questions answered to my satisfaction.
- I understand that my involvement will include an individual interview and observation of me during teaching concerning my perceptions on the use of technology in the science classroom.
- I understand that I can withdraw from the study at any time, which I do not have to give any reason for withdrawing. I understand what is required of me during this project.
- I understand that all information will be treated in strictest confidence; that it will be difficult to remain anonymous during the study since some members of my school community will know that I have been observed and interviewed. However, my anonymity and confidentiality will be maintained in all publications and that no information that could identify me will be given to other researchers or agencies. I understand that all data from this research will be securely stored in password

protected facilities and/or locked storage at the University of Canterbury for five years following the study before being destroyed.

- I understand that within these restrictions, the findings may be submitted for publication to national or international journals or presented at educational conferences; that the results of the study can be made available to me at my request and that I can request additional information at any time.
- I understand that interviews will be tape recorded and I can ask the recording to be stopped any time temporarily or permanently. I will be provided with a copy of interview transcript to check for accuracy. I understand that notes will be taken during the observation.
- I have read the information sheet and consent form. I agree to participate in the study.

Name: ____

Signed: ____

Date: ____________________________________

Appendix 5: Items for the TPACK survey

In this section, you will be asked to report on your understanding of **TECHNOLOGY KNOWLEDGE**. Please read each item carefully and **SELECT** the response that best fits your abilities.

TECHNOLOGICAL KNOWLEDGE (TK)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I know how to solve my own technical problems					
I keep up with important new technologies					
I know about a lot of different technologies					
I have the technical skills I need to use technologies					
I have had sufficient opportunities to work with a range of technologies					
I can learn to use new software easily on my own					
I can install a new program that I would like to use					

In this section, you will be asked to report on your understanding of **CONTENT KNOWLEDGE**. Please read each item carefully and **SELECT** the response that best fits your abilities.

CONTENT KNOWLEDGE (CK)	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
I have sufficient knowledge about the subject I teach					
I have various ways and strategies of developing my understanding of the subject I teach					
I have a deep and wide understanding of the subject that I teach					
I can comfortably plan the scope and sequence of concepts that need to be taught within my class					
I know about various examples of how my subject matter applies in the real world					
I can use a scientific way of thinking					
I have good understanding of the Nature of Science					
I follow up-to-date resources and developments in my subject area					

In this section, you will be asked to report on your understanding of **PEDAGOGICAL KNOWLEDGE.** Please read each item carefully and **SELECT** the response that best fits your abilities.

PEDAGOGICAL KNOWLEDGE (PK)	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
I know how to assess student performance in a classroom					
I can adapt my teaching based upon what students currently understand or do not understand					
I can adapt my teaching style to cater for diverse learners.					
I can use a wide range of teaching approaches in a classroom setting					
I can use different assessment tools and techniques					
I know how to organize and maintain classroom management					
I can determine the strategy best suited for the lessons I teach					
I am able to prepare lesson plans for the various topics I teach					

In this section, you will be asked to report on your understanding of **PEDAGOGICAL CONTENT KNOWLEDGE**. Please read each item carefully and **SELECT** the response that best fits your abilities.

PEDAGOGICAL CONTENT KNOWLEDGE (PCK)	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
I can select effective teaching approaches to guide student thinking and learning in my subject matter					
I can produce lesson plans with a good understanding of the topic in my subject matter					
I can anticipate likely student misconceptions within a particular topic					
I can assist students in identifying connections between various concepts in my subject matter					
I can distinguish between correct and incorrect problem solving attempts by students within my class					
I am familiar with common student understandings and misconceptions in my subject matter					
I am able to meet the objectives described in my lesson plans					
I explicitly target aspects of the Nature of Science when teaching					

In this section, you will be asked to report on your understanding of TECHNOLOGICAL CONTENT KNOWLEDGE. Please read each item carefully and SELECT the response that best fits your abilities.

TECHNOLOGICAL CONTENT KNOWLEDGE (TCK)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I know about technologies that I can use for teaching specific concepts in my subject matter					
I know how my subject matter can be represented by the application of technology					
I know about technologies that I can use for enhancing the understanding of specific concepts in my subject matter					
I can use technological representations (i.e. multimedia, visual demonstrations, etc.) to demonstrate specific concepts in my subject matter					
I can use various types of technologies to deliver the content of my subject matter					
I can use technology to make students observe phenomenon that would otherwise be difficult to observe in my subject matter					
I can use technology to create and manipulate models of scientific phenomenon (e.g. animations, modelling, etc)					

In this section, you will be asked to report on your understanding of TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE. Please read each item carefully and SELECT the response that best fits your abilities.

TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE (TPK)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can choose technologies that enhance the teaching approaches for a lesson					
I can choose technologies that enhance students learning of a concept					
I can choose technologies that are appropriate for my teaching					
I can apply technologies to different teaching activities					
I can effectively manage a technology-rich classroom					
I can use technology to help assess student learning					

In this section, you will be asked to report on your understanding of TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE. Please read each item carefully and SELECT the response that best fits your abilities.

TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPCK)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can teach lessons that appropriately combine my subject matter, technologies, and teaching approaches					
I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn					
I can use strategies that combine content, technologies, and teaching approaches in my classroom					
I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school					
I can choose technologies that enhance the understanding of the content for a lesson					
I am able to find and use online materials that effectively demonstrate a specific scientific principle					
I can use technology to facilitate scientific inquiry in the classroom					
I am able to use technology to create effective representations of content that departs from textbook approaches					

End of survey

Appendix 6: Interview protocol for the study

Theme 1: Training teachers have had in using technology to teach

Was there any ICT training during your initial teacher education programme?

If Yes: was it focused on how to use ICT to teach?

If No: how did you learn how to use ICT in teaching?

Have you had any ICT PD?

What was the focus of the PD?

How long have you been teaching?

How long have you been teaching with ICT tools?

Theme 2: Available technology in the school

What ICT facilities do you have in the school?

How does the school acquire technology for teaching?

Do teachers play any role in the school's decision to acquire technology?

Are you able to get access to any ICT tool you wish to use?

How does the school help in your quest to teach with ICT tools?

Theme 3: Teaching with technology

Are you able to determine the educational qualities of a technological device or tool?

If so how do you do it?

What informs your selection of a particular ICT tool to use in a lesson?

Describe the process you go through to select a particular ICT tool to teach a lesson.

Have you had to modify your teaching to accommodate the use of ICT? If so how?

How do ICT tools change your teaching in general?

How different is teaching with ICT from teaching without ICT?

To what extent do ICT tools selected impact the content you teach?

Which of your classes do you mostly use ICT to teach?

Why do you use ICT mostly in these classes?

Theme 4: Role of ICT in teaching

Why do you use ICT in your lessons?

What role does ICT play in your lessons? Can you list some of the ways you use ICT in your lessons?

Appendix 7: Observation protocol

ACTIVITY	RESPONSE YES	RESPONSE NO	TECHNOLOGY BEING USED SOFTWARE	TECHNOLOGY BEING USED HARDWARE
To present content knowledge to students				
To use ICT tools to allow students to examine/observe pictures, diagrams etc.				
To let students gather information /conduct an inquiry				
To support students generate data using digital devices				
To allow students put together collected data				
To demonstrate a concept through video				
To allow Students to present their work				
To explain or elaborate on a scientific concept				
As a management tool				
To explore science content through simulations				
To allow students take a quiz				
To allow students discuss opposing viewpoints				
To allow students review a test				
To let students recognize patterns, describe relationships and discrepancies				
To engage students in discussion				

Appendix 8: SPSS output for the regression analysis

Standard multiple regression output

Descriptive Statistics

Constructs	Mean	Std. Deviation	N
Technological Pedagogical Content Knowledge	4.2564	.53075	98
Technological Knowledge	3.7638	.71387	98
Pedagogical Knowledge	4.3865	.50992	98
Content Knowledge	4.5306	.44078	98
Pedagogical Content Knowledge	4.3291	.49331	98
Technological Content Knowledge	4.2318	.57125	98
Technological Pedagogical Knowledge	4.1531	.55773	98

Correlation

		TPCK	TK	PK	CK	PCK	TCK	TPK
Pearson Correlation	Technological Pedagogical Content Knowledge	1.000	.455	.573	.498	.563	.710	.819
	Technological Knowledge	.455	1.000	.135	.255	.287	.567	.451
	Pedagogical Knowledge	.573	.135	1.000	.660	.740	.475	.663
	Content Knowledge	.498	.255	.660	1.000	.770	.522	.599
	Pedagogical Content Knowledge	.563	.287	.740	.770	1.000	.583	.649
	Technological Content Knowledge	.710	.567	.475	.522	.583	1.000	.768
	Technological Pedagogical Knowledge	.819	.451	.663	.599	.649	.768	1.000

