# PRE-SERVICE TEACHERS' COMPETENCES FOR TEACHING SCIENCE THROUGH INFORMATION AND COMMUNICATION TECHNOLOGIES DURING TEACHING PRACTICE

**By**

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# DECLARATION

I, Thuthukile Jita, declare that the Doctoral Degree research thesis that I herewith submit for the Doctoral Degree qualification PhD in Education degree at the University of the Free State is my independent work, and that I have not previously submitted it for a qualification at another institution of higher education.

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# DEDICATION

Much credit for the completion of this thesis goes to my husband, Loyiso Jita, who believed in me and whose undying love and support kept me going through long nights of research, reading, writing, and re-writing. Moreover, I dedicate the completion of my doctoral degree to my children, the real life savers: Hlengekile, Bulelwa, Nwabisa and Mzimkhulu.

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**SUMMARY OF THE STUDY**

Most observers, curriculum designers and policy makers agree that ICTs are an important competency for university students to have in order to compete and perform successfully in their careers in the 21st century. Teacher education students or pre-service teachers are no exception. While some universities, including the one I studied at, encourage ICT usage in their policies and seek to integrate ICTs in all teacher education modules, there is neither a guideline on how pre-service teachers should integrate the ICT tools in their own subject teaching nor a set of performance standards or expectations for teacher educators in South Africa to assess and support the integration of ICTs by students, especially during teaching practice. This study arises out of the concerns that the majority of teachers in schools, some of whom are recent university graduates, struggle to integrate ICTs in their teaching of specific subjects and/or topics. In trying to explore the role of universities generally and the teacher education programmes specifically in the development of ICT capacities and identities of newly qualified teachers, the present study investigated the opportunities to learn and the perceived competences of pre-service teachers in the use ICTs for teaching science in schools. Using a sample of 103 final year science pre-service teachers at one university in South Africa, this concurrent mixed methods study used an adapted version of the TPACK survey for pre-service teachers, developed by Schmidt and colleagues in the USA (Schmidt, Baran, Thompson, Mishra, Koehler, & Shin 2009), with lesson plan analysis and focus group interviews to map out the perceived competences of pre-service teachers on ICT knowledge and skills, their opportunities to learn these skills in the teacher education programme and their use of ICT tools for teaching science during school placement in the final semester before graduation to become newly qualified teachers.

Overall, the key findings in the study suggest that there are significant variations in the ICT competences of the final-year science pre-service teachers from even a single university and/or a common teacher education programme. These variations largely result from the uneven opportunities to learn that are provided to the pre-service teachers, especially during their school placement period. While the differences in ICT module requirements for the various groups of pre-service teachers account for some of the variation in competence, the bulk of the explanation seem to come from the differences that accrue from the in-school experience during teaching practice, where some students are assigned to schools with no facilities or opportunities at all to use ICTs for teaching and/or are assigned to mentors who are themselves not adept users of ICTs, let alone being able to mentor them in the use ICTs for teaching. The study also found that most pre-service teachers were, however, aware of the range of ICT tools that are available for use in teaching science as a result of their ICT lecturers' use of these tools and particularly their use by the subject methodology lecturers. During teaching practice, though, many of the pre-service teachers who ventured into using ICTs tended to opt for low-technology tools such as over-head projectors and printers as opposed to the use of multi-media tools such as cell phones and other digital devices. The study found no instances of ICT use for teaching science in ways that engage learners in scientific investigations and/or with activities from their real-life experiences. Interestingly, where mobile technology devices were used, they were commonly for knowledge enhancement by pre-service teachers, not for actual teaching of science.

These findings call for a more carefully considered and structured teacher education programme, based on the principles of quality, equity and access. Programmes should be structured such that ICT modules are accessed by all students in the programme, coupled with a deliberate choice of teaching practice schools that offer opportunities for student teachers to practice with cutting edge ICTs for teaching science and to receive mentoring from school-based mentors who are themselves competent and able to offer support to novices in the use of such tools. Thus, the central thesis of this study is that the richer the quality of opportunities to learn, as defined by both the university-based coursework and the in- school-based opportunities for practice in the use of ICTs, the better the chances for developing competence among all pre-service teachers to use ICTs for subject teaching.

**Key words:** pre-service teachers; science education; Information and Communication Technology; teaching practice; teacher education; competence.

**OPSOMMING VAN DIE STUDIE**

Die meeste waarnemers, kurrikulumontwerpers en beleidsmakers stem saam dat IKT ’n belangrike vaardigheid is waaroor universiteitstudente moet beskik om mededingend en suksesvol in hul loopbane in die 21ste eeu te wees. Onderwysstudente of onderwysers in opleiding is geen uitsondering nie. Terwyl sommige universiteite, insluitende die een waar ek gestudeer het, IKT-gebruik in hul beleid aanmoedig en onderneem om IKT in alle onderwyseronderrigmodules te integreer, is daar nie ’n riglyn oor hoe onderwysers in opleiding IKT-instrumente in hul eie vakonderrig moet integreer nie. Daar is ook nie ’n stel uitvoeringstandaarde of verwagtinge vir onderwysers/opvoeders in Suid-Afrika om die integrasie van IKT deur studente te assesseer en te ondersteun nie, veral gedurende onderwysopleiding. Hierdie studie spruit voort uit die bekommernis dat die meerderheid onderwysers in skole, waarvan sommige onlangs hul universiteitsopleiding voltooi het, probleme ervaar met die integrasie van IKT in hul aanbieding van spesifieke vakke en/of onderwerpe. In die verkenning van die rol van universiteite oor die algemeen en in besonder die onderwyseronderrigprogramme, spesifiek ten opsigte van die ontwikkeling van IKT-kapasiteite en -identiteite van nuutgekwalifiseerde onderwysers, het die huidige studie ondersoek ingestel na die geleenthede om te leer en die waargeneemde vaardighede van onderwysers wat opgelei word in die gebruik van IKTs vir wetenskaponderwys in skole. Met ’n steekproef van 103 wetenskaponderwysers in hul finale jaar van opleiding aan een universiteit in Suid-Afrika, het hierdie samelopende studie met gemengde metodes ’n aangepaste weergawe van die TPACK-opname vir onderwysers wat opgelei word, ontwikkel deur Schmidt en kollegas in die VSA (Schmidt, Baran, Thompson, Mishra, Koehler & Shin 2009), met lesplananalise en fokusgroeponderhoude gebruik om die waargeneemde vaardighede van onderwysers wat opgelei word se IKT-kennis en -vaardighede, hul geleenthede om hierdie vaardighede in die onderwyseropleidingsprogram te leer en hul gebruik van IKT-instrumente vir wetenskaponderrig gedurende plasing in skole in die laaste semester voor die graduering om nuutgekwalifiseerde onderwysers te word, vas te stel.

Oor die algemeen suggereer die sleutelbevindings in die studie dat daar beduidende variasies in die IKT-vaardighede van die wetenskaponderwysers in hul finale jaar van opleiding was, selfs binne ’n enkele universiteit en/of ’n gemene onderwyseropleidingsprogram. Hierdie variasies is grootliks as gevolg van die ongelyke leergeleenthede wat aan onderwysers gedurende hul opleiding verskaf word, veral gedurende die periode van plasing in skole. Terwyl die verskille in IKT-modulevereistes vir die verskillende groepe van onderwysers gedurende hul opleiding deels die variasie in vaardigheid verklaar, kom die grootste deel van die verduideliking skynbaar uit die verskille wat vanweë die ervaring binne skole gedurende onderwysopleiding opbou, waar sommige studente in skole geplaas word waar daar geen fasiliteite of geleenthede is om IKT vir onderwys te gebruik nie, en/of hul mentors self nie vaardige gebruikers van IKT is nie en glad nie in staat is om hulle in die gebruik van IKT te mentor nie. Die studie het ook bevind dat die meeste onderwysers wat opgelei word, egter bewus is van die verskeidenheid IKT-instrumente tot hul beskikking vir gebruik in wetenskaponderwys, vanweë hul IKT-dosente se gebruik van hierdie instrumente en in besonder hul gebruik deur die dosente in vakmetodologie. Gedurende onderwyspraktyk het baie van die onderwysstudente wat die gebruik van IKT aangedurf het, geneig om basiese tegnologie te gebruik, soos oorhoofse projektors en drukkers, eerder as multimedia-instrumente soos selfone en ander digitale toestelle. Die studie het geen gevalle gevind waar IKT in wetenskaponderwys op ’n manier gebruik word wat leerders by wetenskaplike ondersoeke of ervarings uit hul daaglikse lewe betrek nie. Dit is interessant dat, waar mobiele toestelle gebruik is, hulle oor die algemeen vir kennisversterking deur onderwysstudente gebruik is en nie vir daadwerklike onderwys in wetenskap nie.

Hierdie bevindings vra vir ’n meer versigtig oorweegde en gestruktureerde onderwyseropleidingprogram, gebaseer op die beginsels van gehalte, gelykheid en toegang. Programme moet op so ’n manier gestruktureer wees dat IKT-modules deur alle studente in die program gebruik kan word, tesame met ’n doelbewuste keuse van onderwysopleidingskole wat geleenthede vir onderwysstudente bied om met die nuutste IKTs vir wetenskaponderwys te oefen en om mentorskap te ontvang van skoolgebaseerde mentors wat self vaardig is en in staat is om ondersteuning aan nuwelinggebruikers te bied. Die sentrale tesis van hierdie studie is dus dat hoe ryker die gehalte van leergeleenthede is, soos gedefinieer deur beide die universiteitsgebaseerde kursuswerk en die skoolgebaseerde geleenthede vir oefening in die gebruik van IKTs, hoe beter is die kanse op die ontwikkeling van vaardigheid onder onderwysstudente om IKT vir vakonderwys te gebruik.

**Sleutelwoorde:** onderwysstudente; wetenskaponderwys; Inligting- en kommunikasietegnologie; onderwysopleiding; onderwyseronderrig; vaardigheid

## LIST OF HONOUR AND AWARDS

1. Member of **Golden Key International Honour Society**.
2. Winner of three minutes thesis competition (3MT) at the University of the Free State in 2016.

## LIST OF PAPERS PRESENTED AT CONFERENCES

| Name of organization | Title | Place | Date of conferences | Host |
|---|---|---|---|---|
| Higher Education Learning and Teaching association of Southern Africa (HELTASA) | Using e-learning tools to facilitate postgraduate teaching and supervision: case studies from the University of the Free State | Bloemfontein | 18-21 November 2014 | University of the Free State |
| Eleventh International Congress of Qualitative Inquiry | Using technology to improve teaching and learning: a case study on the use of e-learning tools for assessment at a higher education institution in South Africa | United State of America (USA), Illinois state | 20-23 May, 2015 | University of Illinois at Urbana-Champaign |
| | Alternative Approaches to Graduate Research Supervision: A Case Study on the Use of Online Tools for Cohort Supervision in South Africa | | | |
| South African Education Research Association (SAERA) | Pre-service and new graduate teachers' competences to teach science through Information and Communication Technologies | Bloemfontein | 27-30 October, 2015 | University of the Free State |
| Twelfth International Congress of Qualitative Inquiry (ICQI) | A qualitative analysis of pre-service teachers' use of Information and Communication Technologies to teach science during teaching practice | United State of America (USA), Illinois state | 18-21 May 2016 | University of Illinois at Urbana-Champaign |

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## ACRONYMS

| | |
|---|---|
| B.Ed. | BACHELOR OF EDUCATION |
| CAPS | CURRICULUM ASSESSMENT POLICY STATEMENT |
| CHE | COUNCIL ON HIGHER EDUCATION |
| CK | CONTENT KNOWLEDGE |
| DBE | DEPARTMENT OF BASIC EDUCATION |
| DIRAP | DIRECTORATE FOR INSTITUTIONAL RESEARCH AND ACADEMIC PLANNING |
| DoE | DEPARTMENT OF EDUCATION |
| FET | FURTHER EDUCATION AND TRAINING |
| FP | FOUNDATION PHASE |
| ICT | INFORMATION AND COMMUNICATION TECHNOLOGY |
| ICTs | INFORMATION AND COMMUNICATION TECHNOLOGIES |
| IP | INTERMEDIATE PHASE |
| IWB | INTERACTIVE WHITEBOARD |
| LMS | LEARNING MANAGEMENT SYSTEM |
| LS | LIFE SCIENCES |
| NS | NATURAL SCIENCES |
| OTL | OPPORTUNITIES TO LEARN |
| PCK | PEDAGOGICAL CONTENT KNOWLEDGE |
| PGCE | POSTGRADUATE CERTIFICATE IN EDUCATION |
| PK | PEDAGOGICAL KNOWLEDGE |
| PS | PHYSICAL SCIENCES |
| PST | PEDAGOGY, SOCIAL INTERACTION AND TECHNOLOGY |
| PTICK | PEDAGOGICAL TECHNOLOGY INTEGRATION CONTENT KNOWLEDGE |
| SANRAL | SOUTH AFRICAN NATIONAL ROADS AGENCY LIMITED |
| SAS | STATISTICS ANALYSIS SOFTWARE |
| SP | SENIOR PHASE |
| TEP | TEACHER EDUCATION PROGRAMME |
| TPC | TECHNOLOGY, PEDAGOGY AND CONTENT |
| TK | TECHNOLOGICAL KNOWLEDGE |
| TCK | TECHNOLOGICAL CONTENT KNOWLEDGE |
| TPACK | TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE |
| TPK | TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE |
| UFS | UNIVERSITY OF THE FREE STATE |

# 1. CHAPTER 1: ORIENTATION AND BACKGROUND TO THE STUDY

## 1.1. Introduction

Most curriculum designers, teachers and policy-makers agree that ICTs are an important competency for many university students to have. Teacher education students are no exception when it comes to the need to learn these modern day skills for effective teaching and learning of school subject content. The trend in many universities is to offer special courses in ICTs for the pre-service teacher education students and/or to recommend that lecturers integrate technology in their subject method courses. While some of these universities, including the one being studied, encourage ICT usage in their policies and the integration of ICTs in almost all modules, the decision on whether to use ICTs for teaching remains largely a personal choice of the graduating students (Meyer & Xu, 2007). There is neither a guideline on how pre-service teachers should integrate ICT tools in their subject teaching nor a set of performance standards for teacher educators in South Africa to assess and support the application of ICT tools, especially during the teaching practice sessions or during their first years in the teaching field where prospective teachers are expected to demonstrate practical teaching competence. Pre-service teachers or new graduates' competence in the application of ICTs requires training during teacher preparation programmes in the higher education institution and practical application during teaching practice (Twining, Raffaghelli, Albion & Knezek 2013). Teaching practice is a platform where pre-service teachers get an opportunity to practically apply and demonstrate competence in the various skills. It forms an important part of the teacher education programmes where the theory courses are applied in real classrooms with specific types of audiences such as actual learners and peers.

Teaching practice thus provides a useful setting for assessing pre-service teachers and new graduates' competence in the use of ICTs for teaching their subjects. In its recent policy guidelines for teacher education programmes, the Department of Higher Education and Training (DHET, 2013), classifies ICTs as fundamental learning that all graduating South African teachers are required to be competent in. In spite of this policy pronouncement and ambition, to date there is no clear policy statement and/or national research on how teacher educators should provide for, support and assess such competence in the use of ICTs for teaching subject matter in the various subject disciplines.

As a teacher educator myself who is involved in the teaching of various ICT modules to prospective teachers, I have noticed a great deal of variation in terms of how prospective teachers use ICTs to teach their subjects. The variations range from some pre-service teachers who are uncomfortable and avoid the use ICTs in class, to those who are highly skilled and deploy ICTs with reasonable comfort and enthusiasm to the benefit of their learners. My research arises out of the concern with these observed variations in pre-service teacher competence in the use of ICTs and their potential for creating and/or perpetuating inequalities of access in ICTs by learners or what is often called the "digital divide" in South African schooling. Accordingly, I am interested in exploring the following set of questions: What do prospective or new graduate teachers know about ICTs and their use in teaching particular subjects? How is their knowledge and ICT skills used in the actual act of teaching their subjects? The answer to these two questions is important for providing feedback regarding the preparation of prospective teachers in teaching effectively in their future career. ICTs have not only become an option for improving teaching and learning nowadays but a necessity for social justice in terms of breaking the "digital divide". Such an investigation will provide answers on the questions of: whether the teacher education curriculum aligns with the expectations of the national curriculum on ICT integration in schools; and how the teacher education curriculum aligns with the policy on ICTs as fundamental learning that is expected of all pre-service teachers in South Africa (DHET, 2013). Furthermore, the study also seeks to provide empirical evidence (Johnson, & Christensen, 2008) regarding the ability of prospective teachers to integrate theoretical knowledge on ICTs with the practical aspects of teaching, including lesson preparation and presentation in science subjects specifically.

While a number of national researchers have sought to address the subject of the integration of ICTs in education, especially for teachers in schools, to date, I have not been able to locate any similar studies in the South African context which use teaching practice as a site for exploring the possible integration of ICTs with subject teaching by prospective teachers and follow them in their new experiences in the teaching field.

## 1.2. Background to the study

Literature suggests that in-service teachers remain potentially unprepared to use ICT tools in the classrooms despite being trained by higher education institutions (Niess, 2005). Some local researchers also contend that although in-service teachers are trained to use ICTs in various platforms many are still not competent using ICTs in their subject teaching (Mlitwa & Kesewaa, 2013; Ndlovu & Lawrence, 2012; Luan, Fung, Nawawi & Hong 2005). Collectively, the current evidence seems to point towards a disturbing conclusion that the bulk of the training of in-service teachers to teach with ICT does not seem to contribute to competent teaching with the application of ICT tools in the classroom. This has prompted some observers and policymakers to argue that there is a need to revisit the way teachers are prepared, especially in the use of ICTs, prior to entering the teaching service.

The national Department of Education (DoE) in South Africa sought to provide some guidance on the subject of ICT integration and argued as follows: "Students currently in higher education institutions should be fast-tracked to bring them to at least the adoption level by the end of their studies" (Hindle, 2007: 8). This statement of intent was also in line with the Council on Higher Education's (CHE) report (2006), which cites the recommendation that "there is a need to ensure that the new generation of teachers emerges from higher educational institutions with an understanding of how to incorporate and use ICT in their ***(subject)*** teaching in schools" (Czerniewicz, Ravjee & Mlitwa, 2006). Both these arguments underscore the need for higher education institutions to include the use of ICTs for theory and practical applications for subject teaching in their teacher education programmes. Chikasha, Ntuli, Sundarjee, and Chikasha. (2014) and Jung (2005) hold the view that teachers have high chances of using ICTs in their subject teaching if they experience ICT skills as learners themselves (i.e. during their teacher education programmes). It is important therefore that student teachers, as learners in the teacher education programmes, be provided with multiple opportunities to learn and use ICTs during their studies, especially during the in-school experience. There are few empirical studies that have focused on the problem of the integration of ICTs in teacher education and even fewer that focus on such integration of ICTs during teaching practice specifically. The proposed study seeks to close this gap by investigating the competence and use of ICT tools by pre-service teachers at one South African university.

## 1.3. ICT integration in SA schools

It is noteworthy that the push for the integration of ICT into subject teaching in South African schools has been going on for a number of decades since it started in the 1980s in private schools and former model C (or formerly whites-only) schools (Mdlongwa, 2012). Initially ICT integration was more about the use of one device, the computer and its application software, but lately there are a number of devices that are integrated within school teaching such as tablets. The integration of these ICT tools has escalated in many schools since 1994, with the support of different sponsors such as the South African Schoolnet; Gauteng on-line; Connectivity Project in the Northern Cape; donations from the Shuttleworth Foundation and ICT for rural development education (ICT4RED) just to mention a few (Assan & Thomas, 2012; Dzansi & Kofi, 2014). Yet, my literature review continues to draw attention to the number of challenges that often lead to the failure of ICT integration in subject teaching such as the lack of competent ICT personnel. For instance, Assan and Thomas (2012: 8) specifically observed that teachers were “unable to use computers software in the science and mathematics subjects teaching due to lack of training to use these materials”. Furthermore, these researchers conclude their study by arguing that teachers have more administrative work and thus have less time “to devote to integration of information and communication technology in teaching” (Assan & Thomas, 2012: 14). This suggests that the professional development of in-service teachers in the use of ICT to teach content is not as effective as would be expected. Therefore there is a need for a study that shifts away from examining the competence of in-service teachers on ICT integration in schools but begins to trace the problem backwards by examining the preparation of future teachers to be competent in their subject teaching using ICT tools.

What is currently happening with ICT usage in the classroom of South African schools? As a former teacher, during the democratic phase of South Africa (i.e. post-1994), mostly in schools that were already equipped with many ICT tools such as televisions and computer laboratories, I can clearly remember how I rarely used ICTs for the teaching of science subjects, specifically life sciences and natural sciences for which I was responsible. Yet, I was the designated ICT teacher responsible for helping my colleagues and learners with such basic computer literacy skills such as typing lesson plans in a word-processing document and/or entering grades into an Excel spread sheet. I refer to this example as one case in point to illustrate the rather limited use of computers in the schools, where most computers are used to teach basic computer literacy skills or computer related subjects such as computer application technology (CAT) or the IT subject and almost nothing on integrated teaching in other subjects or disciplines. The focus on the use of computers for ICT related subjects only tends to discourage others from using ICTs to teach and learn across-curricular disciplines. However, as mentioned earlier, the South African national curriculum requires not only that the learners be computer literate but also for ICTs to be integrated across curricula subjects in schools (DoE, 2004, Wilson-Strydom & Thomson, 2005). This study thus focuses on how pre-service teachers become competent in the use of various ICT skills, tools and devices to teach their subjects such as those in the science disciplines.

## 1.4. Purpose and significance of study

The study explores how pre-service teachers learn to teach science through the use of information communication technologies (ICTs), by investigating their competences and practices during teaching practice. The practical application of ICTs for subject teaching remains a significant challenge for many teachers in South Africa and other developing countries, especially when compared with teachers in such developed countries such as the United States of America (USA), the United Kingdom (UK) and many Asian countries commonly referred to as the "Asian Tigers". This ICT challenge tends to create what is called a "digital disconnection or divide" between graduating students who have to compete for teaching jobs. Furthermore, the divide often continues to the schools and learners where the pre-service teachers may find employment. Attention to the divide or disparities in terms of access to ICTs is an important consideration when seeking to address inequalities of schooling and opportunities to learn (OTL) for all children. This is an important social justice issue, especially in the South African context where inequality and privilege in education continue to manifest themselves as apects of the ugly legacy of the apartheid past in the country. The proposed study focuses on three possible contributions that have important implications for issues of redress and provision of quality education:

First, designated ICT courses which are part of the teacher education programmes will be investigated for possible relevance and currency in providing pre-service teachers with knowledge, capabilities and the skills for the effective teaching of their subjects. Second, the integration of ICTs within the science-related (methodology) courses in the teacher education programme will be examined for their efficacy in providing the pre-service teachers with the requisite skills to use in their own teaching of science during teaching practice. Third, the study will provide information about pre-service teachers' classroom practices and sketch out the patterns on the integration of ICTs during their teaching of science as final year students. Understanding the connection between the three levels of inquiry on ICT integration practices may help provide a basis for a rethink and/or re-design and development of the teacher education curriculum, especially for science teachers, within higher education institutions (HEIs). For the policymakers and other accrediting agencies, this study could also provide a rationale and suggestions for the development of guidelines on the use of ICT tools during teaching practice and thereby help to improve the competence levels in ICT skills for all pre-service teacher preparation graduates in the country and across other developing and developed countries in the world.

The role of higher education institutions in developing and guiding pre-service teachers in the use of ICT skills for subject teaching is a problem that should be investigated. The investigation arises from the observation that to date many teachers who graduate from many universities do not seem fully equipped or ready to use ICTs in their classrooms to improve delivery and facilitate learning of content by learners. Furthermore, there has recently been an increase in the kinds of support and training of in-service teachers on the use of ICTs for teaching but very little seems to have changed in terms of improving learning opportunities on ICTs for pre-service teachers. There is thus a need to determine the levels of competence of pre-service teachers to facilitate learning their subjects using ICTs to be able to incorporate them deliberately into the teacher education programme and specifically during the teaching practice sessions.

## 1.5. Research questions

Several research questions are proposed in order to explore a major purpose of the study, which is to understand the competence of pre-service teachers in teaching science using ICTs during teaching practice. The study will be able to inform teacher educators on how effective the future teachers are to face the real world. The main research question seeks to generate data on the pre-service teachers' competences to use ICTs for subject teaching by exploring the following issue:

> What are the self-perceived competences of pre-service teachers for using ICTs to teach science content during teaching practice?

The following secondary research questions are proposed to unpack the main research question:

1. What is the self-perceived competency of science education pre-service teachers with regard to the various tools that are applicable for teaching science content in schools? (Competency examines the knowledge, skills and opportunities to learn or what is often captured as the "inputs").
2. Which ICT tools do pre-service science teachers commonly use during teaching practice? (What are the prevailing patterns of use of ICTs during teaching practice?)
3. How are the ICT tools used for teaching science during teaching practice? (For what purposes are they used and the methods of use)
4. How can the competences on ICTs and patterns of use be understood and explained?
5. What suggestions for improvement can be made regarding the development of competence and use of ICT tools for the teaching of specific subjects, for example science?

The study uses a cohort of final year undergraduate students in the Bachelor of Education (B.Ed.) qualification together with those doing the one-year Postgraduate Certificate in Education (PGCE), with specialisations in either natural sciences or life sciences from one teacher education programme that is offered across two campuses of the university. A TPACK survey instrument for pre-service teachers was used to measure their competencies in technology, pedagogy and science content (Schmidt, Baran, Thompson, Mishra, Koehler &

Shin, 2009). A Likert scale survey enabled the collection and analysis of data to provide frequencies, correlations, Cronbach and descriptions on the competency levels and use of ICTs by pre-service student teachers. Furthermore, lesson plan analysis of the lesson presented during teaching practice and focus group interviews provided further data on the competency of pre-service teachers.

## 1.6. Objectives of the study

The aim of the research is to establish the levels of knowledge and skills by prospective teachers on ICT tools that are appropriate for teaching science. The research also aims to map out their patterns of use during teaching practice with the view of clarifying the role of teacher education in supporting prospective teachers to be adept users of appropriate technologies for teaching their subjects.

The specific objectives to be addressed by the study are:

a) Identifying the knowledge and competencies of pre-service teachers on ICT tools for teaching science in particular,

b) Exploring the practices of pre-service teachers in terms of using ICT tools during teaching practice,

c) Identifying patterns in the use of ICT tools for teaching science as a subject by pre-service teachers,

d) Explaining the competence levels and patterns of use of ICTs by the different groups of pre-service science students,

e) Making suggestions and recommendations for improvements in the education of pre-service teachers on the use of ICTs for subject teaching.

## 1.7. Theoretical framework

For the theoretical grounding of the present study, I drew on eclectic theories and the TPACK framework to explore the challenges of technology integration in subject teaching.

Eclectic theories explain how pre-service teachers make sense in their choices (cognitive theory) of topics, ICT tools, connecting it with science content (connectivism) to produce the best possible outcome in any teaching and learning environment, such as the one for teaching practice (behaviourism). To understand the possible teaching practice experiences (constructivism) for student teachers through the integration of ICTs in teaching science, various concepts and theories will be discussed for this study. The study follows Ertmer and Newby's (1993: 69) suggestion of "intelligently choosing a theory on the basis of information gathered on the level of competence in that situation".

Many studies that have been conducted in the past decade on the integration of ICTs for teaching and learning have mostly used technological pedagogical content knowledge (TPACK) as their conceptual framework for understanding the construction of (new) knowledge that enables and renders teachers competent to facilitate subject teaching through technology. TPACK is a framework that was first proposed by Mishra and Koehler in 2006 and articulated further by several researchers thereafter (Koehler & Mishra 2009; Harris, Mishra & Koehler, 2009; Schmidt, Cogan & Houang, 2011; Chai *et al.,* 2011; Koh & Chai, 2011). The framework is derived from and extends Shulman's (1986) framework on teachers' knowledge for teaching but only that this time there is a special focus on ICTs. The framework identifies a different kind of knowledge or competence that subject teachers need in order to teach effectively with technology. The details of the frameworks and their utility for the present study are discussed in chapter two of this thesis.

The TPACK framework for the present study lies in the fact that it provides the means to measure and map out the competence levels of pre-service education students in terms of the different knowledge components and allows researchers to make sense of the integration of these components during teaching practice.

## 1.8. Research design and research methodology

The proposed research study drew on mixed methods approaches with a triangulation, multi-level research design (Yin, 2012). A single case that investigates the competencies of pre-service teachers in the use of ICT tools for teaching science related content. The research design followed a concurrent mixed methods design with data collected from the survey questions, the lesson plan analysis used during teaching practice and focus group interviews collected at the same time (Johnson & Onwuegbuzie, 2004; Creswell, 2014).

In the quantitative phase, a survey questionnaire, with three major sections (including knowledge and awareness of ICTs, competence on the use of ICTs and biographical or background data) was administered to all final year students taking natural sciences, physical sciences or life sciences. The sample included students who specialise in the teaching of all science disciplines, viz. natural sciences, physical sciences and life sciences. The sample therefore cuts across three different phases of schooling in South Africa where science is taught, i.e. the middle school or senior primary or intermediate phase, the lower secondary or senior phase and the senior secondary or further education and training (FET) phase.

The sampling design enabled multiple comparisons across phases of specialisation and across campuses and teaching practice school types. The study provided for a systematic analysis of comparative data on ICT competences across various phase specialisations in the teacher education programme using the data from the pre-service students' survey.

For the survey instrument, a Likert scale was used to collect and analyse the data and provide frequencies, descriptions and correlations on the use of ICTs and the competency levels of the pre-service student teachers. The Statistics Analysis Software (SAS) was used for the survey's data analysis. The SAS is a software suite developed by SAS Institute for advanced analytics, multivariate analyses, business intelligence, data management, and predictive analytics (SAS, 2013). It was used to explore and examine the large amount of data collected manually through the completion of 103 questionnaires. The survey forms were partly distributed and collected from the pre-service teachers during teaching practice and others were distributed and collected immediately after completion of teaching practice on the main campus. While the science teacher educator for the other campus assisted the researcher in distributing and collecting the surveys on that campus. The researcher and assisting teacher educator were able to clarify questions that may affect the validity of the collected data and the return rates.

In the qualitative phase, all lesson plans used during teaching practice were requested verbally and in writing after the survey from all participants. A follow-up invitation was sent online through a doodle scheduling system to all survey participants, cordially inviting them to a focus group interview. Six time schedule options were given in the scheduling system for one specific date for the pre-service teachers to select their preferred time. Participants for the focus group interview (0<n<8) per focus group were interviewed to explore their reasons for using particular tools and in specific ways during the teaching of science. The reasons for using mixed method research are mainly to bring together the strengths of quantitative and qualitative data sources to answer the questions in the study. Accordingly, the pragmatic framework that triangulates the mixed methods designs used by different data collection and analysis strategies to complement each other in answering the same research question informed my approach (Teddlie & Tashakkori, 2009).

For the qualitative interviews, data was transcribed into texts that could then be coded and categorised into various themes for developing the narrative accounts that explained the observations and descriptive statistical data.

## 1.9. Delimitations of the study

The study selected final year science pre-service teachers who participated in teaching practice during the July/August period in 2015. The research was confined to an in-depth case study with survey questionnaires, document analysis and focus group interviews to gain an understanding of the teacher preparation programme at one university. However, the results of the data collected from a single population from one institution with teaching practice allocated in different schools of the same province may be applied with caution to other pre-service teachers, for example those who:

1. Graduate from similar teacher education programmes that use a similar curriculum,
2. Graduate from different higher education institutions in the same country with similar challenges on competence in ICT skills, and
3. Graduate from any country with higher education institutions that do not stipulate the evidence of competence in ICT required for graduating students.

## 1.10. Limitations of the study

The study assumed the data collected represented student teachers across teacher education programmes in different higher education institutions and subject teachings accurately and concisely using ICTs. Though this design was best for this research study, the following possible limitations were identified.

Firstly, survey research issues such as the clarity of the questions, the honesty of respondents and response rates could affect the validity of the data. The researcher dealt with such challenges by allowing the completion of survey questions in one sitting in her presence and in a face-to-face classroom encounter to allow participants to pose questions for clarity and increase the response rate by personally and immediately collecting the completed survey questionnaire.

Secondly, the availability of ICT resources for teaching science was an issue that could affect the collection of reliable data since the researcher had no control over the selection and placing of students in schools for their teaching practice. The placing of student teachers in schools is the responsibility of teaching practice administrators who communicate all the arrangements with the schools surrounding the university. However, the limitation determines the capability of competent pre-service teachers to deal with the lack of adequate ICT resources and their independence and resourcefulness in using the available resources. The availability of resources in schools was also helpful in informing educational leaders on the extent of the adoption of ICTs in schools as advocated in the country's e-Education paper of 2004. According to The DoE (DoE, 2004: 17) "every South African learner in the general and further education and training bands will be ICT capable (that is, use ICTs confidently and creatively to help develop the skills and knowledge they need to achieve personal goals and to be full participants in the global community) by 2013". Since the study is done two years after the deadline set by the White Paper for the promised "integration of ICTs into teaching and learning practices specifically" (Wilson-Strydom, & Thomson, 2005: 1), this research will assist the government in identifying schools that still require further support with ICT resources in the province being studied.

Thirdly, the research applies to one specific university across two campuses for the teaching of science subjects during teaching practice in schools. Therefore, the challenge in applying the data to other teacher education programmes and in the teaching of other subjects such as mathematics remains.

Document analysis was done in order to further corroborate the validity and reliability of the data. Further triangulation, through detailed field notes and a clear coding system were used during the analyses of the collected data (Creswell, 2014).

## 1.11. Value for the study

The value of this doctoral study is to examine the competences of pre-service teachers to teach science using information and communication technologies (ICTs). The study has the potential to benefit future teachers by providing them with descriptions and narratives on a range of possible uses of ICT tools for teaching science in schools. It will also provide HEIs with insights on how to structure ICT learning opportunities for pre-service teachers.

The study aligns with the South African national curriculum and its imperatives on information and communication technologies (ICTs) integration in education and the University of the Free State's (UFS) strategic plan on the use of ICTs for improving teaching and learning. Specifically, I propose to investigate the implementation of the national policy on ICTs in the teacher education programmes of the higher education institutions (HEIs) which prepare future teachers.

The PhD thesis will specifically provide answers to the questions of whether the teacher education curriculum aligns with the expectations of the national curriculum on ICT integration and how the teacher education curriculum aligns with the policy on ICTs as fundamental learning that is expected of all pre-service teachers in South Africa (DHET, 2013).

Furthermore, the university's strategic plan highlights the importance of "Campus citizens (students) to perform at the top of their game in terms of learning achievements" (UFS, 2012: 10). The study seeks to establish the performance of the student teachers on one aspect: the integration of technology in science teaching, all in support of the research evidence that teaching with technology may help improve learning.

## 1.12. Definition of key terms

The following terms are defined to assist the reader in understanding the operationalisation of terms in the thesis:

**Information and communications technologies (ICTs)**: refers to the use of electronic devices such as computers as a form of sharing, receiving, designing, delivering and/or developing information and content for different purposes such as educational purposes.

**Pre-service teachers**: refers to future or prospective teachers who are studying teacher education programmes as undergraduate or postgraduate students. In the South African context, these are students who are studying for a Bachelor's degree in education (B.Ed.) or who are already in possession of another Bachelor's degree. For example a Bachelor of Science (B.Sc.) and are either studying to be teachers in a one-year programme such as a postgraduate diploma or certificate in education (PGDE/PGCE).

**In-service teachers**: refers to professionals who have qualified as teachers and are working either fulltime or part-time as teachers in schools, districts or other institutions of education such as technical institutions.

**Teacher educators**: refers to lecturers or teachers of higher education institutions who participate in activities such as teaching, research, community engagements and supervision of teaching practice in macro-teaching, lecture halls and in schools.

**Teacher preparation programme** or **teacher education programme**: refers to the programme of study offered at a higher education institution, typically for students who intend to be future teachers and enrol for a Bachelor's degree or undertake postgraduate studies at a postgraduate level.

**Methods course**: this course focuses on the theories and practice of teaching specific subjects in the classroom, grade or school. The methods courses are done by pre-service teachers who specialise in specific subjects for certain levels of learners such as FET, GET and intermediate phase but not in the foundation and early childhood phases.

**School**: is a community of learners with approximately similar age groups from as early as birth to the optional age group, which is divided into three phases in SA namely foundation, intermediate and further education and training (FET) phase. In this study, teaching practice was conducted in the community of learners between the ages of 9 and 19 from grade 1 to 12, which includes foundation phase, intermediate phase and FET.

**TPACK**: Technological pedagogical content knowledge, "emphasizes the connections among technologies, curriculum content, and specific pedagogical approaches, demonstrating how teachers' understandings of technology, pedagogy, and content can interact with one another to produce effective discipline-based teaching with educational technologies" (Harris *et al.*, 2009: 396).

**Competence** in general is defined as an indication of "what the individual brings to the job (the input), what the individual does on the job (the process), or what is actually achieved (the output)" (Greenhalgh & Macfarlane, 1997: 162). In this study, competence refers to knowledge, skills and abilities that pre-service teachers are required to perform in the use of ICTs in subject teaching to demonstrate the high quality of ICT knowledge and application of skills learned in the teacher education programme (Yuksel, 2014).

**Teaching practice**: is the period when student teachers practise what they have learned in the teacher education programme (TEP) or micro-classes, experimental classes or in schools through either observation of peers or in-service teachers in practice and/or practically teach their subject and partake in other school activities such as sports. Teaching practice is also known as school placements in other countries such as the USA.

**Science teaching**: is the teaching of subject knowledge, skills and abilities to develop students who can practice scientific thinking for the learning of biology, natural sciences, life sciences, chemistry and physical sciences.

## 1.13. Summary of the chapter

The present chapter discussed a compelling argument for the need to investigate pre-service teachers' self-perceived competence as output knowledge, capabilities and skills with regard to the integration of information and communication technologies (ICTs) in teaching science during teaching practice. As ICTs influence every aspect of the development of future teachers and evidence suggests that these technologies are beneficial to the teaching and learning process, the need to understand how pre-service teachers are prepared to teach science in real-life situations in schools grows. However, to date most research has only focused on in-service teachers with minimal information on how pre-service teachers display competences in ICT skills during teaching practice.

Furthermore, the chapter provided the background on the research problem, the purpose of the study and information related to the theoretical foundation of the investigation. Finally, the limitation, delimitation and multiple definitions pertaining to this study were discussed.

The next chapter will focus on a literature review related to pre-service teachers' competence in the teaching of science using ICTs followed by chapter 3, which will give details of the research methodology that was used. Chapter 4 discusses the findings from this mixed methods investigation and chapter 5 concludes the study with discussions and recommendations.

# 2. CHAPTER 2: LITERATURE REVIEW

## 2.1. Introduction

The literature review in this study is framed into sections. The first part consists of the introduction to information and communication technologies (ICTs) with the following subheadings: ICTs in South African schools, ICTs in teacher education programmes (TEP), teaching science with ICTs and pre-service teachers' competence in ICT usage.

The second part of the review explores the theoretical and conceptual frameworks that will be used for the study. The study uses eclectic theories to explain how pre-service teachers make sense of their choices (cognitive theory) of topics and ICT tools and connecting it with science content (connectivism) to produce the best possible outcome in any teaching and learning environment such as the one for teaching practice (behaviourism). To understand the possible teaching practice experiences (constructivism) for student teachers through the integration of ICTs in the teaching of science, various concepts and theories will be discussed for this study. The study follows Ertmer and Newby's (1993: 69) suggestion of "intelligently choosing a theory on the basis of information gathered on the level of competence in that situation". Specifically, the study discusses the technological pedagogical content knowledge (TPACK) as a conceptual framework for exploring pre-service science teachers' competences and practices with ICTs, especially within the context of their teaching practice experiences. In discussing the TPACK model, I examine the details of each of the six categories of knowledge that are described in the conceptual framework. Then I follow with a rationale for choosing the TPACK framework as the best framework to be used in this study. I then close the review with an identification of the gaps in the literature with respect to the topic of study.

The present study also focuses more closely on the literature relating to ICT usage in the preparation of teachers through designated ICT courses and teaching methodology science courses in the teacher education programmes. It also draws on literature that examines the competence of pre-service teachers in ICT, research on the teaching of science with ICTs and scholarly work on how pre-service teachers use ICTs during teaching practice.

## 2.2. Summary of the problem statement

Literature suggests that in-service teachers remain largerly unprepared to use ICT tools in the classrooms in spite of being trained by higher education institutions (Niess, 2005). Some local researchers also contend that although in-service teachers are trained to use ICTs in various platforms, many are still not competent to use ICTs in their teaching (Luan *et al.*, 2005; Mlitwa, & Kesewaa, 2013; Ndlovu & Lawrence, 2012). Collectively, the current evidence seems to point towards a disturbing conclusion that the bulk of the professional development training of in-service teachers, to teach through ICTs, does not seem to contribute to competent teachers who are ready to use ICT tools in their classroom. This has prompted some observers and policymakers to argue that there is a need to revisit the way teachers are prepared, especially regarding the use of ICTs, even prior to entering the teaching service. One of the few documents issued by the national Department of Education in South Africa that sought to provide some guidance on the subject of ICT integration argued as follows: “Students currently in higher education institutions should be fast-tracked to bring them to at least the adoption level by the end of their studies” (Hindle, 2007). This statement of intent is also in line with the CHE’s report (2006) which cites the recommendations that “there is a need to ensure that the new generation of teachers emerges from higher educational institutions with an understanding of how to incorporate and use ICT in their (subject) teaching in schools" (Czerniewicz *et al.*, 2006). Both these arguments underscore the need for higher education institutions to include theory and practical application courses on the use of ICTs for subject teaching in their teacher education programmes. Jung (2005) holds the view that teachers are more likely to use ICTs in teaching content if they experience ICT skills as learners themselves (i.e. during their teacher education programmes). It is important therefore that student teachers, as learners in the teacher education programmes, be provided with multiple opportunities to learn and use ICTs during their studies, especially during the in-school experience or what is often referred to as teaching practice. To date, there are few empirical studies that have focused on the problem of the integration of ICTs in teacher education and even fewer that focus on such integration of ICTs during teaching practice in specific subjects. The proposed study seeks to close this gap by investigating the pre-service teachers' competence for teaching science during teaching practice at one South African university.

## 2.3. Information and communication technologies (ICTs)

Researchers define the term information and communication technology (ICT) as a group of software and hardware tools that help to facilitate communication between people in any place and at any time (Bialobrzeska & Cohen, 2005; Roodt, Paterson, & Weir-Smith, 2007; Murphy & Carmody, 2015). In an educational context, ICTs help students to access learning at any time and from any place in the world without the inconvenience of time and relocation.Mobile devices such as cell phones and many other ICT tools can even enhance the learning in face-to-face classes as they can allow the learning to continue outside the brick and mortar walls. Devices such as televisions deliver information all over the world and people are able to learn from others across multiple physical spaces. There has recently been a substantial increase in the usage of ICT tools in many aspects of life, including informal learning. At the same time, the demand for the use of ICT in formal learning environments such as schools and higher education institutions has been on the rise.

ICTs have become the key tools for business, entertainment, homes, offices and every sector in the country. In today's society, ICT competencies are some of the skills that are expected of graduating professionals (such as teachers) by policymakers, employers and members of the community in developed and developing countries (Ertmer & Ottenbreit-Leftwich, 2010). South Africa is one of the developing countries that has witnessed a rapid growth of ICTs in different industries while at the same time witnessing an accelerated need for active usage of ICTs in other sectors such as education. The current study explores the competence levels of pre-service teachers in the accomplishment of various teaching tasks in science classrooms through ICTs. More specifically, the study examines the use of the ICTs during a specific phase of teacher training – student teaching practice in schools.