Sig. (1-tailed)	Technological Pedagogical Content Knowledge	.	.000	.000	.000	.000	.000	.000
	Technological Knowledge	.000	.	.093	.006	.002	.000	.000
	Pedagogical Knowledge	.000	.093	.	.000	.000	.000	.000
	Content Knowledge	.000	.006	.000	.	.000	.000	.000
	Pedagogical Content Knowledge	.000	.002	.000	.000	.	.000	.000
	Technological Content Knowledge	.000	.000	.000	.000	.000	.	.000
	Technological Pedagogical Knowledge	.000	.000	.000	.000	.000	.000	.
N	Technological Pedagogical Content Knowledge	98	98	98	98	98	98	98
	Technological Knowledge	98	98	98	98	98	98	98
	Pedagogical Knowledge	98	98	98	98	98	98	98
	Content Knowledge	98	98	98	98	98	98	98
	Pedagogical Content Knowledge	98	98	98	98	98	98	98
	Technological Content Knowledge	98	98	98	98	98	98	98
	Technological Pedagogical Knowledge	98	98	98	98	98	98	98

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Technological Pedagogical Knowledge, Technological Knowledge, Content Knowledge, Pedagogical Knowledge, Technological Content Knowledge, Pedagogical Content Knowledge	.	Enter

a. All requested variables entered.

b. Dependent Variable: Technological Pedagogical Content Knowledge

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.833[a]	.694	.674	.30294

a. Predictors: (Constant), Technological Pedagogical Knowledge, Technological Knowledge, Content Knowledge, Pedagogical Knowledge, Technological Content Knowledge, Pedagogical Content Knowledge

b. Dependent Variable: Technological Pedagogical Content Knowledge

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.973	6	3.162	34.456	.000[a]
	Residual	8.351	91	.092		
	Total	27.324	97			

a. Predictors: (Constant), Technological Pedagogical Knowledge, Technological Knowledge, Content Knowledge, Pedagogical Knowledge, Technological Content Knowledge, Pedagogical Content Knowledge

b. Dependent Variable: Technological Pedagogical Content Knowledge

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	.720	.341		2.115	.037	.044	1.397					
	TK	.062	.054	.083	1.140	.257	-.046	.169	.455	.119	.066	.637	1.571
	PK	.114	.102	.109	1.114	.268	-.089	.316	.573	.116	.065	.350	2.855
	CK	-.062	.113	-.051	-.548	.585	-.287	.163	.498	-.057	-.032	.381	2.625
	PCK	.006	.116	.005	.051	.960	-.225	.237	.563	.005	.003	.288	3.470
	TCK	.157	.093	.169	1.678	.097	-.029	.342	.710	.173	.097	.333	3.007
	TPK	.578	.103	.607	5.600	.000	.373	.782	.819	.506	.325	.286	3.497

a. Dependent Variable: Technological Pedagogical Content Knowledge

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	TK	PK	CK	PCK	TCK	TPK
1	1	6.946	1.000	.00	.00	.00	.00	.00	.00	.00
	2	.027	15.926	.01	.59	.02	.01	.01	.00	.00
	3	.010	25.736	.34	.08	.00	.01	.00	.12	.13
	4	.006	33.775	.41	.28	.10	.01	.10	.27	.01
	5	.004	39.797	.08	.04	.23	.12	.16	.23	.25
	6	.003	48.286	.00	.00	.44	.31	.01	.30	.49
	7	.002	55.997	.17	.01	.21	.54	.72	.08	.11

a. Dependent Variable: Technological Pedagogical Content Knowledge

Casewise Diagnostics[a]

Case Number	Std. Residual	Technological Pedagogical Content Knowledge	Predicted Value	Residual
26	5.496	5.00	3.3350	1.66499