### 2.3.1 ICT in South African schools

The development of ICTs has taken place over a long historical period, beginning with the paper and pencil technologies that represented a low level of ICTs. In ancient times, sticks and stones were also commonly used as technologies for writing. In this study, however, I will explore the use of 21$^{st}$ century ICT tools in the creation, distribution and sharing of information for teaching and learning in schools during the teaching practice of science pre-service teachers from one university in South Africa. The high level of use of ICTs in society has seen school learners being engaged in the distribution of information through the use of such tools as the Internet and more commonly YouTube. Given the competence of many young learners with ICT tools, it makes me wonder whether pre-service teachers have the same competencies as their learners in the use of such tools and how teachers can take advantage of their own and the learners' competencies in the teaching of (science) content. It has been common practice, throughout history that whenever tools for teaching are developed, such as chalk, the pencil and the chalkboards, teacher education programmes and education departments generally respond by instituting courses and training programmes to equip both in-service and pre-service teachers to use these tools effectively in their classrooms. Pre-service teachers were, in some cases, expected to obtain a score on themes or courses that demonstrate an ability to write or create a chalkboard summary for example, to prove their competence in the tool before obtaining a professional teaching qualification. It is thus not far-fetched to expect that a similar trend would be expected with these 21$^{st}$ century ICTs.

In an international study on the implementation of 21$^{st}$ century competences across 17 countries, Ananiadou and Claro (2009) found that most developed countries in Europe had adopted the use of ICT as a requisite skill for teaching and learning. The new government in South Africa followed suit by introducing various strategies to try to close the gap on ICT skills across the different schools in the country. For instance, the Department of Basic Education has produced documents on *Teacher Training and Professional Development in ICT* (Hindle, 2007) that serve as guidelines for teacher education programmes in their preparation of future teachers. Research suggests that although many in-service teachers in South Africa have been trained to use ICTs in various platforms, they however continue to lack the necessary competence to use them in their subject teaching in schools (Mlitwa & Kesewaa, 2013; Ndlovu & Lawrence, 2012). Some observers have thus argued that the training of in-service teachers to teach with ICTs may not be the most effective intervention for creating competent teachers in the use of ICT tools in the classroom. Ndlovu and Lawrence (2012) point out that the new government in South Africa had planned to use ICTs to address the challenges facing the quality of teaching and learning in schools, yet the take-up in the use of ICTs to improve learning is itself still very low. This research examines the role of universities, especially the teacher education programmes in preparing future science teachers to use 21st century ICTs for teaching specific subjects such as science in this case. I specifically investigate a particular group of science education students' level of ICT knowledge and their patterns of use during their teaching practice. These science education students are from a mid-size university in SA.

According to the guidelines on teacher training and development in ICT (Hindle, 2007: 8), "Students currently in higher education institutions should be fast-tracked to bring them to at least the adoption level by the end of their studies". Furthermore, the e-Education policy promised the deployment of ICTs into the school curriculum, to be completed by the year 2013 (DoE, 2004). Both these reports provided an indication on the clear intent by the new South African government with respect to the integration of ICT tools into the school curriculum. Sadly, it is now 2016 and the goals of the e-Education policy to complete the deployment of ICTs into the curriculum by 2013 is still as elusive today as it was more than a decade ago when the policy was promulgated. The CHE report (2006) cited that, "there is a need to ensure that the new generation of teachers emerges from higher educational institutions with an understanding of how to incorporate and use ICT in their schools teaching" (Czerniewicz *et al.*, 2006).

This, in turn, suggests that there is a need for higher education to include the practical experiences of using ICTs in the coursework of teacher education programmes. The CHE report (Czerniewicz *et al.*, 2006) further noted that while there has been an increase in the use of ICTs in higher education institutions, as of yet there is no central specific standard against which to measure the ICT skills of South African graduates. The 2007 guidelines for teacher training and professional development in ICTs are the closest that the government came to defining the level of expected competence for pre-service teachers when it declared:

> All students leaving higher education for the teaching profession should have reached at least the adoption level. This means that they should have the knowledge and skills to use a computer and application software. Furthermore, they should have the ability to use various ICT, including a computer, to support traditional management, administration, teaching and learning, and be able to teach learners how to use ICT (Hindle, 2007: 7).

This suggests that teachers are expected to be able to at least use ICTs to teach in a practical classroom situation such as during the teaching of science. After the release of this paper, many institutions in the country began including ICT courses in their teacher preparation programmes (Lundell & Howell, 2000). Teacher training in ICT usage and the development of competent teachers is a real challenge across the world. Jung (2005) reported that various training environments have been developed for teachers within higher education institutions and also for in-service teachers with a view of providing teachers with the required knowledge and skills for the effective implementation of ICTs in schools. However, much of the development of courses in ICTs within the universities has happened within the context of a knowledge vacuum. There is not much research or literature on how to design and implement effective ICT training programmes specifically for pre-service teachers. If we take what Jung (2005) argues from his earlier work seriously (Collis & Jung, 2003), i.e. that teachers would tend to integrate ICTs in their own teaching if they experienced ICT skills as learners, then better experiences for practice are required for pre-service teachers. Recent scholarship seems to suggest that there has been a proliferation of courses to address the challenges of integrating ICTs for students at universities and for teachers in the field. What is still unclear, however, is the impact of such training and coursework. Are the pre-service teachers from the universities adequately prepared to implement what they have learned in such courses when they enter the classrooms? There is less empirical research on the dynamics of ICT integration by pre-service teachers during teaching practice.

While research suggests that universities have made great strides in developing modules that seek to provide ICT skills to their students, there is still a concern about the students' ability and inclination to use technologies appropriately and effectively during their teaching, especially in the gateway subjects such as science and mathematics. A complementary question thus arises on the experiences of the pre-service teachers regarding the integration of technology in the methodology courses. That is, to what extent do the experiences of learning to teach – within the university's teacher education programme – incorporate and privilegefavour the integration of ICTs? The present study will therefore seek to uncover the pre-service teachers' perceived ICT competences and skills and their use for teaching science during teaching practice. I also plan to explore how these competences relate to, if at all, their experiences in the methodology courses during teacher training.

### 2.3.2 ICTs in teacher education programme (TEP)

Many higher education institutions (HEIs) seek to enforce the integration of technology through their policies and investment in various ICT infrastructures (Valtonen, Kukkonen, Kontkanen, Sormunen, Dillon & Sointu 2015). Similarly, the sampled university for this study has invested a great deal in technology infrastructure to support the increased use of ICTs by all its students, such as improved wireless connections at all its (three different) campuses (UFS, 2012). The support and upgrade of technology on campus suggests the importance placed by the HEI on issues of competence and skills development in the area of ICTs. Not surprisingly, final year pre-service teachers experience the use of range of ICTs from the beginning of their studies to the end. The university relies on such tools as the learning management system (Blackboard), high-speed Internet connectivity; wireless connection points across the campuses and exposure to designated ICT courses in the various programmes.

Haydn (2014) studied how teacher education programmes in European countries prepare pre-service teachers to be competent in teaching their subject. According to Haydn (2014), pre-service teachers who will be regarded as good with ICT will be those who are creative and who can apply high order thinking in teaching their own subject. The question is then can pre-service teachers apply ICT skills learned in real situations in schools as part of the teacher education programme? The teaching practice will then serve as a ground to test how well they use what they have learned. The results from Haydn's (2014) study indicate that expert practitioners for teacher education programmes are in favour of a subject specific approach with the argument that ICT applications differ according to the subject being taught. What was not explored are the experiences of final year pre-service teacher education students with all these ICTs and the application of learning experiences in the teaching field during teaching practice. The knowledge that future teachers have and the manner in which they use that knowledge to teach various subjects in schools during teaching practice was examined in this study.

Valtonen, *et al.* (2015: 50) argue, "teacher education holds an important position in considerations aimed at enhancing the use of ICTs for teaching and learning". Many higher education institutions have had to redesign and redevelop their teacher education programmes through re-curriculation partly to include the computer skills required by teachers for facilitating their subjects (Kim, 2012). The teacher education programmes are viewed as important vehicles to equip the new generation of teachers with ICT skills that are required in teaching content in the various subjects. Thus, many universities including the one in this study have introduced designated ICT courses for future teachers, some at the entry level where students are taught distinct skills on the computer (for example, word-processing; e-mail, etc.) and others at a more advanced level where technology skills are integrated in all other modules that the students take during teacher preparation. Whatever approach is taken, an important question for research is to uncover the resulting competence in the pre-service teachers, especially in terms of using the ICT knowledge and skills to teach specific subjects. The study sought to explore this research question for science students, in part because of the abundance of ICT tools for supporting science and mathematics and because of the status of science as a gateway subject in the country. A survey to establish the perceptions of competence on ICTs among final year science pre-service students was administered, followed by lesson plan analysis and focus group interviews. It is hoped that the study will shed light on the competences of final year pre-service teachers on ICTs at a point where they are just about to enter the teaching profession. Furthermore, a spotlight will shine on the ICT experiences and competences or what others include under the umbrella term of digital identities, on one group of students who are about to graduate as teachers in South Africa (Nykvist, & Mukherjee, 2016; Prensky, 2001; Wenger, 1998).

In one study that investigated the challenges and opportunities for integrating ICT into a pre-service teacher education programme, the authors argue that there is a need to create more opportunities for pre-service teachers to engage and practise the use of ICTs in an "authentic environment which will give students more practice" (Goktas, Yildirim & Yildirim, 2009:200-201). Clearly, pre-service teachers have to learn and engage in real-world learning environments such as the school, where they are likely to work in future. Exploring their competences within that context and environment is thus a useful undertaking to focus on. The provision of guidelines for teacher educators and pre-service teachers on the use of ICTs and the required competence during teaching practice is a rather more urgent task in the South African context where currently there is none. My study seeks to contribute to the development of a national (policy) document that sets out the expectations of pre-service teachers on the use of ICT tools for the teaching and learning of specific subjects. At the international level, Goktas *et al.* (2009) have called for research on how teacher education programmes prepare pre-service teachers for the implementation of ICTs in schools. The best environment for pre-service teachers to practise and enrich their experiences on the use of ICTs is in the classroom, under the guidance and supervision of teacher educators (and classroom teachers) during teaching practice. Teacher education programmes need to provide rich experiences for ICT usage in the classroom, mixing theory and practical experiences. Teaching practice provides one such platform where teacher educators can deliberately plan for and assess the integration of theory and practice in terms of whether the ICTs learned in various teacher education modules are applicable and used in the real classroom situation. That is, teaching practice allows for a check on the alignment between theory and practice and for alignment between teacher preparation and the national curriculum that is taught in schools.

### 2.3.3 Teaching science using ICTs

Some researchers suggest that classroom teaching has not changed much over the past fifty years or so (Cuban, 1986; 2013; Hiebert & Stigler, 2000; Twenge, 2009). This is despite many changes in curricula and in the development of new technologies. Furthermore, other researchers argue that ICT usage has the potential to improve teaching and learning in the classroom (Cleaves & Toplis, 2008; Holden, Ozok & Rada, 2008; Kisalama & Kafyulilo, 2012; Van Rooy, 2012). For centuries, teachers have used various ICT tools that match the context of pedagogy to improve the quality of teaching (Manning & Johnson, 2011). For example, a science teacher would use two stones as tools to demonstrate friction. In such a case, the teacher searched for tools that are commonly available within the learning environment. Nowadays, however, the search and exploration of available technology tools still applies with the use of the Internet, library databases and learning communities to teach a series of topics that are covered in the school curriculum. This is more urgent especially in subjects such as science and mathematics where traditional methods of teaching have not worked as well. However, the possibilities for using ICTs to improve teaching and learning can only be realised when teachers themselves identify with the technologies and have the knowledge and skills to use it in the teaching of their subjects. There is a lot of research that records low performance in the science subjects relative to other school subjects in South Africa and other developing countries (Martin, Mullis, Foy & Stanco, 2012). As a result, researchers and practitioners are on the lookout for strategies to improve the teaching and learning of science in schools. It is against this background that ICTs have been proposed as a possible solution to improve the quality of teaching and learning in science and/or mathematics (Cleaves & Toplis, 2008; Holden *et al.*, 2008; Kisalama & Kafyulilo, 2012; Van Rooy, 2012).

Peeraer and Van Petegem (2011) suggest that it is important to integrate ICTs in a subject or course. One approach to this form of integration involves embedding the teaching of knowledge and skills in technology within the methodology courses for the specific content/subject. Further evidence comes from a study on Australian secondary schools, which concluded that when relevant ICT skills are presented within a subject such as biology, there was relatively more take-up by in-service teachers (Van Rooy, 2012). Similarly, the use of ICTs during teaching practice has the potential to improve the competence levels of future teachers. Using ICTs in the teaching of science content and methodology, for example, is likely to bring to life the idea of constructivism, which supports active learning of content that is often recommended for science. Teaching practice can be an opportunity for pre-service teachers to apply their own understanding of ICTs in the teaching of their own subject matter in a real-world context (Kisalama & Kafyulilo, 2012). Therefore, the present study proposed to examine pre-service teachers' understanding and use of ICTs in the teaching of a specific subject (science).

Few studies examine the competence of pre-service science teachers during teaching practice, especially in the context of science teaching in an African country where the failure rate in science is relatively high. Even when there are studies that review pre-service science teachers' experiences with ICTs, they tend to explore the integration of technology in general without examining specific components of the teacher education programme such as the teaching practice element. Cleaves and Toplis (2008), for instance, examine pre-service science teachers' use of ICT as a form of community practice. The findings of that study, which included surveys, observations and interviews, suggest that pre-service teachers tend to use ICTs only to meet the training standards or requirements and not necessarily to enhance learning of the subject (Cleaves & Toplis, 2008). It is for this reason that my study sought not just to examine the competence levels of the science pre-service teachers but also to push the focus to the application of the competences in the actual teaching situation, during teaching practice. The instruments for the study were specifically designed to uncover how the ICTs are used in the classroom. In the present study, a standard questionnaire for recording ICT usage during teaching practice was distributed to the students during the final series of two weeks of school teaching practice and immediately after completion of school teaching practice, which is at the beginning of the second semester of classes. The focus of the questionnaire was on the background knowledge on the use of ICT. The questionnaire was immediately followed by the collection of lesson plans and the focus group interviews in the following month. Lesson plans used during teaching practice assisted me in determining whether ICTs were used during teaching practice. The focus group interviews done in the following month helped me uncover the reasons pre-service teachers give for their use or non-use of particular ICTs during the teaching of science in the schools. I was interested in documenting the emerging narratives of competence and ICT usage by pre-service teachers in the South African context where no guidelines mandate such ICT usage by pre-service teachers.

Kisalama and Kafyulilo (2012) used quantitative and qualitative methodologies to study competences of science and mathematics pre-service teachers in two African countries, within two institutions. The study reported that pre-service teachers have low levels of knowledge and competence in the use of ICTs and almost had no practical experience of using them during their coursework at university. The latter study provides useful data on the competences of pre-service teachers with respect to ICTs in an African context but does not help us understand much about the integration of these ICT skills in a less comfortable environment in the real world of teaching in the schools. Furthermore, the study recommended more qualitative research to explore the reasons for pre-service teachers either using or not using ICT tools in the classroom.

Some researchers from developed countries such as the UK, Australia and USA suggest the need for studies on the ICT competences of students within teacher education programmes. Haydn & Barton (2007) for example report on the use of ICTs in schools across a group of in-service science and history teachers. Participants in that study were given prescribed lists of expected ICT tools to be used in order to determine their competences (Haydn and Barton, 2007). In contrast, the South African Curriculum and Assessment Policy Statement (CAPS) developed for each subject does not stipulate how the ICT skills have to be used in the teaching of the subjects (DBE, 2011). Khoza (2016) supports this notion by pointing out that CAPS's indication of skills (psychomotor domain) is more confusing for all subject teachers as it is also not breaking down the type of skills that should be assessed. In the UK, "the New Opportunities Fund (NOF) training program that was criticized as being unwieldy, over prescriptive and insufficiently geared to meet the needs of different subject specialisms" was also definitive that ICT skills should be encouraged (Hayd & Borton, 2007: 365). My study is therefore partly an investigation into the democratic or *laissez faire* approach to the use of ICTs by pre-service teachers in South Africa, the feasibility of this approach and its effectiveness.

In a study of Australian pre-service teachers using ICTs to teach chemistry, Chittleborough (2014) points out that the pre-service teachers faced the challenge of coming across ICTs that completely differed to what they had learned in their teacher education programmes. Such a challenge therefore suggests the need for closer collaboration between planners, policymakers and teacher educators so that new ICT tools that are introduced in schools can be taught to pre-service teachers even before they complete their studies. Chittleborough (2014) further contends that there is a need to equip pre-service teachers with “new technologies to support a change in the culture of using technology” (Chittleborough, 2014: 373). In a world where technology changes so rapidly, it is no longer enough for pre-service teachers to know about the existing ICT tools and the manner in which to use a limited number of existing technologies. Teacher education programmes should strive to produce innovative pre-service teachers that can adapt to different teaching and learning environments and be able to use different ICTs in their content teaching (Hennessy *et al.*, 2007). The pre-service teachers also need to be aware of as many as possible ICTs that are commonly used in their specific discipline such as science and which are applicable to learners at specific grade levels or phases in schools.

### 2.3.4 Pre-service teachers’ competence in the use of ICTs

The term pre-service teachers refers to students who have chosen teaching as a career. The requirement to include ICTs is generally encouraged across all courses offered within the teacher education programme at most South African universities. Yet, there are no defined stipulations on the required competence levels and/or required usage criteria by students, especially during teaching practice. The sampled university includes one elective course per semester for intermediate (grades 4-6) and foundation phase (grades 1-3) pre-service students on “Teaching with ICTs” (Wentworth, Graham, & Tripp, 2008). The senior phase (grade 7) and further education and training (FET) pre-service teachers do not have a mandatory ICT related module at the university being studied. The mandatory ICT related courses for primary and intermediate phase pre-service teachers are independent and do not focus on technology as it is applied specifically to disciplines or the teaching of subjects. The course provides generic skills on emerging technologies and competences on ICTs with the hope that the pre-service students will be able to “transfer” these skills to their discipline and/or subject teaching. Interestingly, there is no similar compulsory course requirement for the senior phase and secondary school pre-service teachers at the sampled university. The implicit assumption for the senior primary (grades 7, 8 & 9) and secondary levels (grades 10-12) is that the students will develop the required ICT skills within their various teaching subject methodology courses. In a context where there are no guidelines for teacher educators on how to integrate ICT skills in their courses or guidelines on mandatory practices on the use of ICT integration in pedagogy or assessment criteria for successful integration, one wonders about the potential for successful learning on the use of ICTs. If pre-service teachers are going to be successful in using ICT skills in the classroom, there is a need for it to be taught deliberately within the teacher education programme and for it to be included in the assessment of teaching practice. Wentworth *et al.* (2008: 65) argue that “pre-service teachers are faced with the challenge of determining how they will use technology in their field experiences and in their future careers”. Usually, in-service teachers face such challenges when they are the only teachers for a specific subject in a school, with no other colleagues who can assist with ideas or no teacher educators to guide them and/or propose solutions. Most in-service teachers would then rely on their instincts or decide not to use ICTs for teaching. It seems useful for pre-service teachers to face such challenges while they are studying with a team of classmates around them and the presence of teacher educators who can play supportive roles. Wentworth *et al.* (2008: 67) observe that most of the “pre-service teachers have grown up in a digital world” but argue that “being comfortable with technology is not adequate preparation for understanding how to meaningfully integrate technology” in their own teaching. Practice teaching can thus provide such a training ground for pre-service teachers to build their confidence and competence in the use of ICTs.

Drucker (1969: 56) points out,

> learning and teaching are going to be more deeply affected by the new availability of information than any other area of human life. There is a great need for a new approach, new methods, and new tools in teaching, man's oldest and most reactionary craft. There is a great need for a rapid increase in learning. There is above all, great need for methods that will make the teacher effective, and multiply his or her efforts and competence. Teaching is in fact, the only traditional craft in which we have not yet fashioned the tools that make an ordinary person capable of superior performance.

Teaching practice, which is also known as school placements in other countries, is an important component of preparing students to be competent in their profession as future teachers. Marais and Meier (2004) argue that teaching practice exposes pre-service teachers to a number of experiences which includes the integration of theory and practice. Those experiences include practical coherence of theory from the teacher education programme and practical application of ICT skills in subject teaching such as science. Since ICT and methodology courses are part of the theory from teacher education programmes, it is also important for them to practise and be evaluated not only on the theory but also in terms of performance during teaching practice. Kabilan, & Izzaham, (2008: 87) state that teaching practice is "an excellent opportunity for pre-service teachers to experiment and test their knowledge and skills". The argument is that teaching practice gives pre-service teachers ample opportunities to practise their skills in order for them to be more confident in the use of ICT tools as in-service teachers in the classroom. Downes (1993) examined the experiences of pre-service teachers using computers during teaching practice by conducting a quantitative study two weeks after the student teachers began their practical teaching in schools. The results suggest that there was no connection between the modules done at the university and the use of computers in the classroom during teaching practice. According to the author, computer use in the classrooms during teaching practicals was more spontaneous than being guided by what students had learned from the university. It is therefore important to establish the connection with learning in teacher education programmes with the practical applications in the schools.

Galanouli and McNair (2001) argue that many research studies have proposed that it is important for student teachers to use ICTs during teaching practice and they themselves strengthen these studies by examining factors affecting the use of ICT during teaching practice. The argument is that the use of ICTs during teaching practice is more likely to contribute to competent future teachers who are able to use ICTs more effectively. Galanouli and McNair's (2001) study concludes that the standard of what is done at university does not seem to align with the curriculum in schools regarding the use of ICTs. The study thus recommends the need for a careful selection of schools that are used to place students for teaching practice based on the level of available resources in each school to give equal opportunities to all the students to practise the use of ICTs (Galanouli & McNair, 2001). The present study explores the issue of ICT use by pre-service teachers who are placed in different schools with varying levels of resources. An important question to examine is whether and how the school context determines and shapes the ICT practices of the pre-service teachers. The argument for the provision of equatable opportunities to learn how to use ICTs for teaching subject content necessitates that teacher education institutions pay careful attention to school placements as sites for further learning and development by the students.

Laird and Kuh (2005) raise the question of whether more practise with the use of ICTs increases the opportunity for pre-service teachers to be more competent in ICTs in general? After examining students' experience with the use of ICT at higher education institutions, these scholars conclude that student engagement with ICTs results in a number of engagement activities that are not necessarily ICT related. For example, students can search the Internet on how to grow a tree but would then follow similar instructions obtained from the Internet to grow their own tree in their own physical environment. It is thus possible for the student teachers to use similar engaging activities to enhance their teaching practice during school teaching practice. Student teachers can use an Internet search on how to teach a specific topic but use similar ideas or concepts to teach a different audience using available teaching resources. For example, a YouTube video can display parts of the leaf but the lesson would be more engaging if learners can individually access real leaves in their physical environment. Hartsell and Yuen (2006) point out the value of the use of videos as a practical tool for meeting the needs of the pre-service teachers as learners in teacher education programmes or use them to effectively teach learners in schools.

It is the responsibility of teacher education preparation programmes to produce professionally competent teachers. The preparation of such teachers needs innovative teacher education programmes that set high expectations for the teaching practice as would be expected of working teachers. Gülbahar (2008) discusses a number of factors that contribute to the effective use of ICTs and explores how these factors relate to the development of competent teachers. One of the factors relates to the quality and quantity of ICT courses that are offered to the pre-service teachers as prior training before teaching practice. The second key factor deals with the training and preparation of the supporting (or hosting) teachers under which the students are placed during teaching practice. The third factor deals with the availability of ICT resources and their use by pre-service teachers at each of the placement schools. Gülbahar (2008: 36) argues that “without technology competent role-model instructors, it is difficult to integrate technology into curriculum and graduate technology competent teachers”. Therefore, the present study sought to triangulate all known obstacles that have the potential to contribute to less competent teachers by examining the university-based ICT training of pre-service teachers while at the same time examining the in-school experiences of the students. In conducting a study on final year pre-service teacher education students that are likely to have completed a number of teacher education courses with ICT skills, I hope to shed light on the levels of competence and readiness to apply the ICT knowledge and skills in the teaching of content by pre-service teachers during teaching practice in schools.

## 2.4. Conceptual framework

### 2.4.1 Eclectic theories

As highlighted earlier, the present study has "chosen not to advocate one theory over the others, but to stress instead the usefulness" of how science pre-service teachers' knowledge and use of ICTs during teaching practice can be understood through the use of several theories (Ertmer & Newby, 1993: 69). Delivering content knowledge for a pre-service teacher has different challenges for each situation that s/he faces during teaching practice such as diverse communities, audience ages, situation analysis and mentors such as teachers and teacher educators. Ormrod, Schunk and Gredler (2009: 101) point out that "learning is a multifaceted process that individuals typically take for granted until they experience difficulty with the complex task". This is to argue that pre-service teachers can learn to use ICTs without necessarily being taught in a formal class, for example, when they learn through the support they receive from their teacher educators or through the encouragement of rewards such as grades for integrating technology and/or from the school environment where teaching practice is done. This study takes the view that multiple theories such as behaviourism, cognitivism, constructivism and connectivism will be useful to understand the issues of competence, knowledge and skills development by pre-service teachers.

Pre-service teachers' use of ICTs to teach science can for example be understood from a behaviourist perspective. Jordan, Carlile and Stack (2008: 38) argue that, “behaviourism is efficient in promoting rapid learning because of its precise specification of actions and learning outcomes”. For example, pre-service teachers could be inspired and motivated to use ICTs if the integration of technology is included in the lesson plan templates or if it becomes a requirement for the completion of their teacher education qualification. Just as is the case with other aspects of teaching, which is formally assessed during teaching practice, integration of ICTs could similarly be assessed and rewarded with (good) marks. By examining the opportunities to learn in terms of course requirements on ICTs for example and the presence or absence of ICT integration in lesson plans, the study will be informed by a behaviourist approach.

Constructivism is also one useful theory that may define final year pre-service teachers’ learning on ICTs. Final year pre-service teachers have experiences of at least 12 years of schooling plus three or more years as undergraduate students at university. These experiences are often used as learning curves from observing other in-service teachers and teacher educators as they seek to incorporate ICTs in their own teaching. This is what Lortie (1975) calls the “apprenticeship of observation” when pre-service teachers draw on their experiences of observing their own teachers during their careers as students. These experiences have to be reconstructed to shape the pre-service teachers’ knowledge base on ICTs and their uses for teaching. My understanding on the relevance of these experiences are informed by Ertmer and Newby’s (1993: 62) use of Bedner *et al.*’s (1991) definition of constructivism as a “theory that equates learning with creating meaning from experience”. In Ertmer and Newby (1993: 62), it is argued “constructivists believe that the mind filters input from the world to produce its own unique reality”. During teaching practice, final year student teachers are driven in part by evaluation results and by the need to reconstruct their own previous experiences or observations from others such as in-service teachers, colleagues, teacher educators or how they were taught science in a teacher education programme using ICTs. These experiences can also include the teaching of science concepts obtained from the Internet, videos or listening to other students' experiences on the use of ICTs while teaching science. Therefore, constructivism became applicable in the study and helped to make meaning during focus group interviews where the participants engaged with ideas from others about how to use ICTs during teaching practice.

The connectivist learning theory is also applicable because in the 21st century most students own cell phones and use them to learn from the Internet and to connect with others. McHaney (2011: 68) states, "Students pointed out in the survey that mobiles are one technology they [students] cannot live without". The Singapore 21st century teaching strategies titled: "Education Everywhere series" is an example that illustrates how ICTs stimulate sharing and communication in schools amongst teachers and learners. With mobile learning devices such as cell phones, tablets and iPads, pre-service teachers could also record videos of the demonstration of science concepts such as 'the view of the moon at a specific time or in a specific area' from a well-resourced space such as the university or a lesson on difficult science concepts. They could then share these recordings with learners in a school with limited resources. Connectivism theory points out that learning occurs as the learner engages in learning with the use of different ICT tools such as using a digital device to record a science experiment (McHaney, 2011). This illustration is an indication that student teachers would be able to use the different tools independently, even for teaching science content. The application of the cognitive theories comes in when a pre-service teacher chooses to use online quizzes in a well-resourced school for example, with computers or decides to print an online quiz for a school with limited resources during teaching practice. Similarly, constructivism and cognitivism may also apply when student teachers make sense of using the mobile devices to build personal networks and to learn from their own experiences as they engage in learning and the use of mobile applications (McHaney, 2011:183). It becomes clear therefore that a study on the use of ICTs in teaching science during teaching practice has the potential to draw on multiple learning theories and thereby enhance our understanding of the development of competence and skills for using ICTs for subject teaching.

Understanding the entire learning process is important for me as an instructional designer, a teacher, a researcher and a lifelong learner in order to analyse the present study's findings in their entirety. Thus, the blended theories or eclectic approach seems to offer the best way to analyse the learning process of pre-service teachers and to reflect more on the role of prior knowledge and experience in the context of the challenges and experiences faced in schools during teaching practice. The study hoped to contribute to improving the curriculum for teacher education programmes based on the various possible approaches, specifically during teaching practice for specific subjects. Using these different theories as a point of reference on how to make sense of and understand the development of competence for the teaching of science content with ICTs during teaching practice, was helpful in assessing the potential challenges and difficulties pre-service teachers experience in reaching optimum levels of competence.

### 2.4.2 Technological pedagogical content knowledge (TPACK)

TPACK is a framework that was first proposed by Mishra and Koehler in 2006, and has since been articulated further by several researchers in the field of ICT integration in schools (Chai *et al.*, 2011; Harris *et al.*, 2009; Koehler & Mishra 2009; Schmidt *et al.*, 2011). Lin, Tsai, Chai, & Lee (2013) advocate for more TPACK studies after the use of the TPACK model in their study of Singapore science teachers unpacked the seven domains labelled as the TPC for technology, pedagogy and content. The framework is derived from and extends Shulman's (1986) framework on teachers' knowledge for teaching with a special focus on ICTs. As with Shulman's framework, TPACK identifies a different kind of knowledge or competence that subject teachers need in order to teach effectively with technology. The important extension from Shulman is that TPACK begins to describe additional and specific dimensions of knowledge that subject specialists need to integrate technology into their teaching successfully. Specifically, TPACK describes knowledge that results from a synthesis of six different kinds of knowledge components. The knowledge components and their relationship form what is called TPACK and are usually represented in the form of a Venn diagram with three intersecting circles with TPACK in the middle representing the synthesis or intersection of all the different knowledge components (see figure 1 below). The core components of TPACK are content knowledge (CK); pedagogy knowledge (PK) and technology knowledge (TK) with the other knowledge elements representing the intersections of these three core knowledge components. This study uses the framework of TPACK to measure the competence of pre-service science teachers during teaching practice.

In this study, the TPACK framework provides the means to map out and measure the competence levels of the pre-service teacher education students in terms of the different knowledge components and allows the researcher to make sense of how they integrate these components during teaching practice. It is important to note that the TPACK model is a holistic framework including all different parts of knowledge and all the parts that need to integrate with one another as one domain of knowledge (Harris *et al.*, 2009). TPACK includes the use of online communication tools to represent science concepts, noting different teaching styles by pre-service teachers to accommodate various learning styles by learners in different phases of schooling (Harris *et al.*, 2009).

Overall, the TPACK framework presents a model that essentially describes the balance between three main components; that is content knowledge, pedagogical knowledge and technological knowledge. The researchers who have used the model argue that none of these elements exist in a vacuum and emphasise the importance of all three factors when determining how to apply ICTs practically during teaching practice with content such as science.

In the next section, I specifically discuss the six sub-domains of TPACK (see fig.1), with a view of understanding what each domain includes and how it can be developed and assessed, especially in the context of school teaching.

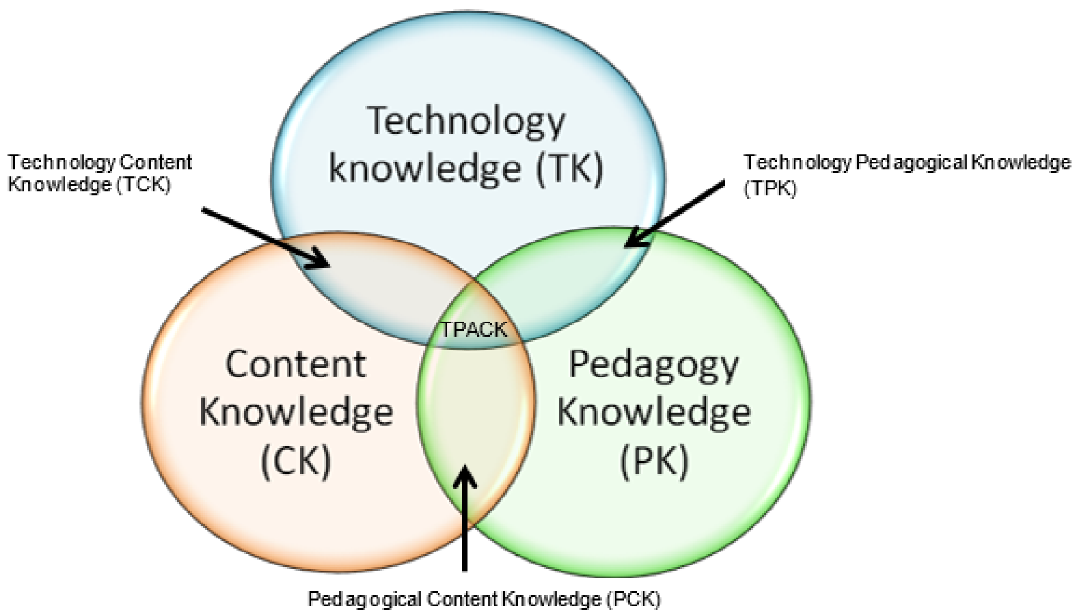


Figure 1**:** TPACK model (technological pedagogical content knowledge)

(Adapted from Mishra, & Koehler, 2006:1025)

#### 2.4.2.1 Content knowledge (CK)

Scholars define content knowledge (CK) as knowledge about the subject matter to be learned or taught such as mathematics or science (Harris *et al.*, 2009; Koehler, Mishra, & Cain, 2013). A teacher needs to have a comprehensive base of content knowledge to be considered competent in their subject area. Content knowledge is one of the six sub-domains of TPACK which is linked to pedagogical content knowledge (PCK) and technology content knowledge (TCK). For future teachers to be competent in content knowledge, they have to understand and link different domains when preparing to teach their subject matter (Shulman, 1986). Shulman (1986: 9) mentions that:

> The teacher has special responsibilities in relation to content knowledge, serving as the primary source of student understanding of subject matter. The manner in which that understanding is communicated conveys to students what is essential about a subject and what is peripheral. In [the] face of student diversity, the teacher must have a flexible and multifaceted comprehension, adequate to impart alternative explanations of the same concepts or principles.

The use of information communication technologies (ICTs) presents the possibility of reaching and helping a diverse audience of learners in different learning environments to apply content to real world situations. For example, a pre-service teacher might use a video to help learners understand the topic taught with more practical examples in a school with limited resources. This suggests that a competent pre-service teacher will be able to search for other resources to supplement what is provided in the school. Therefore a lack of resources no longer becomes a limitation for delivering content effectively for the pre-service teachers. This study examines what and how pre-service teachers learn from ICT courses and science methodology content courses in the teacher education programmes which enables them to bridge this resources gap by using ICTs. Furthermore, the study seeks to observe how technology is used in the teaching of science during teaching practice. It is important that pre-service teachers understand the disciplinary approaches to the use of ICTs for teaching subject matter and that they are taught in ways that prepare them to integrate the discipline and ICTs seamlessly as teachers in future.

Blignaut (2002) argues that there is a need to provide well-structured support for pre-service teachers who, in her observation, generally have low levels of ICT skills. This study then sought to examine what and how ICT support is provided to assist pre-service teachers during teaching practice and what role that support plays in the development of competence in using ICTs in the teaching of science in schools.

#### 2.4.2.2 Pedagogical knowledge (PK)

Pedagogical knowledge (PK) is one of the three main domains of knowledge in the TPACK model (detailed in figure 1). Harris *et al.* (2009) and Koehler *et al.* (2013: 397) define PK as follows:

> teachers' deep knowledge about the processes and practices of teaching and learning, encompassing educational purposes, goals, values,strategies, and more. PK is a generic form of knowledge that applies to student learning, classroom management, instructional planning and implementation, and student assessment. It includes knowledge about techniques or methods used in the classroom, the nature of the learners' needs and preferences, and strategies for assessing student understanding.

The argument is that graduating pre-service teachers have to possess skills on how to teach under different situations such as micro-teaching, experimental teaching and also be able to teach in real conditions of schools. Pre-service teachers would also need to be able to teach in schools with different socio-economic conditions such as poverty-stricken schools, ill-disciplined schools and/or well-resourced and well-managed schools. For example, a teacher can restrict the use of mobile technology in class as part of the school's discipline strategy but permit its use during the teaching of a particular topic that is not accessible to the learners such as a recording in history or an image of an internal organ being dissected in life sciences. The recorded video or images can then be posted to partnering schools who may lack these resources. A competent pre-service teacher would thus be able to use different forms of discipline management and many teaching strategies to enhance learning of any content in any environment as stipulated in the teacher education programme or in national documents such as CAPS.

#### 2.4.2.3 Technological knowledge (TK)

Technological knowledge (TK) is the third and main domain in the TPACK model that was added to delineate TPACK from Shulman's (1986) PCK model. Many researchers argue that it is difficult to define technological knowledge as it easily becomes outdated (Harris *et al.*, 2009; Koehler *et al.*, 2013). Koehler *et al.* (2013: 15) argue that "certain ways of thinking about, and working with, technology can apply to all technological tools and resources". Therefore, this definition matches with the definition of ICTs, which includes knowing how to use different digital information and communication technologies for teaching and learning such as the Internet, video simulations and other devices related to computers. The basic skills of using technological tools and the practical application of technical skills is necessary to regard pre-service teachers as competent to engage learners with ICTs and is considered as TK (Mouza, Karchmer-Klein, Nandakumar, Ozden & Hu 2014). TK also includes basic computer skills such as the use of PowerPoint presentations to deliver a lesson and the use of technology to prepare a lesson such as chat, word processing and emails with other pre-service teachers. It could also include Excel spreadsheets to effectively present information to a class. The more opportunities for practical applications of TK that pre-service teachers get during teaching practice, the more they will develop to be more competent in ICTs. It is not far-fetched to imagine that pre-service teachers who are more competent with TK will also likely be independent to learn other technologies on their own and keep up with rapid changes in ICT growth. It is up to the individual pre-service teacher to decide what ICTs to use and how to use it during teaching practice. If the teacher education programmes provide pre-service teachers with ample opportunities to practise the use of ICTs, in class and during teaching practice, the possibilities for deeper learning will exist, leading to more competent pre-service teachers. For example, an innovative pre-service teacher placed in a school with emerging technologies will be able to quickly learn on their own and from mentors how to operate the technologies for teaching purposes.Therefore, including TK in the guidelines for practice teaching will give pre-service teachers an opportunity to access ICTs, time to practise its use, build their skills of technological knowledge (TK) and be independent, competent teachers.

#### 2.4.2.4 Pedagogical content knowledge (PCK)

PCK refers to the meaning given by the pre-service teacher as s/he applies teaching principles in the context of the subject matter to enhance learning or mixing content and pedagogy to simplify the learning process (Shulman,1986). Teaching practice provides a platform to expose pre-service teachers to a variety of learners, different teaching environments and content that demands of them to adapt the curriculum to meet the needs of all learners. Thus, PCK automatically features as they plan and implement teaching of the subject matter using ICTs.

Shulman (1986) raises the importance of blending content and teaching so that knowledge is accessible to all students. ICTs is one kind of skill that pre-service teachers have to develop in order to be able to be considered competent to teach content. For example, a video can be used to re-enforce the same content that has been taught in order to give learners more access to content by viewing the video multiple times at their own pace and in their own time.

#### 2.4.2.5 Technological content knowledge (TCK)

TCK refers to the knowledge of how technology, in the form of ICTs, can influence and create new challenges in the teaching of new content and how teachers can use a specific technology to change the way learners practice and understand concepts within a content area (Koehler *et al.*, 2013).

Future teachers not only need to be competent in their subject matter, science, but also need to be trained to have a solid understanding of the various ways the subject matter can be taught, especially with the practical application of ICTs. Pre-service teachers who are already competent in ICT usage can select the proper tools to help them present a lesson better and enhance learning. For example, using an educational software program, such as augmented reality (AR) to show the function of a heart can help learners better understand certain processes of the heart. The ability to operate ICT tools can help improve the quality of learning in addition to knowing one's subject matter, which is more important in the delivery of a lesson. The merging of ICT tools and the appropriate teaching of content is the key to the development of competent pre-service teachers.

Pre-service teachers not only need to understand their subject matter such as science but they also have to practise the use of different technologies to best represent the content and be able to represent that content to their students in an effective manner.

#### 2.4.2.6 Technological pedagogical knowledge (TPK)

Koehler *et al.* (2013) define TPK as the use of ICTs in different ways to accommodate changing situations for teaching and learning. TPK is a skill that pre-service teachers can learn in the teacher education programme courses such as in the designated ICT courses or methodology courses. TPK has the potential to develop only when the pre-service teachers are provided with opportunities to practise teaching under different conditions. Pre-service teachers must be able to understand the strengths and challenges of using ICTs when designing and developing lessons for different audiences. A competent pre-service teacher would need to be able to assess the value of using ICTs to teach a particular section of the content or choosing one tool over the other.

### 2.4.3 TPACK Applications and limitations

At a conceptual level, the study further details the technological pedagogical content knowledge (TPACK) as a model for examining the various elements of the study that relate to the teaching of science content using ICTs in schools during teaching practice. TPACK is used as a model for examining the various elements of the study that relate to the teaching of science content using ICTs in schools during teaching practice. There are a number of studies that have been conducted in the past decade on the integration of ICTs for teaching and learning that have used TPACK as the framework. The TPACK survey instrument has been used by several researchers in other parts of the world to study pre-service teachers' integration of technology. In order to narrow my search, I focused my review more on articles published within the past 3 years (2013-2015) where TPACK was used to evaluate pre-service teachers' teaching of specific content. The review shows that the instrument has been used to study the use of ICTs for delivering subject specific content such as English, mathematics and science. Zelkowski, Gleason, Cox & Bismarck (2013) specifically investigated the validity and reliability of the TPACK survey for mathematics pre-service teachers. The conclusion was that while TPACK has been tested across multiple contexts not much has been done to use it in subject specific studies. The studies that used the TPACK instrument for the science subjects mostly examined in-service teachers' practice or pre-service teachers in the learning of the theory (science) courses during a teacher education programme (Doyle & Reading, 2013; Lin, *et al.*, 2013; Hechter & Vermette, 2013). The current study thus differs from these studies in that the focus is on pre-service teachers' practical application during teaching practice and its use of mixed methods further distinguishes the present study from the rest. Moreover, the TPACK instrument has only been successfully used in a South African context in a secondary data analysis study where the purpose of the study was to investigate the level of TPACK for grade 8 mathematics in-service teachers (Leendertz, Blignaut, Nieuwoudt, Els & Ellis 2013). Most of the international studies that trace the development of TPACK for specific subjects indicate high levels of development of the TPACK knowledge dimensions, for example studies in Turkey for evaluating English TPACK knowledge (Öz, 2015). In contrast, the use of TPACK in South Africa is still in its infancy (Leendertz *et al.*, 2013). Therefore, the current study opted to use the TPACK instrument which has been successfully tested and validated in other internationally studies (see table 1).