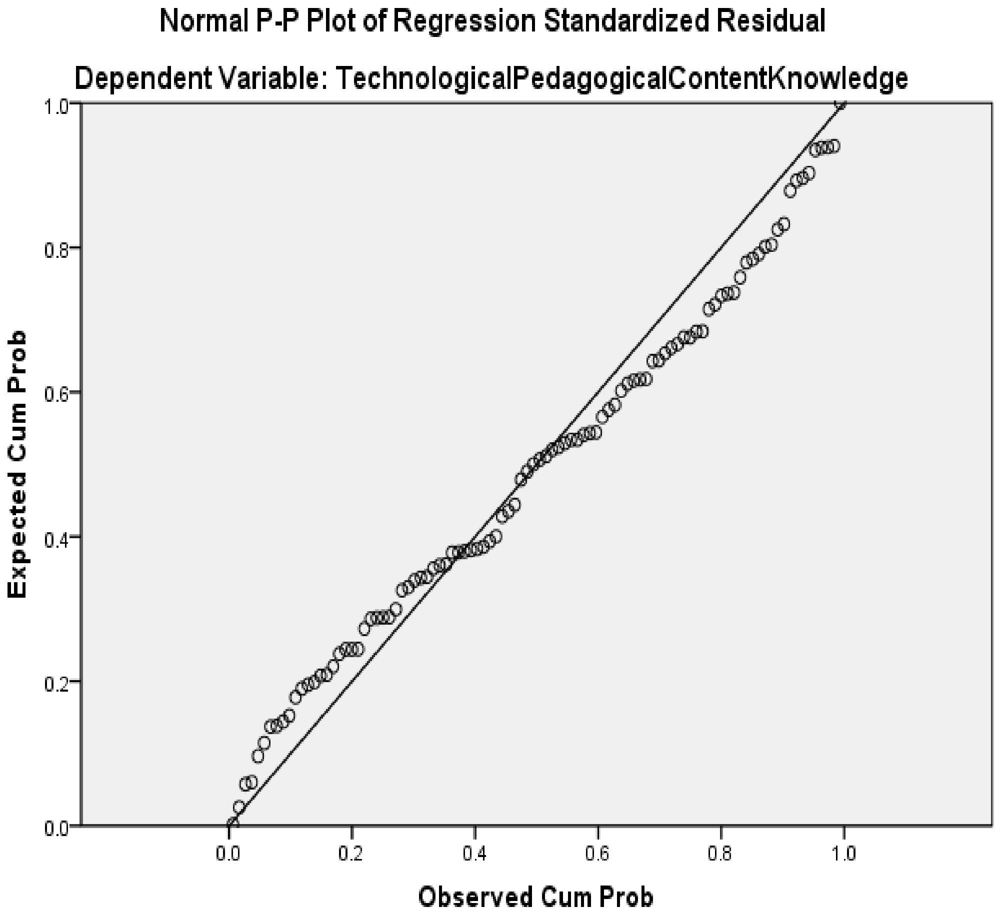
a. Dependent Variable: Technological Pedagogical Content Knowledge

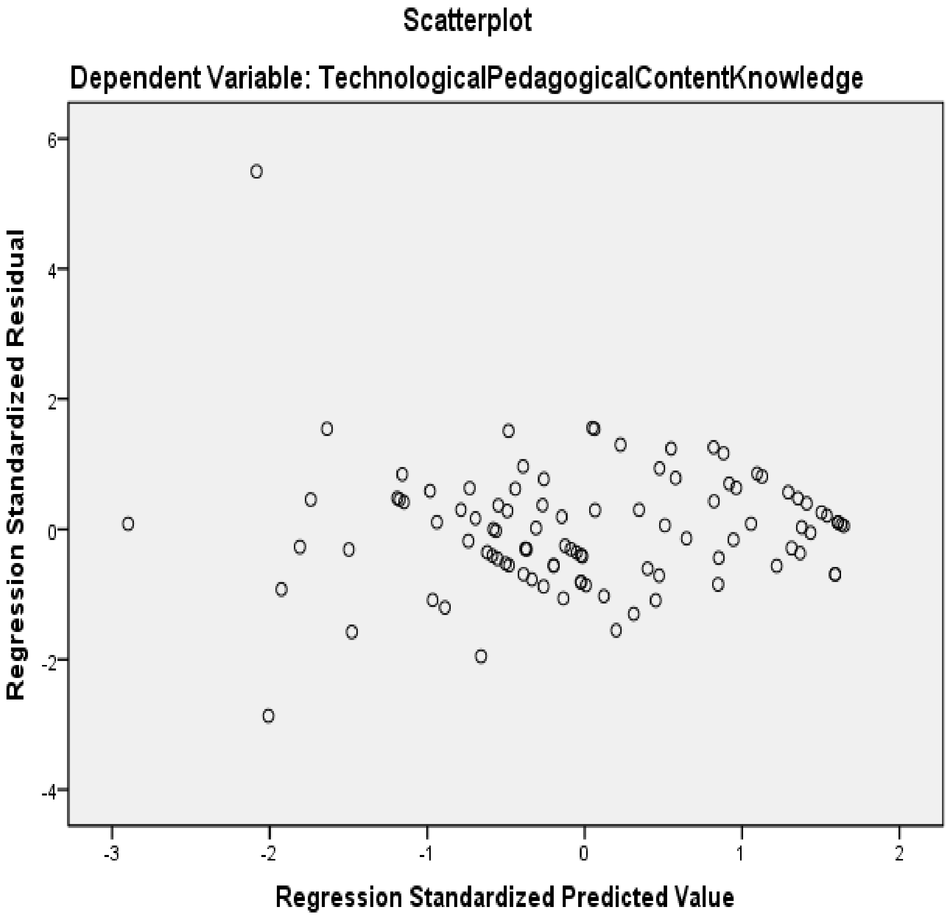
Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	2.9742	4.9845	4.2564	.44226	98
Std. Predicted Value	-2.899	1.646	.000	1.000	98
Standard Error of Predicted Value	.041	.142	.078	.022	98
Adjusted Predicted Value	2.9670	4.9836	4.2567	.44208	98
Residual	-.86797	1.66499	.00000	.29342	98
Std. Residual	-2.865	5.496	.000	.969	98
Stud. Residual	-3.086	5.773	-.001	1.014	98
Deleted Residual	-1.00668	1.83719	-.00034	.32157	98
Stud. Deleted Residual	-3.243	7.212	.013	1.111	98
Mahal. Distance	.767	20.200	5.939	3.960	98
Cook's Distance	.000	.492	.014	.054	98
Centered Leverage Value	.008	.208	.061	.041	98