**Table 1:** The use of TPACK in subject specific studies

| AUTHOR/DATE | SUMMARY | CONCLUSION |
|---|---|---|
| Haydn, T. 2014 | The aim of the paper was to examine how teacher preparation programmes in England prepare future teachers to teach their subject using ICTs. The study explored the strategies used in the development of pre-service teachers. The results indicate the need for subject specific integration of technology. | The study's conclusion is that there is a need for subject specificity in the preparation of future teachers in the use of ICTs.<br>The present study thus examines the use of ICTs in a specific subject during teaching practice in South Africa. |
| Zelkowski, J., Gleason, J., Cox, D.C. & Bismarck, S. 2013 | The study examines the competence of pre-service teachers in teaching mathematics through ICTs in the teacher preparation programme. The quantitative study was done in higher education institutions in the USA with the use of TPACK specifically for the subject (mathematics). | The study concludes with the suggestion for the use of mixed methods to examine the use of TPACK in a specific subject.<br>The current study took up the suggested proposal by using a mixed methods approach to explore the use of ICTs for science in a school context, during teaching practice. |
| Doyle, H. & Reading, C. 2013 | The study explores the experience of a cohort of science pre-service teachers in a curriculum-based virtual world. The paper is focused on how teachers change in the use of an ICT tool from being not in favour to being supportive. | The use of TPACK provided evidence that a research-based virtual world can be used for teaching and learning. |
| Lin, T.C, Tsai, C.C, Chai, C.S. & Lee, M.H. 2013 | The paper explores pre- and in-service science teachers in Singapore. | The results confirm the existence of seven domains of TPACK and recommend the addition of technology, pedagogy and content (TPC). |

| | | |
|---|---|---|
| Öz, H. 2015. | The purpose of the study was to examine TPACK development among pre-service English teachers in Turkey. | The study confirms that discrepancies exist between TPACK models used by teacher educators in lecture halls for the development of competent teachers in "combining content, technologies and teaching approaches in classroom lessons". The authors further recommend that more research be done on the practical application of TPACK in schools. |
| Leendertz, V., Blignaut, A.S., Nieuwoudt, H.D., Els, C.J. & Ellis, S.M. 2013. | The purpose of the investigation was to determine the level of TPACK of mathematics grade 8 teachers and how TPACK attributes contribute towards more effective mathematics teaching in S.A. | The results revealed that the TPACK of mathematics teachers contributes towards more effective grade 8 mathematics teaching in South African schools. The authors further advocated the need to embrace TPACK in South African schools in order to improve the teaching and learning and teachers' experiences across various subjects. |
| Nordin, H., Davis, N. & Ariffin, T.F.T. 2013. | The study aimed to determine pre-service teachers' perceptions of their TPACK mastery level before and after field experience. The 107 pre-service teachers completed a questionnaire and 3 pre-service teachers were interviewed in a research-intensive university programme in New Zealand. | The findings suggested that pre-service teachers are more knowledgeable in the non-technology related content knowledge (CK) than in technology related knowledge (TK) within TPACK before and after field experience. The study proposed further research to unpack TPACK in relation to the field experiences of pre-service teachers. |

Other TPACK studies have identified weaknesses in the use of the framework in subject teachings such as science and mathematics (Chai, Koh, & Tsai, 2013; Özgün-Koca, Meagher & Edwards, 2010). Chai *et al*. (2013) reviewed 74 empirical research papers using the TPACK framework of which 20 were based on subject-specific technologies focused on using the framework for science teaching. The findings suggest that issues and gaps exist in using TPACK in the teaching of subject content and proposed a revision of the TPACK framework to guide future research. The Özgün-Koca *et al*. (2010) study of 20 students in a mathematics teaching methodology course analysed surveys and assignments using the TPACK framework. The result of the study supported an argument that pre-service teacher TPACK development is related to the shift in identity from "learners of mathematics" to "teachers of mathematics", but did not report evidence of development for mathematics student teachers.

Previous TPACK studies related to pre-service teachers' competences in teaching content subjects indicate the possibilities that future teachers may not be comfortable using technology during their teaching practice. Yet the need for future teachers to be competent in the use of ICTs are essential in the teaching of a difficult discipline such as science.

### 2.4.4 Rationale for using TPACK and the different frameworks

There are various frameworks available that relate to ICT competencies for teaching and learning. The researcher used search engines to find studies and articles from journals and books that relate to competence in ICT, teaching content with ICT and using ICT during teaching practice for pre-service teachers. The search provided various frameworks that could be adapted for the study. Therefore, there is a need to justify the selection of the theoretical framework that was used in this study in terms of its alignment with the purpose of the study and research problem. The following section will then compare the TPACK framework with other models or frameworks that examine technology, pedagogy and content as the three key concepts that are central in the present study. The rationale for the selection of TPACK has to do with the possibility of the framework helping to generate data to answer the main research question: What are the competences of pre-service teachers in using ICTs to teach science content during teaching practice?

The search for a relevant framework began with a comparison of a number of possible frameworks that relate to the use of ICTs by pre-service teachers. After all other theories were eliminated by the lack of relevance to the study, TPACK became the best framework for engaging the science content, the pedagogical knowldege possesed by student teachers and the technological knowldege developed during ICT related courses. It is important to note that the TPACK survey does not only combine the three complex and inter-dependent concepts of technology, pedagogy and content but It epresents the application of specific knowledge of science content, practical use of ICT knowledge and the art of teaching during teaching practice in a school context. Thus, it demostrates the interactions among the TPACK concepts which can provide a measure of competence on the use of ICTs by pre-service teachers during teaching practice.

TPACK gave me a solid theoretical framework with which to examine many of the issues that arise when learning to combine technology, content and pedagogy in teaching science. The sections below provide a brief comparison of the TPACK framework with the other possible frameworks that were excluded, viz. the pedagogy, social and technology or PST framework, and the pedagogical technology integration content knowledge or the PTICK model.

#### 2.4.3.1 PST model

Wang (2008: 1) developed a generic model namely the pedagogy, social interaction and technology (PST) model. The PST model has similarities with TPACK in that both models focus on improving teaching and learning through the integration of ICTs. The discussion below mainly focuses on why the PST model was not selected for the current study as a theoretical framework.

The first difference between these two models is that the PST focuses on the addition of interaction to develop the three main concepts pedagogy, social interaction and technology, while in the TPACK model, all concepts interact or overlap with each other throughout the framework (Koehler & Mishra, 2006). The PST model stresses the importance of interaction within the context of learning. Wang (2008: 414) states, "the interactivity in a learning environment can be simplified into learner-content, learner people and learner-interface interaction". Similarly, Garrison (1993: 15) argues that "the quality of an educational experience is dependent upon encouraging students to critically analyse differing perspectives, thereby constructing personal meaning and validating that understanding by acting upon it through communicative acts". Therefore, social interaction is important in promoting deep learning for pre-service teachers in the school context during teaching practice as they interact with the society (see fig. 2). The application of such a model to explore the competence of pre-service teachers in the use of ICT tools would however be limited by different learning environments which might not be applicable in an online mode of delivery as suggested by the PST model. The interaction with the learning environment during teaching practice differs from school to school and thus the PST model would not align with the research questions posed for the present study.

On a positive note, the emphasis on interactions is not lost in the TPACK framework, which examines the overlapping of the skills and knowledge on the three key concepts: technology, pedagogy and content. This is examined throughout the preparation of teachers in a teacher education programme and even includes the field experiences as the final point of interaction during teaching practice. Garrison (1993: 14) mentions that "without sustained interaction there is no way to facilitate critical learning". It is not clear how the PST model helps to ensure sustainability in monitoring and assessing competence levels of participant pre-service teachers as it applies to only a "technology-enhanced environment" and the model has only been tested in an online environment (Wang, 2008). The TPACK model, on the other hand, proved to be more practical for this study as it has been developed and evaluated mainly on pre-service teachers in different environments and for participants who are at different stages in the teacher education programme.

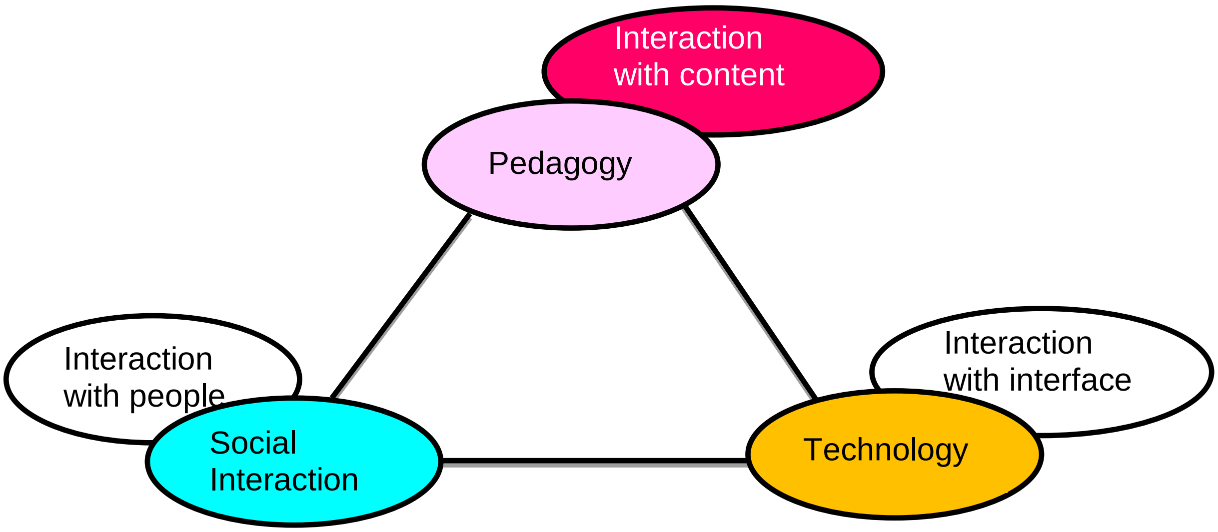


**Figure 2:** Relationship between the model components and interaction

(Adapted from Wang, 2008)

Secondly, the PST model reviews the affordances of ICT tools through the lenses of pedagogy, social interaction and technology as the three main concepts (Wang, 2009). The researcher takes a pragmatic stance here in arguing that the affordances of an ICT tool would not be effective without a competent teacher who has knowledge and skills on how to use ICT tools to teach the content. Thus, the capability of an ICT tool to function in a classroom largely depends on the competence level of a pre-service teacher to relate the use of a tool with the science content that is being taught. A more competent pre-service teacher could even use the ICT tool for class preparation or change a high-level ICT tool to become a low-level tool for the classroom. For example, a pre-service teacher can view tutors, simulations or videos on teaching certain scientific concepts on his/her own. Then customise it for the classroom through pasting images or activities into a Word document that could be distributed to a class. Therefore, the application of the PST model would not be practical for the current study, as it requires that the teaching and learning environment be online.

#### 2.4.3.2 PTICK model

The pedagogical technology integration knowledge (PTICK) model was developed with the two main themes of reflective and community knowledge (Brantley-Dias *et al.*, 2007). The authors of the PTICK model argued that other authors such as Shulman (1987) and Koehler and Mishra (2006) based their models (PCK and TPCK) more on “procedural, conceptual and pedagogical content knowledge” (Brantley-Dias *et al.*, 2007:143), thereby missing out on the fact that technology integration involves reflective and community knowledge.

The researcher agrees that reflection and community knowledge does play a role in the development of pre-service teachers’ competence. The key question I had to consider was whether the reflective and community knowledge would add more value to the current study in terms of answering the research questions.

Keagan (1993: 1) mentions, “there is nothing as practical as a good theory as it provides the touchstone against which decisions can be taken with confidence”. It was then important for me to understand the underlying five dimensions of PTICK and relate them to the study in order to be able to decide which theoretical framework would best fit my study. Brantley-Dias *et al.* (2007), describe the PTICK’s framework as a model that will add reflective and community knowledge into procedural, conceptual and pedagogical content knowledge that had been discussed by authors such as Shulman (1986) and Mishra and Koehler (2006). The five dimensions of PTICK (figure 3) are discussed below, mainly to illustrate how the PTICK model differs from the

TPACK model in terms of its suitability for the purpose in the present study (Brantley-Dias *et al.*, 2007; Torraco, 1997).

- Technical procedural knowledge (knowledge and ability to operate the technology). This is practical and forms the central component of teacher education programmes where pre-service teachers have to demonstrate their competence level to operate ICTs during teaching practice. It was therefore necessary for this study to analyse the technological knowledge (TK) of the pre-service teachers as described by the TPACK framework.
- Technology integration conceptual knowledge (integrated concepts, principles, strategies and ideas behind effective uses of technology for teaching and learning). Practically, as pre-service teachers use different ICT tools to teach science content, they would become familiar with various technological concepts and be more competent. The competence to use technology when teaching content is assessed through TCK in the TPACK survey/framework.
- Pedagogical content knowledge (knowledge and ability to transform subject matter content addressing learners' needs). This is more practical as the pre-service teachers would have to apply content knowledge with the use of technology during teaching practice. This is PCK in TPACK.
- Reflective knowledge (metacognitive abilities to reflect, problem-solve and learn from experiences). This is practically the reason why every lesson a teacher teaches needs to be reflected on. I opted to use focus group interviews to assist pre-service teachers to reflect more on the way they taught during teaching practice. Furthermore, the TPACK framework includes instruments that are a well-developed component of reflection in the form of questionnaires/surveys. As the participants respond to each knowledge domain in the TPACK framework, they tend to engage in reflection.
- Community knowledge (knowledge of the local community and participation in a professional learning community) may be applicable to pre-service teachers during teaching practice but was not directly relevant

to this study. The aim of the study was to explore the competence levels of pre-service teachers to teach science content using ICT tools. The practical application of technology and teaching is within the school community and pre-service teachers visit schools for only two weeks, which is a very limited time for them to engage with local communities of the school. Though the time is limited, it is an opportunity for pre-service teachers to engage with the unknown and with what they know. Wenger (1998: 149) states that people “define who they are by the familiar and unfamiliar, by the way they reconcile various forms of membership into one identity”. Therefore, pre-service teachers would engage with either their peers who may not necessarily be teaching similar content or with other in-service science teachers and may not necessarily be mentors for science subjects. They do this in order to identify themselves as members of the same school or community in which they belong. In this case, participation in the use of ICTs to teach any content would encourage pre-service teachers “to form ICT communities of practice to support their teaching practice” (Vandeyar, 2013:1). Therefore, the only available opportunity for pre-service teachers to develop community knowledge is by connecting with learners, peers, mentors, school management and teacher educators in a school during teaching practice.

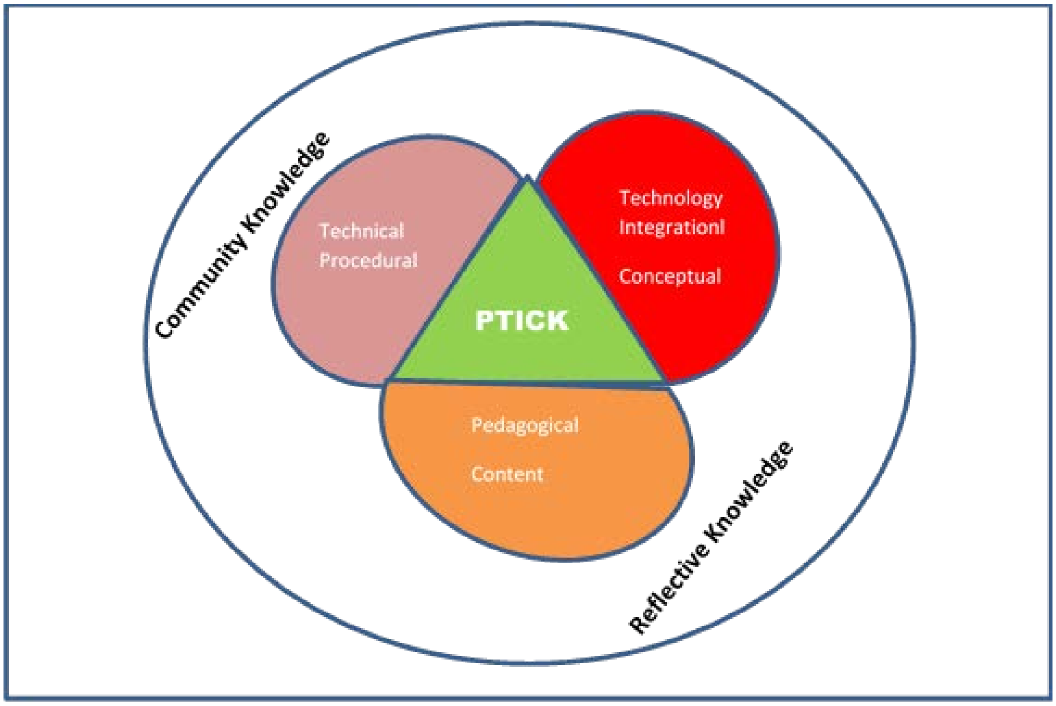


**Figure 3:** Pedagogical technology integration content knowledge (PTICK)

(Adapted from Kinuthia, Brantley-Dias & Clarke, 2010)

In conclusion, as the researcher for the current study, there was a need for me to understand a number of theoretical frameworks, conceptual frameworks or models that relate to technology integration so that I could select the most relevant framework. The PST and PTICK models provided guidelines for my decision-making but did not fully align with the current study. Therefore, TPACK proved to be the best theoretical framework for the study. TPACK originates from Shulman's (1986) theoretical framework that emphasised general aspects of teaching subjects. The TPACK framework adds the important technological aspects that can be used to enhance teaching of content such as science. Therefore, TPACK became a useful model for studying the use of ICTs, as one example of the technological aspects with pedagogy and content knowledge during teaching practice.

## 2.5. Gaps in the literature

My review of the literature on the integration of technology into subject teaching has identified four major strands or themes. The first examined the literature on ICTs in South African schools. From the local literature, we now know that theoretically the government has put out some guidelines on what is expected from graduates of higher education institutions and thus the present research sought to explore how these guidelines are working in practice. Even the international literature points to a gap in the training of pre-service teachers in teaching with ICTs in specific subjects. However, existing research has failed to address itself to the issue of determining the level of competence by graduating teachers to use ICTs in specific subjects.

The second theme of the literature discusses the issue of ICTs in teacher education programmes (TEP). The major conclusions from this literature is that national curriculum policies for teacher education programmes are not necessarily implemented in the specific subjects such as science, within higher education institutions. While scholarship has been improved by the addition of resources such as ICT infrastructure and innovative academics, questions on whether graduates are competent to use ICTs in schools remains unanswered.

The third major theme from the research on the use of ICTs for teaching and learning of content regards teaching science with ICTs. Literature shows a scarcity of research into the pre-service teachers' use of ICTs to teach science, in particular. The research that is available tends to focus on the ICT competences of students or "digital identities" of students as it is sometimes known (Nykvist, & Mukherjee, 2016; Prensky, 2002). While this strand of research is useful, to date it has not been able to give us a clear and disaggregated picture by subject specialisation of the students competences for instance. We do not know whether digital identities vary by subject specialisations among cohorts of students. We know very little about what accounts for the variations in the observed digital identities of the students where they exist. The present study also sought to contribute to the research on digital identities by disaggregating the data for a sample of all science education pre-service students within the sampled university.

What is more troubling from the entire review of the literature is that while all pre-service teachers go for teaching practice to determine their competence to teach, there is as of yet no study that speaks to the ICT level of competence that is expected of pre-service teachers before they qualify to start their careers as in-service teachers. Given that some of the 21st century ICT tools have been around for a number of decades, the fact that little research has focused on this part of the teacher training programme seems like a gross oversight by researchers, especially in developing countries.

### 2.6. Summary of the chapter

The literature review began with the exploration of information communication technologies (ICTs) in South African schools before zeroing in on the teacher education programmes (TEP) within the higher education institutions. Furthermore, the literature review examined the use of ICTs for teaching science content and specifically discussed the pre-service teachers' competences in the use of ICT tools during teaching practice. Finally, my literature review explored the TPACK model as the conceptual framework for the study and gave an account of the various dimensions of the model and its applicability to the present study. The review ended off with a discussion of the gaps in the literature relating to the topic being studied.

The study hopes to add to the body of knowledge regarding the practical application of ICTs during teaching practice. Furthermore, this study also sets an example on how to use the components of the TPACK framework to develop and assess the competence of future teachers. The literature review has uncovered the need to explore what ICT skills pre-service teachers use during teaching practice and what kind of support is needed to help them develop the required competence. The combination of knowledge dimensions in the TPACK model may be useful in guiding teacher education programme designers to include courses that align with the national curriculum in terms of its requirements on ICT competence for subject teachers.

The next chapter provides the details of mixed methodology approach and research design on how it was used to explore pre-service teachers' competence for teaching science using ICTs during teaching practice.

# 3. CHAPTER 3: RESEARCH METHODOLOGY AND DESIGN

## 3.1. Introduction

This chapter discusses the research methods used to study the competence of pre-service teachers in teaching science using ICTs during teaching practice. The chapter begins by restating the purpose of the study, the research questions, discussion of the research design, a description of the process of collecting data, the selection of participants and the research instruments utilised for data collection and data analysis and concludes with a discussion of the limitations and ethical considerations before providing a brief summary of the chapter.

## 3.2. Purpose of the study

The purpose of this study was to explore the competence of pre-service teachers in teaching science using ICTs during teaching practice. The study also sought to determine the alignment of the teacher education programme with the application of ICT tools for the teaching of subjects such as science. In other words, the study discusses the readiness of pre-service teachers to use ICTs in the teaching of content as stipulated by the Department of Higher Education and Training (DHET, 2013). It is hoped that insights from the study will help universities assess the level of competence of the prospective teachers they produce in their programmes.

## 3.3. Research questions

The main research question sought to generate data on the pre-service teachers' competences in using ICTs for subject teaching by asking the following question:

What are the self-perceived competences of pre-service teachers for using ICTs to teach science content during teaching practice?

The following secondary research questions were proposed to unpack the main research question:

1. What is the self-perceived competency of science education pre-service teachers with respect to the various tools that are applicable for teaching science content in schools? (Competency examines the knowledge, skills and opportunities to learn or what is often captured as the “inputs”).
2. Which ICT tools do pre-service science teachers commonly use during teaching practice? (What are the prevailing patterns of use of ICTs during teaching practice?)
3. How are the ICT tools used for teaching science during teaching practice? (For what purposes are they used and what are the methods of use?)
4. How can the competences on ICTs and patterns of use be understood and explained?
5. What suggestions for improvement can be made regarding the development of competence and use of ICT tools for teaching of specific subjects, for example science?

### 3.4. Research design

The present research used a mixed methods approach with a multi-level triangulation research design (Yin, 2012). A single case that investigates the competencies of pre-service teachers in the use of ICT tools for teaching science was developed.

According to Creswell (2014), the decision regarding the research design and methodology depends on the research problem and questions, personal experiences of the researcher and the audience that will read and review the research report. The researcher opted for a “combination of qualitative and quantitative research” which took advantage of her personal experiences of using both approaches in previous research. The mixed methods approach helped to unpack the challenges and opportunities that pre-service teacher education programmes face in reaching appropriate ICT competence levels, especially during teaching practice. In one way, the present research sought to solve a complex problem on the use of ICTs for subject teaching, not only for the benefit of higher education but also for the schools that employ the newly qualified teachers. Locke, Silverman and Spirduso (2010: 199) argue that “mixed methods studies are not created simply by mixing methods from two paradigms”. Therefore, this section discusses how the study dealt with the challenges of the chosen approach that combines qualitative and quantitative approaches. Creswell (2014: 219) also notes that the combined methods bring challenges to the researcher such as the “extensive data collection, the time intensive nature of analysing both qualitative and quantitative data, and the requirement for the researcher to be familiar with both forms of research”. Thus, the decision to use mixed methodology was mainly determined by the research problem, research questions and the expected readers of the study. Since this study was concerned with pre-service teachers’ competence and practices in teaching science using ICTs, a quantitative survey methodology was appropriate to supply numerical data on the individual participants and the knowledge levels of ICTs by the pre-service teachers. Beginning the study with statistical tests gave me the required background information about the participants and their ICTs competence, while the qualitative methodology helped to explain the relationships between ICT knowledge and practice as measured during teaching practice. Furthermore, the interviews provided information on the pre-service teachers’ reasons for using ICT or why they were not used. A quantitative research design also provided an overall picture of what is happening in the teacher education programmes and about the ICT competence of pre-service teachers, while the qualitative methods gave detailed insights for “understanding the situation from the perspective of the participant” through interacting with the documents or with the individuals during the interviews (Locke *et al.*, 2010: 183).

Johnson and Onwuegbuzie (2004: 17) posit that a mixed research methodology is "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language in a single study". In choosing a mixed methods approach, I took into consideration that the utilisation of one particular approach depends on what is being researched, the research aim and objectives and the researcher’s preference, rather than the inherent superiority of one approach over another. I therefore opted for qualitative and quantitative data collection methods in order to gain deeper insights into the research questions than either approach would have provided separately. I benefited from using a mixed methods approach in this study in that the survey report given by pre-service teachers was complemented by the information from the documents used during the actual teaching practices and by “thick-descriptions” from the focus group interviews (Locke *et al.*, 2010). Furthermore, I took advantage of the fact that the mixed method approach draws from the strengths of each method and minimises the weaknesses of each method (Johnson & Onwuegbuzie, 2004). For instance, the survey data provided the participants’ background information that allowed for sorting of the participants based on subject specialisation and teaching phase.

The study used a case study as the research design for the mixed methods (Yin, 2012). Cohen, Manion and Morrison (2011: 129) note that the purpose of a case study is “to portray, analyse and interpret the uniqueness of individuals and situations through accessible accounts”. This single case describes pre-service teachers’ competencies in the use of ICT tools for teaching science during teaching practice in actual schools. The case study “presents and represents reality” of teaching specific content with ICT tools in a teaching and learning environment (Cohen, Manion & Morrison, 2011: 129). A case study design was selected in order to be able to examine and compare different applications of

ICTs for different science content, different grades and different phases (Creswell, 2014; Yin, 2014). The case study selection was assumed to provide rich insights on one particular university, about a specific teacher education programme and for a group of students who are in the final year of their studies. The study used a cohort of final year pre-service teachers from one teacher education programme at a single higher education institution across two campuses. The research design followed a concurrent mixed methods design with data collected from the survey questions, the lesson planning forms and from focus group interviews at almost the same time or during the same time period – making the design “concurrent” (Johnson & Onwuegbuzie, 2004 & Creswell, 2014).

In the quantitative phase, a survey questionnaire with three major sections (including background data, knowledge and awareness of ICTs and observation on the use of ICTs in the classroom) was administered to all final year students taking science-teaching subjects. The sample included students who specialise in the teaching of all science disciplines, viz. natural sciences, physical sciences and life sciences. The sample therefore cuts across three different phases of schooling in South Africa where science is taught viz. the middle school or senior primary/intermediate phase, the lower secondary or senior phase and the senior secondary or further education and training (FET) phase.

The qualitative phase addressed the questions on what and how ICT tools are integrated in the teaching of science by analysing the artefacts and interview transcripts. This study was designed to explore what ICTs are used, what patterns are followed in the use of ICTs and what reasons are given for using specific tools for certain content and specific groups of learners. The researcher examined qualitative data collected through document analysis and open-ended questions in focus group interviews, to explore the reasoning and patterns for using ICT tools. The process was that a follow-up focus group interview was conducted for a sample of pre-service science teachers who had completed a survey questionnaire and who had volunteered to submit the lesson plans they had used during teaching practice prior to or on the day of the interview. The few volunteers (0<n<8 per focus group) were interviewed in order to explore their reasons for using particular tools and in specific ways during teaching practice. The reasons for using mixed methods research are mainly to bring together the strengths of quantitative and qualitative data sources to answer the questions in the study. Accordingly, my approach is informed by the pragmatic framework, which triangulates the mixed methods designs by using different data collection and analysis strategies to complement each other in answering the same research question.

Mertens (2010: 294) posits, “mixed-methods have the potential to contribute to addressing multiple purposes and thus meeting the needs of multiple audiences for the results”. Therefore, mixed methods research worked best for this study because the results are designed to benefit multiple audiences such as student teachers, teacher educators, curriculum developers and designers of teacher education programmes, management of higher education institutions, non-profit organisations involved in teacher placement and training, government officials and policymakers in general.

## 3.5. Position of the researcher

The present research emanated from my role as a teacher educator who is responsible for different courses related to ICTs in the teacher education programme of the same university where the study was conducted. I considered myself as an insider, as I plan to remain a member of staff within the field even after my research is completed (Coghlan, 2007). As part of the job, I was also responsible for assessing the pre-service teachers during their teaching practice sessions, at least before I took research leave to focus on the data collection for the present study. Cohen *et al.* (2011: 296) argue that what makes a good case study researcher is the ability to relate the collected data to the purpose and an ability to make meaningful analysis. Throughout the research process, I personally facilitated all the research participation and data collection from the completion of the survey to the document analysis, conducting the focus group interviews and the data analysis. I did not pretend to be a neutral and objective researcher. I acknowledged to the participants that I am a teacher educator and that I have opinions regarding the issue of ICT usage in teaching and the lack of alignment between the ICT tools available in schools with what is taught in the teacher education programmes. I agree with the recent government policy that sees ICTs as an essential skill for every teacher education student. Although I was not the participants' science methodology course teacher educator nor did I assess their teaching practice specifically, some participants could still have been “vulnerable” as I was the instructor for some of the optional courses they needed to attend. I made it a point to assure the participants, both verbally and in writing, that their participation or lack thereof would not affect their grades in any way. As a matter of principle, I base the grades for all my courses on a set of transparent criteria or rubrics that are discussed and distributed to all my students beforehand. The possibilities for “vulnerability” of the participants were thus mitigated even though I cannot assert that they were eliminated from the data collection processes.

## 3.6. Participants

The study selected a cohort of pre-service teachers doing either the Bachelor of Education (B.Ed.) qualification or Postgraduate Certificate in Education (PGCE), with specialisations in either physical sciences, natural sciences and/or life sciences. The study selected only final year science pre-service teachers who participated in teaching practice for 4 weeks during the April and July periods in 2015 (with each teaching practice period limited to a minimum of two weeks). The research was confined to doing an in-depth case study, with survey questionnaires, document analysis and focus group interviews.

The researcher initially met the participants individually, in the different schools where they were placed for teaching practice. Others were invited through their subject methodology teacher educator, who gave permission for the researcher to administer the survey instrument during the last few minutes of his scheduled lecture with the students. On the main campus, the subject methodology lecturer provided space and time for the recruitment of participants, completion of consent forms and the survey questions. On the rural campus of the university, the teacher educator agreed to administer the survey to the students after the debriefing processes with the researcher. All the participants completed the survey in a face-to-face seating at both campuses (Creswell, 2014). Out of all the participants who attended class on the day of the survey, the return rate was 100%. The teacher educators at both campuses informed the researcher about the relatively low class attendance that day because of test week where some students use the time to catch up and prepare for the test.

All participants were assumed to have been admitted to the teacher education programme during the year of the study and to have participated in both teaching practice sessions. It was also assumed that participants had been enrolled in the university for at least 3 years either in the teacher education programme or outside the education stream and thus to have taken ICT designated courses. The total number of participants was 103 and this was comprised of 27.18 per cent males and 71.81 per cent females with 0.97 per cent missing data. The main campus group had 58 participants out of a possible 80 final year students who are listed as enrolled for science methodology on the university database. Only seven of those who completed the survey submitted their lesson plans and thus participated in the follow-up focus group interview. In the rural campus, there were 45 students who participated in the survey out of a possible 72 students registered for the science methodology modules. Fourteen volunteers submitted lesson plans and participated in the interviews. Thus, the study had a 68% participation rate in terms of all the science methodology students enrolled at the university across the two campuses.

The sampling design enabled multiple comparisons across phases of specialisation and across campuses and teaching practice school types. The study provided for a systematic analysis of comparative data on ICT competences across various phases of specialisations in the teacher education programme using the data from the pre-service students' survey.

### 3.7. Ethical Issues

Ethical issues were taken into consideration and respect for the privacy of the participants and sites was paramount (Creswell, 2015; Yin, 2014). The study obtained approval from the University of the Free State ethics committee (see Appendix D) using the human subjects' approval process. Fictitious names were used to protect the names of the participants and their institution. For instance, focus groups are labelled as groups one to four and the interviewees are labelled as numbers in each of the focus groups (Creswell, 2015; Yin, 2014). Participants' rights of involvement consent form and confidentiality was included in the survey, explained and pre-service teacher participants signed a consent forms before completing a survey. No participant was identified in the study. The first page of the survey has a letter (see Appendixes A) to participants informing them that participation was strictly voluntary and their response would be kept confidential.

### 3.8. Data collection

The data collection for the study began with a pilot study in May-June, 2015. Full data collection occurred at the start of the second semester, July–September 2015, with a rigorous quantitative purposeful sampling which was closely followed by the qualitative data collection phase. The procedures included the administration of a close-ended survey questionnaire, document analysis of the individual lesson plans and open ended interviews with several focus groups.

The researcher personally distributed and collected the survey forms with consent forms to the pre-service teacher education students on the main campus in order to clarify questions that may affect the validity of the data collected and the return rates. The focus group interviews followed on both campuses within a few weeks after the quantitative survey was completed with lesson planning forms either brought before the focus group interviews or on the day of the focus group interviews. In this study, multiple methods were used for gathering data on the competence levels of pre-service teachers to teach science using ICTs during teaching practice. The researcher "incorporated validity strategies" in collecting data by requesting the submission of lesson plans from the teaching practice classrooms that had been observed by the different teacher educators and mentors in schools (Creswell, 2014: 201). These were likely to have been the "best lesson plans" prepared by the pre-service teachers who would have known in advance about the impending visits by the teacher educators and/or mentors for observation and assessment. I needed to have samples of the best lesson plans in order to determine competence under the best circumstances, so to speak. Multiple data collection points enabled me to collect plenty of data to address the research questions and contributed to internal validity of the findings and triangulation of data.

The data collection was done in different sites across the two campuses and across the university. To improve the trustworthiness of the data, the data collection began with a pilot study to ensure reliability and validity of the instruments. The pilot study was done with a group of pre-service teachers on the main campus only, for convenience. Furthermore, the research uses various triangulation techniques that include a survey questionnaire, document analysis, and focus group interviews. The resulting data sets allow me to verify and strengthen the kind of claims that emerge from the project. The researcher had to ensure respect for the different sites during completion of the survey, collection of documents and interviews to minimise disruption (Creswell, 2014; Yin, 2014).

This was done through online sign-up sheets (using doodle) where student teachers had to indicate time slots that were suitable for them to participate in the focus group interviews.

### 3.8.1. Pilot study

The pilot study used new graduates who had recently completed their studies and had started working as teachers in schools. The invitation was circulated on the learning management system (LMS) for one of the postgraduate programmes requesting recent science graduates to participate in the pilot study. Four students responded to the invitation, completed a survey and participated in a focus group interview. The testing process was important for establishing validity of the instruments and for improving the quality of questions in either the survey or interviews (Creswell, 2014). The testing process assisted in modifying final survey questions and interview questions. A few questions were removed and wording changed to better reflect the familiar South African terminologies. In Cohen *et al.* (2011: 204) it is argued that it is important to have structured interview questions to provide reliability to the study. The pilot study assisted the researcher to practise using similar questions and wording for each of the focus group interviews.

### 3.8.2. The survey questionnaire

The final survey questionnaire was administered to final year student teachers studying to be science teachers in the B.Ed. or PGCE programme in the three phases of specialisation. The survey questionnaire was employed to determine ICT competency levels that student teachers associated themselves with, whether pre-service teachers are knowledgeable and aware of the ICTs associated with teaching science and are capable of using them in their science classrooms.

The TPACK survey for pre-service teachers was used as the instrument for assessing the ICT competencies of the pre-service teachers. This instrument is intended to measure knowledge of pre-service teachers in relation to teaching science with the use of ICTs. The researcher administered the TPACK survey for pre-service teachers in a face-to-face sitting after the teaching practice sessions of 2015 had been completed. The researcher personally introduced the study and discussed the reasons for conducting the research, including the consent form that students had to sign. The survey was also distributed during the methodology class immediately after teaching practice had been completed. During the introduction of the survey to participants, the researcher allowed participants to ask questions. On the rural campus, the teacher educator for the science methodology course administered the survey based on the briefing and debriefing provided by the researcher.

The TPACK survey consists of different question types that include eight demographic questions, one question adapted from Coffman's (2013) study where the students had to select the relevant item where ICT skills were predominantly learned and six knowledge questions on models with a Likert scale of TPACK. The knowledge questions used a five-level Likert scale to assess the six TPACK domains. The questions from the TPACK questionnaires ask the participants to rate their agreement on a five point Likert scale from "strongly agree" to "strongly disagree". On the questionnaire and for data entry the responses were coded as 4="strongly agree", 3="agree", 2="neutral", 1="disagree" and 0="strongly disagree". The South African Statistics (SAS) software was used for the analysis. The codes were then used in all subsequent statistical analyses.

A survey method of data collection was chosen so that pre-service teacher ICT competence and student knowledge about teaching science with ICTs could be determined. The survey was adapted from the "Survey of Pre-service Teachers'

Knowledge of Teaching and Technology" (known as the TPACK survey for pre-service teachers) (Schmidt *et al.*, 2009:144) which was developed from several prior research studies. Permission was requested for the use of the instrument by the researcher. The questionnaire has been administered to participants at different levels in the teacher education programme. One particular study named, *Technological Pedagogical Content Knowledge (TPACK): The Development and Validation of an Assessment Instrument for Pre-service Teachers* (Schmidt *et al.*, 2009) engaged survey experts, professors from Iowa State University and professors from Michigan State University to validate the survey. In that 2009 study, survey data were collected from 124 students enrolled in Education programmes at a Midwestern four-year institution of higher learning (Schmidt *et al.*, 2009).

The adaptations to the survey for the purpose of the present study included the removal and restructuring of a few questions to match the university's teacher education programme and to enable the use of language or terminology with which the local students would be familiar. As mentioned before, one item was added to determine where students had learned their ICT skills. The modified question reads as follows: "Predominantly, where did you learn your technology skills?" (Coffman, 2013: 109). The students had the option to choose from six possible responses: from school, from university courses, from a friend, from a private paid place, from a website, on my own.

### 3.8.3. Document analysis

Lesson plans that were used during teaching practice had to be submitted by the participants before the focus group interviews. The choice of documents was guided by the research questions and objectives as well as by literature review on the state of science teaching in South Africa. Volunteers submitted at least one copy of their lesson plans (See appendix C). The hard copy documents were copied and original copies returned to the students. The hard copies were then filed in a locked cabinet. The information from each lesson plan was manually entered in an Excel sheet for analysis.

### 3.8.4. Interviews

Prior to the study, the researcher set up an interview with the director for teaching practice at the university in order to understand how the teaching practice process is conducted and explain the whole study and possible benefits thereof. During the one-on-one interview with the director, the purpose of the study and the extent of student involvement were discussed after which the director agreed to share any information that would be useful for the study. The discussion enlightened the researcher on the university processes for conducting such research, on teaching practice and on other important issues regarding the teacher education programme at the university.

Four (4) focus groups were conducted for the actual study, with participants ranging from two to seven per interview session. By pure coincidence, each group mostly consisted of students from the same phase of specialisation; that is intermediate phase (IP), and/or further education and training (FET) phase with the exception of one focus group that had mixed phases. Only one participant had taught in both intermediate phase and in the senior phase (SP or grade 7). None of the participants had taught grade 8 and 9 in the senior phase or grade 12 in the FET phase (The practice in most schools is to allocate pre-service teachers to lower rather than the higher grades). I conducted two focus group interviews on each campus. The grouping of participants was automatic as students selected scheduled slots through doodle (for interviews). Each of the pre-service teachers participated in one of four focus groups with each group interviewed only once with a similar set of pre-prepared questions. No interpretation or translation services were required since all participants understood and used English as a medium of instruction (even though the university provides for a dual medium of instruction).

Participation in the focus group interviews was voluntary and invitations were done through face-to-face methodology classes, emails and were posted in the learning management system (Blackboard) with sign-up sheets on Doodle. Cell phone numbers were requested in the survey and consent forms at the beginning of data collections were used to send reminders to the participants about the selected time slots. The researcher adopted a dispassionate stance in facilitating the interviews and began each interview by assuring participants of confidentiality. Interviews were conducted in one of the departmental boardrooms on the main campus and in the science laboratory for the branch campus with audio recordings made at each of the focus groups. The recordings were later transcribed into text for analysis. The focus group numbers, number of participants and participants' labels was assigned to protect the identities of the participants in each focus group. Table 2 below provides the details of each focus group with the grades and phases taught during teaching practices and the duration of each session:

**Table 2:** Details of focus group interviews

| Focus group number | No. of participants | Participants' identifier | Grades taught | Phase | Duration |
|---|---|---|---|---|---|
| ONE | 3 | 1 | 4,&5 | Intermediate phase (IP) | 57.44 |
| | | 2 | 4,5,&6 | | |
| | | 3 | 4,&5 | | |
| TWO | 4 | 4 | 4,5,6,&7 | IP | 51.09 |
| | | 5 | 11 | FET | |
| | | 6 | 10 | | |
| THREE | 7 | 7 | 10 &11 | Further education & training (FET) | 61:02 |
| | | 8 | 10 &11 | | |
| | | 9 | 10 &11 | | |
| | | 10 | 10 &11 | | |
| | | 11 | 10 &11 | | |
| | | 12 | 10 &11 | | |
| | | 13 | 10 &11 | | |
| FOUR | 4 | 14 | 10 &11 | Further education & training (FET) | 47.41 |
| | | 15 | 10 &11 | | |
| | | 16 | 10 &11 | | |
| | | 17 | 10 &11 | | |

### 3.9. Data analysis

The data collection produced a large volume of information from the close-ended data and open-ended data and it took approximately three months to complete the analysis. The researcher used a "side-by-side approach where the two types of data collected, were analysed separately and brought together in the convergent parallel design" (Creswell, 2014: 222).

The study consisted of 103 participants for the quantitative data collection. The TPACK survey for pre-service teachers was initially captured from paper into an Excel spreadsheet. The demographic information from eight questions was entered first, followed by the Likert scale questions focusing on the TPACK knowledge and models. The data was captured in approximately 52 variables and analysis provided through frequencies, means, regression and other descriptive statistics to describe the use of ICTs and the competency levels of the pre-service student teachers. Data were then exported to South African Statistics (SAS) software by the Department of Statistics at the University of the Free State for a more elaborate analysis.

For the qualitative interviews, data was transcribed into texts that were coded and categorised into various themes for developing the narrative accounts that explain the observations and descriptive statistical data. There were 33 lesson plans submitted and 21 participants for focus group interviews. The researcher made it a requirement for participants to have submitted a lesson plan or to bring it to the interviews in order to participate in the focus group interviews. In cases where only the lesson plan had been provided but with questionnaire completion and no focus group interview participation, the lesson plan was excluded from the analysis. The researcher captured data from lesson plans in an Excel sheet and coded it before analysis. The researcher analysed interview transcripts from the audiotapes and compared them with her notes taken during the interviews. Question by question, the responses were entered as phrases into an Excel spreadsheet and then coded based on recurring themes in the participants' answers. Once the phrases in the spreadsheet had been coded for each participant, each response code was totalled for the focus groups and the percentages calculated for competence status. These percentages were then entered to determine patterns of ICT use across pre-service teachers.

### 3.10. Limitations of the study

The methods of the study and its design were limited to one university across two campuses, to explore the competence levels of science pre-service teachers during teaching practice in schools. The data collection, analysis, results and findings may not be representative of other universities, and for other teaching subjects. The study however begins to provide important insights that can be extended with caution to other campuses and/or programmes.

Even though the mixed methods design was best for this research study, the following limitations are possible:

Firstly, survey research issues such as clarity of questions, honesty of the participants and response rates could affect the validity of the data. The researcher dealt with such challenges by allowing the completion of survey questions in one sitting in her presence and in a face-to-face classroom to allow participants to pose questions for clarity and increase response rate by personally and immediately collecting the completed survey questionnaire. For the rural campus, the survey was completed in the absence of a researcher although the presence of a teacher educator colleague for a science methodology course helped to provide similar conditions.