a. Dependent Variable: Technological Pedagogical Content Knowledge

Charts


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: TechnologicalPedagogicalContentKnowledge
Expected Cum Prob
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob



Scatterplot
Dependent Variable: TechnologicalPedagogicalContentKnowledge
Regression Standardized Residual
Regression Standardized Predicted Value
6
4
2
0
-2
-4
-3
-2
-1
0
1
2

Stepwise Regression Output

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Technological Pedagogical Knowledge	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	Technological Content Knowledge	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: Technological Pedagogical Content Knowledge

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.819[a]	.670	.667	.30625
2	.829[b]	.686	.680	.30029

a. Predictors: (Constant), Technological Pedagogical Knowledge

b. Predictors: (Constant), Technological Pedagogical Knowledge, Technological Content Knowledge

ANOVA[c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.320	1	18.320	195.336	.000[a]
	Residual	9.004	96	.094		
	Total	27.324	97			
2	Regression	18.758	2	9.379	104.012	.000[b]
	Residual	8.566	95	.090		
	Total	27.324	97			

a. Predictors: (Constant), Technological Pedagogical Knowledge

b. Predictors: (Constant), Technological Pedagogical Knowledge, Technological Content Knowledge

c. Dependent Variable: Technological Pedagogical Content Knowledge

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.020	.234		4.368	.000
	Technological Pedagogical Knowledge	.779	.056	.819	13.976	.000
2	(Constant)	.843	.243		3.473	.001
	Technological Pedagogical Knowledge	.635	.085	.667	7.442	.000
	Technological Content Knowledge	.183	.083	.197	2.203	.030

a. Dependent Variable: Technological Pedagogical Content Knowledge

Excluded Variables[b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	Technological Content Knowledge	.197[a]	2.203	.030	.220	.411

a. Predictors in the Model: (Constant), Technological Pedagogical Knowledge

b. Dependent Variable: Technological Pedagogical Content Knowledge

Appendix 9: National teachers and observed teachers mean scores on TPACK constructs

Constructs	National mean (S.D)	Mean of observed teachers: Group mean (S.D)	Elliot	Sharon	Janet	Susan	Colin	Ben
Technological Knowledge	3.7 (0.7)	4.4 (0.4)	3.9	3.9	4.7	4.1	4.8	4.5
Pedagogical knowledge	4.4 (0.5)	4.5 (0.4)	4.3	5.0	4.0	5.0	4.5	4.1
Content Knowledge	4.5 (0.6)	4.4 (0.5)	4.4	4.6	3.6	5.0	4.9	4.0
Pedagogical Content Knowledge	4.3 (0.5)	4.2 (0.5)	3.8	4.4	3.5	4.7	4.5	4.1
Technological Content Knowledge	4.2 (0.6)	4.3 (0.5)	3.6	4.3	4.0	4.6	4.8	4.6
Technological Pedagogical Knowledge	4.1 (0.7)	4.5 (0.4)	4.0	4.2	4.0	4.9	4.9	4.8
Technological Pedagogical Content Knowledge	4.2 (0.6)	4.3 (0.6)	3.5	3.8	3.9	5.0	4.9	4.5