Secondly, the availability of ICT resources for teaching science was an issue that could affect the collection of reliable data since the researcher had no control in the selection and placing of students in schools for their teaching practice. The placing of student teachers in schools is the responsibility of teaching practice administrators who communicate all the arrangement with the schools in the immediate vicinity of the university. However, the limitation determines the capability of competent pre-service teachers to deal with the lack of adequate ICT resources, their independence and resourcefulness in using the available resources. The availability of resources in schools was also helpful to inform educational leaders on the extent of the adoption of ICTs in schools as advocated in the country's e-Education paper of 2004. According to the DoE (DoE, 2004: 17) "Every South African learner in the general and further education and training bands will be ICT capable (that is, use ICTs confidently and creatively to help develop the skills and knowledge they need to achieve personal goals and to be full participants in the global community) by 2013". Since the study was conducted in 2015, two years after the deadline set by the White Paper for the promised integration of ICTs into teaching and learning practices specifically, this research may then assist the government in identifying schools that still require further support with ICT resources in the one locality under study.

Thirdly, the completion of the questionnaire depended on the honesty of participants in providing reliable information. To deal with this limitation, follow-up interviews were conducted with the focus groups of pre-service teachers to clarify reasons for using particular tools to teach science.

Fourthly, the research applies to one specific university across two campuses for the teaching of science subjects during their teaching practice in schools. Therefore, the challenge in applying the data to other teacher education programmes and in the teaching of other subjects such as mathematics remains.

Document analysis was done in order to further corroborate the validity and reliability of the data. Further triangulation, through detailed field notes and a clear coding system were used during the analyses of the collected data (Creswell, 2014).

## 3.11. Summary of the chapter

In this chapter the research methodology and associated research goals have been addressed through the presentation of the purpose of the study, discussing research questions and the research design with its methodology. A description of how data was collected, who the participants were, which research instruments were utilised and the ethical considerations during data collection and data analysis were also given. The chapter concluded with a discussion on the possible limitations of the study and a brief summary of the chapter. The next chapter present the findings from the data collected and analysed.

# 4. CHAPTER 4: PRESENTATION OF THE FINDINGS

## 4.1 Introduction

This chapter discusses the findings from the data collected over a 3-month period, from the last week of July to the last week of September 2015, on final year pre-service teachers in the teacher preparation programme at UFS. It was important for the data to be collected in the final semester of the year on which the pre-service teachers were expected to complete their studies in order to reflect their competence just before they graduate and begin teaching in school. Furthermore, data were collected after the pre-service teachers had completed their final year teaching practice session. The analysis in this section uses a mixed methodology with the purpose of examining the self-perceived competence of pre-service teachers in teaching science using ICTs during teaching practice. The presentation of the findings begins with an overview of the study. That is, I give a brief restatement of the purpose of the study before providing a description of the mixed methodology design that was used to collect and analyse the data. The presentation of the data and analysis follows the structure of the research questions as discussed in the previous chapter and as suggested by Cohen *et al.* (2011).

The purpose of this research study was to investigate pre-service teachers' self-perceived competence in teaching science using ICTs during teaching practice. The study focused on final year pre-service teachers in part because they were at the end of their "training" and ready to enter the profession as teachers. I wanted to know what their perceived competence levels were at that point in their teacher preparation, in terms of their abilities to use ICTs to teach specific subjects, viz. the "natural and physical sciences". The two sessions of compulsory teaching practice in the final year of study, which together amount to a total of four weeks of school placement, provided the context in which to investigate their practical competencies with ICTs in the actual process of teaching. The study sample covered an approximately equal number of urban, suburban and rural schools from the Free State in South Africa. I used three sets of data collection tools, viz. the TPACK questionnaire, lesson plan analysis and focus group interviews.

This chapter uses the mixed methods design to present data examining the following main research question:

What are the self-perceived competences of pre-service teachers in using ICTs to teach science content during teaching practice?

To establish the competence levels of the pre-service teachers, the following secondary research questions were answered:

1. What is the level of self-perceived competency of the science education pre-service teachers with respect to the various tools that are applicable for teaching science content in schools? (Note: Competency defines the knowledge, skills and opportunities to learn or what is often captured as the “inputs”).
2. Which ICT tools do pre-service science teachers commonly use during teaching practice? (That is: what are the prevailing patterns of use of ICTs by pre-service teachers during teaching practice?)
3. How are the ICT tools used to teach science during teaching practice? (For what purposes are they used and the methods of use)
4. How can the competences (as defined by “competency” and “use”) on ICTs and patterns of use be understood and explained?
5. What suggestions for improvement can be made regarding the development of competence and use of ICT tools for teaching of specific subjects, for example science?

Data analysis specifically focused on the four knowledge domains of the TPACK framework that relate to the use of ICTs i.e. technological knowledge (TK), technological pedagogical knowledge (TPK), technological content knowledge (TCK) and technological pedagogical content knowledge (TPACK). The analysis also examined who and where the modelling of TPACK occurs. Thus, pedagogical content knowledge (PCK), pedagogical knowledge (PK) and content knowledge (CK) were not included in the study analysis although they are part of the TPACK theoretical framework.

## 4.2 Demographics of the participants

Data were collected from final-year pre-service teachers (N=103) from one higher education institution across its two different campuses. The volunteer participants were all enrolled in the initial teacher education programme with science education as their teaching methodology course and were recruited during teaching practice and during science education module classes irrespective of their demographic variables.

Table 1 displays the frequency counts on the six demographic variables namely gender, age range, programme of study, area of specialisation, science teaching subject and number of completed computer related modules.

The majority of participants were females (71.84%), which reflected the general enrolment pattern of students in the teacher education programme at UFS. The age range of 23-26 years (51.46%) constituted the majority, which is also the expected age range for a fourth year student who would have matriculated at the age of 18-20. The reviewed literature suggests that age and gender generally have no impact on the use of ICTs in teaching any subject (Teo, 2008; Lin *et al.*, 2013) hence they were not of significance for this study. The majority of participants had enrolled for the four-year Bachelor of Education programme (B.Ed.) (83.50%) with a science specialisation in the FET phase (74.76%) and specifically in the teaching of life sciences (72.82%). The majority of participants had completed computer related modules (96.12%) which supports the university's strategic plan to integrate ICT skills modules to improve students' performance (UFS, 2012).

**Table 3:** Frequency counts for demographic variables (N=103)

| Variable | Category | *n* | (%) |
|---|---|---|---|
| Gender | Missing | 1 | 0.97 |
| | Female | 74 | 71.84 |
| | Male | 28 | 27.18 |
| Age range (years) | Missing | 1 | 0.97 |
| | 18-22 | 42 | 40.78 |
| | 23-26 | 53 | 51.46 |
| | 27-32 | 5 | 4.85 |
| | 18-22 | 2 | 1.94 |
| Programme of study | Missing | 1 | 0.97 |
| | Bachelor of Education (B.Ed.) | 86 | 83.50 |
| | Postgraduate Certificate in Education (PGCE) | 16 | 15.53 |
| Area of specialisation | Missing | 1 | 0.97 |
| | Foundation phase (FP) | 1 | 0.97 |
| | Intermediate phase (IP) | 21 | 20.39 |
| | Senior phase (SP) | 3 | 2.91 |
| | Further education and training (FET) | 77 | 74.76 |
| Science teaching subject | Natural sciences (NS) | 20 | 19.42 |
| | Life sciences(LS) | 75 | 72.82 |
| | Physical sciences(PS) | 8 | 7.77 |

The frequencies of the abovementioned control variables in table 3 reflect the Faculty of Education's institutional data as given by the Directorate for Institutional Research and Academic Planning (DIRAP). This data shows that more females than males are enrolled in the teacher education programme and that more students enrol for the four-year degree (B.Ed.) in the faculty. There was only one participant with the missing control variable information for gender, age, programme of study and area of specialisation categories but the rest of his/her descriptive questions were completed.

### 4.3 Methodology overview

The researcher took a pragmatic approach to answering the research questions by drawing upon quantitative and qualitative research tools and strategies in a mixed methods approach. The study took a concurrent, triangulation mixed methods design where the quantitative data (QUAN) and the qualitative data (QUAL) received equal weight in the analysis and helped to provide deeper and/or alternative explanations of the findings (Creswell, 2014; Yin, 2014). A TPACK survey questionnaire, document (Lesson Plan) analysis and focus group interviews were used for data collection. Only one collected survey had missing background information but it was not eliminated in the analysis as it responded to all the other questions for the different domains of competence that were probed. An overview of the methodology is shown in figure 4.

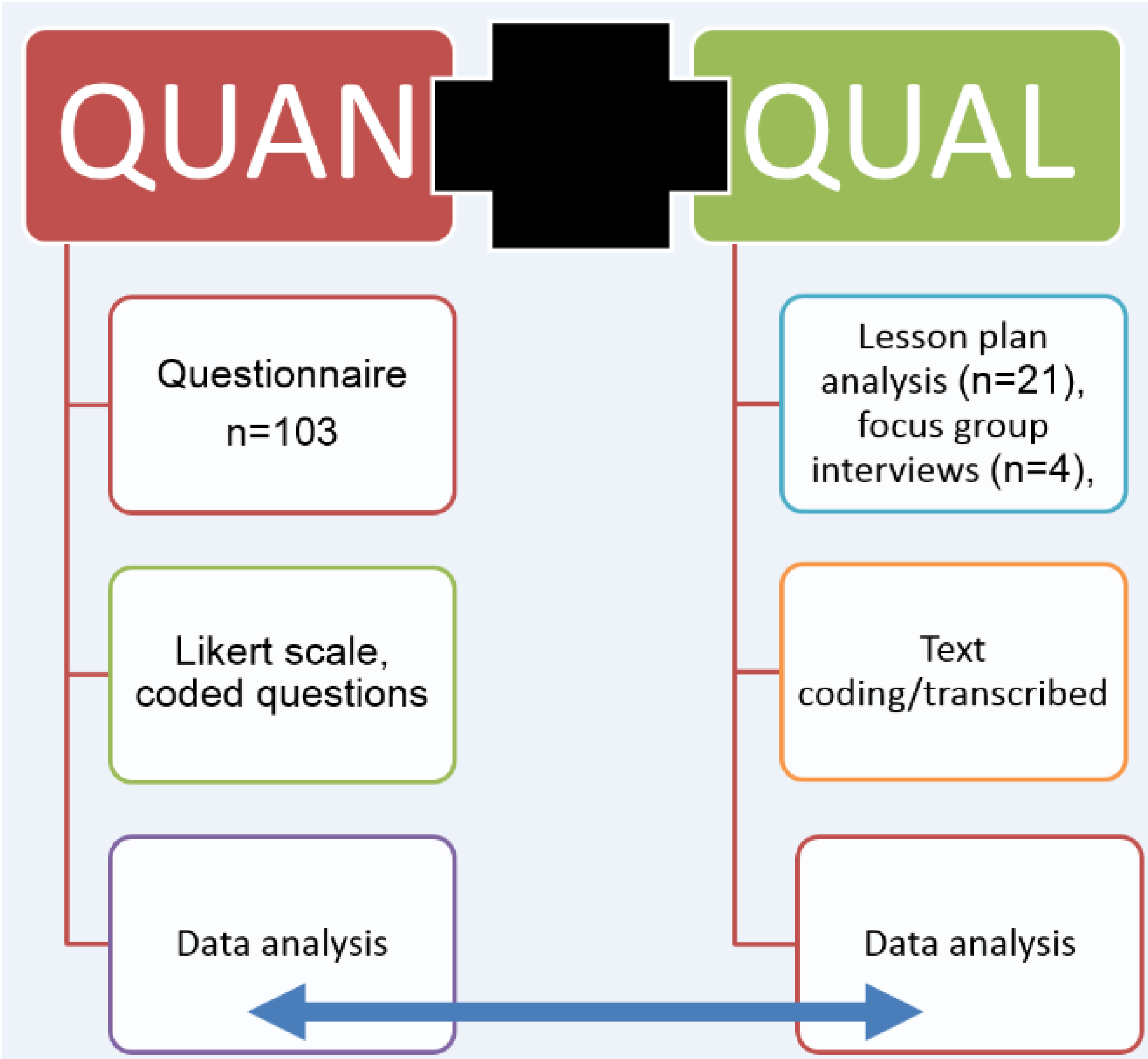


Figure 4: Mixed Methodology overview

As indicated in figure 4, for the concurrent design of the mixed methods approach, the “mixing” occurred at the data analysis and interpretation stages. That is, each data set was collected and analysed separately. It was then used to reflect on the other data (i.e. triangulation) in order to help answer the research questions posed in the study. The next two sections present the detailed quantitative and qualitative results from the case study.

### 4.3.1 Quantitative approach

The first group of questions in the survey questionnaire sought to solicit responses on the competency of pre-service teachers with respect to the use of ICT tools for teaching science. As defined earlier, competency refers to knowledge, skills and opportunities to learn about ICT tools and their use for teaching in general in addition to teaching science subjects in particular. The survey contained clusters of questions on which tools were taught to them specifically in each of the key modules related to the teaching of science at the university. Other question clusters included questions on how the tools were taught or demonstrated to them during lecturers, if and how the tools were used by their school-based mentors and finally what knowledge and skills the pre-service teachers themselves have of such ICT tools and how they used them during teaching practice, if they used them at all. I personally administered all the questionnaires to the students who participated in the study on the main campus and received assistance from one teacher educator on the Qwaqwa campus. The administration began with a group of 23 science pre-service teachers whose placement schools I was able to visit during the second teaching practice session. The second batch of approximately 80 questionnaires were administered in the lecture halls immediately after the second teaching practice session, during the last 15 minutes of their scheduled lecture period as negotiated with their teaching methods lecturers.

The quantitative data were cleaned, coded and entered into an Excel spreadsheet. It was then transferred by a qualified statistician, Robert Schall from the Statistical Consultation Unit of the University of the Free State into the Statistical Analysis System (SAS) software for analysis. The initial analysis was descriptive to report information in a variety of ways such as mode, mean, median, minimum and maximum scores, in particular for the demographic variables. According to Cohen *et al.* (2011: 606), "descriptive statistics describe and present data with no inferences or predictions". Descriptive statistics were calculated for all quantitative data completed by one hundred and three participants (N=103). The demographic information came from seven questions where participants were given a choice of selecting between the options describing their personal information and/or circumstances, with the first four questions used as control variables. The rest of the questions are reported either as part of the dependent or as independent variables. The dependent and independent variables used a five point Likert scale (scored from 0 to 4), with the five types of responses assigned as follows:

- **Question 9** required participants to indicate the source of ICT skills learned with the following options:
    - Not at all, was assigned a score of zero (0);
    - A little bit, was assigned a score of one (1);
    - To some extent, was assigned a score of two (2);
    - To a great extent, was assigned a score of three (3); and
    - A great deal, was assigned a score of four (4).

- **Question 10 to 48** required participants to respond to questions on TK (10-16), CK (17-22), PK (23-30), PCK (31), TCK (32-37), TPK (38-41), TPACK (42-44) and models of TPACK (42-48) domains with the following options: Strongly disagree, 0; disagree,1; neutral, 2; agree, 3; and strongly agree, 4 and

- **Question 49 to 52** asked for the approximate percentages of modelling by the mentors on TPACK, with the following options:
    - 0%-10% was assigned the score of zero (0);
    - 11%-25% was assigned a score of one (1);
    - 26%-50% was assigned a score of two (2);
    - 51%-75% was assigned a score of three (3); and
    - 76-100%, was assigned the score of four (4).

The Pearson's correlation coefficient and multiple linear regression were used to analyse questions on "TPACK exemplary models" **(Question 42 to 48)**, "Modules taken" (**Question 7 to 16**) and "TPACK model time scores" **(Question 49 to 52)**.

**Reliability and validity of the instrument**

The study largely used the TPACK instruments from the study of Schmidt *et al.* (2009) which has previously been checked for reliability by a number of other researchers. Leech, Barrett and Morgan (2015: 53) state that, "using existing measures that have already been tested indicates that the data are reliable and can help to increase the chances of the new data being reliable". The TPACK subject teaching-related research has extensively demonstrated the validity and reliability of the TPACK survey for pre-service teachers (Schmidt *et al.*, 2009). Several examples of studies that have used the TPACK survey as the accepted instrument that is valid and reliable were discussed previously in chapter 2 of this thesis.

To confirm the reliability of the instrument for our study even further, Cronbach's measure for internal reliability was calculated in order to determine the degree of reliability within the context of the present study. Leech *et al.* (2015: 53) argues that, "it is important to assess the level of reliability for new data sets". Thus, the new data for the present study used the Cronbach alpha coefficient to assess reliability for these domains: TK, CK, PK, TCK, TPK, TPACK and models of TPACK.

**Table 4:** Reliability statistics

| Domains | No. of items/variables | Cronbach alpha coefficient based on standardised variables |
|---|---|---|
| TK (technology knowledge) | 7 | 0.78 |
| CK (content knowledge) | 6 | 0.82 |
| PK (pedagogical knowledge) | 8 | 0.82 |
| TCK (technological content knowledge) | 6 | 0.76 |
| TPK (technological pedagogical knowledge) | 4 | 0.83 |
| TPACK (technological pedagogical content knowledge) | 3 | 0.75 |
| Models of TPACK (lecturers and teachers) | 4 | 0.54 |
| Total scale scores | 41 | 0.76 |

The PCK is excluded from the reliability analysis as it had only one variable that contrasts with the use of alpha, which is based on the average correlation of each item in the scale with every other item (Leech, *et al.*, 2015). The Cronbach alpha coefficients calculated for this data varied from a value of 0.76 – suggesting reliability – to a value of 0.83, which suggests high reliability. The only exception was the "Models of TPACK" domain for which the coefficient was 0.54 (see table 4). Cohen *et al.* (2011: 639-640) state that,

> Cronbach's alpha is a measure of the internal consistency and calculate a coefficient of reliability that can lie between 0 and 1 with the guidelines of >0.90 considered to be a very highly reliable score; 0.80-0.90 as highly reliable; 0.70-0.79 reliable; 0.60-0.69 minimally reliable and <0.60 should be considered unacceptable.

Therefore, measures of reliability for the seven domain scores indicate that the survey is reliable with a median alpha of α=0.76. Even though "Models of TPACK" had a low value of 0.54, which is less than 0.60, there is no question that could be identified whose removal would significantly increase the Cronbach alpha for the domain.

### 4.3.2 Qualitative approach

The qualitative data collection and analysis occurred concurrently with the quantitative data collection. In the introduction of the survey, the invitation also explained that the next stage of the study would request sample lesson plans and the participants were allowed to submit lesson plans at any time after completing the survey. All survey participants were invited to voluntarily participate in the second stage by submitting (a) lesson plan(s) they used during their teaching practice and participate in a focus group interview. The invitation to participate was also announced verbally by the researcher during the administration of the survey, followed by an email reminder and instant messages to participants from both campuses. The invitation was also announced on the learning management system (Blackboard) for the teaching methodology modules. The online announcement and email included a Doodle link for a scheduling system. Interested participants had to select a suitable time on a specified date from three given options. The invitations resulted in 21 volunteers who participated in the qualitative phase of the study (n=21), with each participant submitting a minimum of one lesson plan and a maximum of two lesson plans.

The collection of varying types of data aided in the triangulation of the data, validating its accuracy and building internal validity as well as construct validity. Data analysis allowed the researcher to answer the research questions regarding if ICT tools are commonly used by pre-service teachers during teaching practice, the patterns of use and how ICT's are used to teach science subjects in the classroom.

During the data analysis phase of the study, the researcher built internal validity through pattern matching, theme building and explanation building techniques. External validity was used to focus the theory for the single case study. Reliability was built using the first two strategies proposed by Yin (2014) out of the four general strategies suggested for the development of a case study database during data collection. The current case study used the following strategies as a guide:

Firstly, the study followed a theoretical proposition strategy that reflected the objectives of the study using research questions in the analysis of the data. For instance, the study took a pragmatic stance; therefore, it had to use cases where pre-service teachers apply technology knowledge during teaching practice. Lesson plans used during teaching practice serve as evidence on the practical applications of ICT tools during teaching practice in science teaching.

The second strategy proposed by Yin (2014) is that of working with data from the "ground up". In the current case study, the researcher noticed patterns that had showed up for the first time in the pilot study and was able to address them with the inclusion of the lesson plans (which had not been included in the pilot study with newly qualified teachers who do not use the university's prescribed lesson plan). Creswell's (2014: 197) suggestions involving the segmentation of data were used by blending them into the following steps.

1. Lesson plans collected from participants were immediately copied and scanned before returning them to the participants. Focus group interviews were recorded with a recorder and through written field notes.
2. Then data from lesson plans were captured into a MS Word document and then examined according to research questions with themes, codes or categories. Similarly, focus group interview data were transcribed into an MS Word document using field notes to backup information from the audio

recorder. Then “coding, and analysis of data intertwined continually, from the beginning of the study to its end" (Creswell, 2014: 413).

3. Open coding was used in the MS Word document to review ICT tools used in a lesson plan and how they were used during teaching practice. Emerging concepts and themes for analysis were generated from the focus group interviews.
4. The qualitative coding process continued to generate descriptions that built layers of the segmentation of the mixed methodology approach for each of the cases and its context (Creswell, 2014). In the current study, it is the case of pre-service teachers teaching science during teaching practice in different school contexts. Coding was done using CAPSLOCK for codes and different font colours as a highlighter of a code next to the text in a lesson plan.
5. The emerging themes and description were then further analysed by linking them to the research questions and to the analysis of the quantitative data.
6. The interpretation of the qualitative data was done with the “ultimate goal of unifying all data types so that they can be analysed as a single set” (Vogt, Vogt, Gardner & Haeffele 2014: 434). Each case was interpreted and represented in comparison to each other, in comparison with the literature and in comparison with the results of the quantitative data collection and analysis.

The qualitative data analysis was used as a concurrent triangulation strategy mainly to verify findings from the quantitative study, which are organised per research question (Creswell, 2014). Themes established and organised in the qualitative data analysis benefitted the validity of the study. The process of data analysis from quantitative to qualitative went back and forth in order to sort through subsequent data resulting from the concurrent mixed methodology approach. In the next section, I present the findings from the QUAN and QUAL phases of the data as necessary to answer the research questions.

## 4.4 Findings organised by research questions

Triangulation was utilised in the examination of data in a more comprehensive and integrated manner in order to answer all the research questions in the study. This was done through the analysis of the survey, 31 lesson plans and four (4) focus group interviews. The variables in a 5-point Likert style questionnaire were first coded in an MS Word document and then transferred into an Excel spreadsheet. The SAS software was then used for the statistical analysis, which was done by Professor Robert Schall from the Statistical Consultation Unit at the University of the Free State.

The qualitative data gathered from lesson plans and interviews were transcribed and coded for themes and patterns, in an MS Word document. The focus group interviews were conducted with 3-7 participants, mostly in the first week of August 2015 on the main campus of the university being studied. They were also done during the last week of September 2015 on the rural campus of the same university. The focus group interviews were conducted in the departmental boardroom or in the computer laboratory with each lasting approximately an hour per session.

In answering all the research questions based on the primary question "what are the competences of pre-service teachers in using ICTs to teach science content during teaching practice", data triangulation was important to improve the reliability and trustworthiness of the findings. The coding and categorisation of lesson plans and the electronically documented focus group interviews generated a number of themes and subthemes that reflected the findings for the following research questions.

### 4.4.1 Research question one

> What is the competency of science education pre-service teachers with respect to the various tools that are applicable for teaching science content in schools? (Competency examines the knowledge, skills and opportunities to learn or what is often captured as the "inputs").

Research question one is addressed through the data collected using the TPACK survey and the qualitative data collected from the focus group interviews. The TPACK survey is the first to be used to examine sources of ICT skills, knowledge areas and addresses the questions on opportunities to learn by the pre-service teachers. The analysis of the survey used the statistical program, SAS, to identify and average a number of variables for each knowledge domain (Schmidt *et al.*, 2009).

#### 4.4.1.1 Results for pre-service teachers' ICT skills

Competence of pre-service teachers in the use of ICTs was explored through the TPACK questionnaire and triangulation was done with focus group interviews. The TPACK questionnaire required final year pre-service teachers to indicate whether they completed any of the computer related modules during the teacher education programme and identify the applicable module in each case.

**Table 5:** Frequencies of computer related modules

| Variable | Category | *n* | (%) |
|---|---|---|---|
| Have you completed any of the computer related modules in your programme? | YES | 99 | 96.12 |
| | NO | 4 | 3.88 |

The results on whether participants completed computer related modules is presented in table 5 above. The table displays category, frequency (n) and percentage (%), with frequency counts indicating that the majority of students (n=99; %=96.12) had completed computer related modules and only a few (n=4; %=3.88) had not completed any computer related modules (table 5).

In the next question on the selection of modules, pre-service teachers were able to select all the modules that applied to them. Participants who repeated a module could select the same module in different years and a participant who had completed more than one of the computer related modules could select as many as was applicable. Table 6 below shows that the most frequently chosen module was "BRS111" with 74.76% followed by ICT111 and "Other" modules with 14.56%. ECL122 had the lowest percentage between the years 2009 to 2015. The reason for "BRS111" (Basic Computer Literacy) having a higher value may be influenced by the fact that it is a mandatory ICT related module for all undergraduate studies at the university and is offered by the Computer Science Department at UFS. The other two ICT related modules (ICT111 and ECL122) are only mandatory for intermediate phase pre-service teachers but are optional for FET pre-service teachers (phases with science subject teaching). The module with the highest frequency (BRS111) has no specific objectives that relate directly to the issue of developing the capacity of pre-service teachers to use ICT to teach but is more relevant to the university's goal of improving the undergraduate performance at UFS.

**Table 6:** Frequencies on where ICT skills are learned

| Modules taken | 2015 or 2014 | | 2013 or 2012 | | 2011 or 2010 | | 2009 or Before | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % |
| ICT111(Information & communication technologies) | 2 | 1.94 | 10 | 9.71 | 2 | 1.94 | 1 | 0.97 | 15 | **14.56** |
| ECL122 (Use of computers in the teaching context) | 7 | 6.80 | - | - | 1 | 0.97 | - | - | 8 | **7.77** |
| BRS111 (Basic computer skills) | 4 | 3.88 | 30 | 29.13 | **39** | 37.86 | 4 | 3.88 | 77 | **74.75** |
| Other: | - | | 1 | 0.97 | 10 | 9.71 | 4 | 3.88 | 15 | **14.56** |

*Frequency (n) and percentage (%)

To explore the sources of the pre-service teachers' skills and knowledge, that is where their ICT skills were learned, the Likert scale assigned "A great deal", (4); "Great extent" (3); "Some extent" (2); "Little bit" (1) and "Not at all" (0) to the options given.

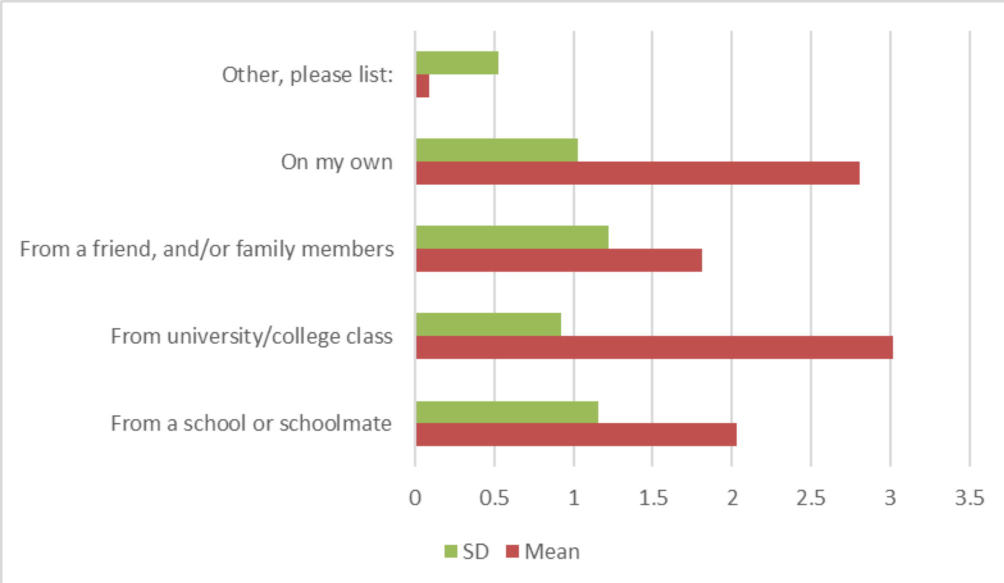


**Figure 5:** ICT skills sources

The graph in figure 5 shows the source with the highest mean being "From university" (M=3.02) followed by "On my own" with a mean of: M=2.81 while the unspecified other has a very low mean value of 0.09. The results were also confirmed in the focus group interviews when participants were asked, "what do you think prepared you more to start using ICT tools or resources in the first place?" The majority of responses identified the university as a source of their ICT skills. To illustrate, one of the participants explained as follows:

> I only started working on computers when I got to the university because of a lack of resources at my schools (Group one, 2).

Overall almost all the participants in the focus groups concurred that the university was a major source of their ICT skills, even those who had ICT skills background from schools confirmed that the university resources assists participants in polishing their ICT skills. Therefore, this observation confirms the argument that the teacher education programme plays an important role in equipping pre-service teachers with ICT skills competence (Twining *et al.*, 2013).

Whether that competence is adequate to enable them to teach using ICTs became the subject of further analysis in this study.

#### 4.4.1.2 Results from pre-service teachers' knowledge areas

To answer research question one I still needed to explore the following question "What is the competency of science education pre-service teachers with respect to the various tools that are applicable to teaching science content in schools?"

Competency examined the different components of the knowledge required to be competent to use ICTs in science (see the discussion of the knowledge domains as articulated by Harris *et al.* (2009); and Shulman, (1986) in chapter two of the present thesis) by calculating descriptive statistics for all seven TPACK knowledge domains and triangulating that with the qualitative data. For the descriptive statistical analysis, each of the seven (7) knowledge areas had a number of questionnaire items to which the participants had to respond. That is, TK had seven items (17-23), CK had six items (24-29), PK had eight items (30-37), PCK had one item (38), TCK had six items (39-44), TPK had four items (45-48), and TPACK had three items (49-51). The scale options assigned for each response were "Strongly disagree", 0; "disagree", 1; "neutral", 2; "agree", 3 and "strongly agree", 4. The descriptive statistics relating to the competency of the TPACK knowledge domains are presented in table 7 below.

**Table 7:** Descriptive statistics for TPACK scale with seven factors

| Knowledge area | Number of participants | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| TK | 103 | 3.02 | 0.47 | 1.86 | 4.00 |
| CK | 103 | 3.32 | 0.44 | 2.00 | 4.00 |
| PK | 103 | 3.18 | 0.45 | 2.13 | 4.00 |
| PCK | 103 | 3.05 | 0.58 | 2.00 | 4.00 |
| TCK | 103 | 2.70 | 0.60 | 1.00 | 4.00 |
| TPK | 103 | 3.15 | 0.56 | 2.00 | 4.00 |
| TPACK | 103 | 2.97 | 0.54 | 1.67 | 4.00 |

Table 7 displays the mean, standard deviation, minimum and maximum for the seven TPACK scales with three being non-technology related and four being technology-related scale scores. The mean scores of the non-technology related TPACK knowledge domains were the highest with means above three, that is CK (M=3.32), PK (M=3.18) and PCK (M=3.05), which were above the minimum score of 2.00. This is an indication that the participants regard content knowledge (CK), pedagogical knowledge (PK) and pedagogy content knowledge (PCK) as significant. The technology-related knowledge domains' mean scores were as follows: TPK (M=3.15), TK (M=3.02), TPACK (M=2.97) and TCK (M=2.70), which had the lowest mean score compared to the rest of the five mean scores. All the standard deviation scores were lower with no impact on any of the knowledge domains. The overall results of the seven TPACK knowledge domains (table 7) showed that pre-service science teachers perceive themselves as having adequate knowledge of TPACK.

To confirm the pre-service science teachers' competency in technology, content and pedagogy (TPACK) knowledge areas demonstrated in the descriptive analysis of the seven TPACK knowledge areas, each of the technology-related knowledge areas was analysed and triangulated with qualitative data analysis.

*Results for technological knowledge*

The seven questionnaire items for technological knowledge (TK) are displayed in table 8. Table 8 provides a break down categorised by the number of participants in each item, the mean, standard deviation, minimum and maximum score.

**Table 8:** Descriptive statistics for technological knowledge (TK) items

| Technological knowledge (TK) items | Number of participants | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| I can learn technologies easily. | 103 | 3.28 | 0.62 | 2.00 | 4.00 |
| I keep up with important new technologies | 103 | 2.92 | 0.76 | 1.00 | 4.00 |
| I frequently play around with technology. | 103 | 2.78 | 0.85 | 1.00 | 4.00 |
| I know about many different technologies. | 103 | 2.55 | 0.75 | 1.00 | 4.00 |
| I can teach using technology. | 103 | 3.25 | 0.62 | 2.00 | 4.00 |
| I am aware which ones of the technologies would work better for my science teaching | 103 | 3.14 | 0.56 | 1.00 | 4.00 |
| I can specifically teach science using technology | 103 | 3.25 | 0.64 | 2.00 | 4.00 |

Table 8 displays the questionnaire item on pre-service teachers' "ability to learn technology easily" with the highest mean score of (M=3.28, SD=0.62), followed by two questionnaire items with similar scores referring to whether they can teach with technology and specifically teach science using technology (M=3.25). The questionnaire item with relatively low mean scores for TK were about the participants' knowledge of different technologies (M=3.21, SD=0.85) followed by a low score of participants' opportunity to work with different technologies (M=2.55, SD =0.75). Overall, the technological knowledge survey data indicated an overall mean score of 3.02 with all individual items above the mean score of 2 which shows that pre-service teachers seem to have an average competence level to work with different technologies.

The analysis of the pre-service teachers' lesson plans also showed that only 6 (18%) out of 33 lesson plans had no evidence of technologies from basic technologies of paper and pencil to digital technologies of videos (see table 14).

Similarly, the focus group interview analysis further indicated that all reports provided evidence of TK. When participants were asked to describe how they had used ICTs during teaching practice, all pre-service teachers provided examples of how they used ICTs to prepare their lessons and specifically to enhance their knowledge of science concepts. The access to various technologies for lesson preparation was not an issue as they could even use their personal devices besides the ones in schools and on campus. Here is how two participants from different focus groups described it for us:

> I also use the Internet; hence, I said they did not have WiFi or data. I use my phone, my USB cable to search using the mobile device and stored the information to print at school. I also used a friend's laptop at the [university] hostel. Take to school for more copies, I printed one copy and printed more pictures at school (Group one, 3).

> I used the university computers and the Internet to prepare for the lesson and then used my mentor's laptop to teach (Group four, 15).

There were issues raised by each of the focus groups with TK (various technologies) related to access to technology resources available at the teaching practice schools and the technical difficulties encountered in teaching science lessons, specifically when having to conduct practical work. Another focus group participant put it as follows

> For example in one of the schools which I attended, the teacher was asking me to help connect the computer in class. Connections were not proper and I did not know how to help (Group one, 2).

Another participant reflected a similar challenge as follows,

> There is nothing there but there is something there at the same time. There is a computer lab of some sort, there are computers but it's the old models or something. It is meant to be used by the learners but they are not allowed to enter or access it but I don't know what the problem was. There is only one computer in the clerk's office, the secretary's, then one in the head of department for life sciences. That's it (Group four, 15).

The findings seem to suggest that although pre-service teachers have developed TK through the teacher education programme they still experience challenges in implementing and sharing knowledge during teaching practice due to a lack of access to resources at the schools.

*Results for technological content knowledge (TCK)*

To investigate pre-service teachers' technological content knowledge (TCK) competency as it applied during teaching practice, the TCK results on the six questionnaire items are displayed in table 9. The analysis of individual items for TCK showed all other items to be above the neutral value of 2, while the question of whether pre-service teachers know how to use audio and video was the only one above 3 (for agree). This seems to suggest that they were not sure of their competency in the use of other tools but were confident of their knowledge of using digital audios and videos (table 9).

**Table 9:** Descriptive statistics for technological content knowledge (TCK) items

| Technological content knowledge (TCK) items | Number of participants | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| I know how to teach science using Clouds e.g. Google drive, iClouds, draw box. | 103 | 2.26 | 0.95 | 0.00 | 4.00 |
| I know how to teach science using digital boards' e.g. Smart board, digital projector. | 103 | 2.98 | 0.91 | 0.00 | 4.00 |
| I know how to teach science using learning management systems e.g. Moodle, Blackboard. | 103 | 2.78 | 0.98 | 0.00 | 4.00 |
| I know how to teach science using Mobile devices e.g. cell phones, tablets, iPad. | 103 | 2.83 | 0.85 | 1.00 | 4.00 |
| I know how to teach science using online educational sites e.g. Mastering Biology, Big Brother series. | 103 | 2.44 | 0.87 | 1.00 | 4.00 |
| I know how to teach science using audios, and videos e.g. YouTube | 103 | 3.21 | 0.75 | 1.00 | 4.00 |

The results of the survey analysis were confirmed by the analysis of the lesson plans where only two of the ICTs identified in the TCK items were found. That is, the question of "I know how to teach science using audios, and videos e.g. YouTube" had the highest mean score (M=3.21) which was mostly used to introduce lessons and explain science concepts. The question of "I know how to teach science using digital boards e.g. Smart board, digital projector" came second in the data analysis with a mean score of M=2.98. These were identified as the overhead projector, slides and the projection screen to be used in class for teaching purposes.

Furthermore, the researcher asked participants about each specific ICT tool indicated in the TCK survey in the follow-up questions. For example, I asked participants to explain how they used this tool to teach science during teaching practice. Below is an extract from two participants from different focus groups who reported as follows,

> When you teach it is not that easy because some schools do not allow cell phones to be used in class (Group three, 9).

> I never attempted to use such because it was going to cost me data bundles to do all those things (Group four, 16).

The findings on TCK provide evidence that although the pre-service teachers are familiar with different ICT tools using them to teach science content has its own challenges. Participants pointed to barriers in using them to teach content or to a lack of knowledge on how to use them to deliver a science lesson.

*Results for technological pedagogical knowledge (TPK)*

The results from the analysis of the seven knowledge domains indicates that the TPK value (M=3.15) is the highest and is higher than the other domains (see table 7). To investigate TPK further, analysis of the four TPK items is displayed in table 10 below.

**Table 10:** Descriptive statistics for technological pedagogical knowledge (TPK) items

| Technological pedagogical knowledge (TPK) items | Number of participants | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| I am able to choose technologies that enhance my teaching approaches for a lesson. | 103 | 3.18 | 0.68 | 2.00 | 4.00 |
| I am able to choose technologies that enhance students' learning for a lesson. | 103 | 3.11 | 0.73 | 1.00 | 4.00 |
| I always think critically about how to use technology in my classroom. | 103 | 3.19 | 0.67 | 1.00 | 4.00 |
| I am able to adapt and use the technologies that I am learning about at university to different teaching activities. | 103 | 3.11 | 0.66 | 2.00 | 4.00 |

Table 10 presents results on the individual analysis of the constituent items that demonstrated the mean scores for all items to be above three. This indicated that pre-service science teachers have well-developed competency knowledge on how to use ICTs to enhance teaching approaches.

The analysis of the pre-service teachers' lesson plan and focus group interview data analysis supported the evidence that participants seem to understand how ICTs help individual teachers teach better. In the lesson planning form, ICTs were identified for their creativity under the question of "Creativity: What do you do in the lesson that is creative?" (See appendix C). In the focus group analysis, participants agreed that teaching with various ICTs improve their teaching approaches and accommodated learners with different learning abilities. One participant in one focus group explained:

> So I wanted something funny for them to actually relate to. If you see that with the kids, you also enjoy the lesson because they cooperate (Group one, 1).

Another participant from focus group two supported the same observation:

> A white board replaces a blackboard/chalkboard and it much more… is easy to clean and it makes the student feels like they are moving to somewhere into life, white board makes them feel they are entering a new dimension and now can learn better and they are easy to use. It makes them feels they learn better. A white board can also act as a white screen projection. The old blackboard cannot be multipurpose, serve as a projector and also has health risks such as dust for asthmatic people because of the use of chalk (Group two, 6).

The findings for TPK show that pre-service teachers know that using ICTs provides different teaching approaches and they are aware of the benefits thereof. The analysis of the TPK questionnaire items in table 10 and the responses on the interview questions suggest that pre-service teachers are knowledgeable about the fact that ICTs can support specific principles and teaching approaches in the classroom. What is unclear is whether they have the ability to select ICT tools that are relevant for each science pedagogical context such as selecting a specific ICT tool for collaboration in conducting an experiment or science inquiry.

*Results for technological pedagogical content knowledge (TPACK)*

The results regarding descriptive statistics for TPACK had the second lowest mean score (M=2.97) with TCK being the lowest mean score (M=2.70) (see table 7). Further analysis on the individual TPACK questionnaire items is displayed in table 11 below. Table 11 displays mean scores for all constituent items for TPACK to be above 2, which shows some ability or a neutral position in combining technical pedagogical and content knowledge.

**Table 11:** Descriptive statistics for technological and pedagogical content knowledge (TPACK) items

| Technological, pedagogical content knowledge (TPACK) items | Number of participants | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| I am able to teach lessons that appropriately combine science content with technology skills. | 103 | 2.98 | 0.70 | 1.00 | 4.00 |
| I am able to teach lessons that appropriately combine science content with different teaching approaches. | 103 | 2.97 | 0.55 | 2.00 | 4.00 |
| I am able to teach lessons that appropriately combine science content, technology skills and my teaching approaches. | 103 | 2.96 | 0.71 | 1.00 | 4.00 |

Consistent with the survey results, the pre-service teachers' TPACK as observed from the lesson plans and focus group interviews was poor. To examine the existence of TPACK in the lesson planning, the researcher used the question on "how ICT tool(s) were used" in the lesson planning form analysis presented in table 14. The results showed that only two lesson planning forms out of 33, explained the combination of technology, content and pedagogy. The two lesson plans addressed TPACK as follows:

> Use the video to demonstrate ventilation of lungs (concepts) (LP 13).
> Used a video to demonstrate one of the concepts (inhalation) (LP 26).

Furthermore, the participants in the focus groups confirmed being unable to implement the knowledge of TPACK, mainly due to constraints experienced in teaching practice schools such as a lack of ICT resources. Other scholars describe a similar scenario on the competence of many in-service teachers in South African schools who continue to lack the necessary competence to use ICT resources in their subject teaching in schools (Mlitwa & Kesewaa, 2013; Ndlovu & Lawrence, 2012). These findings appear to point at the schools as the common factor that needs to be investigated for in-service and pre-service teachers.

#### 4.4.1.3 Results from pre-service teachers' opportunities to learn

Research question one also seeks to provide answers on the development of competence in terms of the opportunities to learn that are available to the pre-service teachers. A question was asked about who models TPACK for the pre-service teachers. The models of TPACK were classified in two categories, first those that are provided by teacher educators (lecturers) from the Faculty of Education on campus, and lecturers from other service faculties on campus. Secondly, modelling that comes from the mentor teachers in the schools where teaching practice is done. The survey included 4 questionnaire items on TPACK modelling 1 (52-55), examining how science content, ICTs and teaching approaches are applied practically by lecturers and teachers in the teacher education programme and in the teaching practice schools. The scale options assigned for each response on TPACK modelling 1 were assigned as “strongly disagree”, 0; “disagree”, 1; “neutral”, 2; “agree”, 3; and “strongly agree”, 4 as the rating scales to be selected by participants. TPACK modelling 2 (56-59), which probed the amount of time involved in the modelling by the various models (to estimate the quantity of modelling involved) also included 4 questionnaire items which were assigned percentage scales to be selected by participants. The percentages scale options assigned were 0-10%, 0; 11-25%, 1; 26-50%, 2; 51-75%, 3 and 76-100%, 4.

**Table 12:** Descriptive statistics for TPACK models in teacher education programmes

| Opportunity to learn (OTL) | Number of participants | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Models_TPACK_1 | 103 | 3.07 | 0.53 | 1.50 | 4.00 |
| Models_TPACK_2 | 103 | 2.85 | 0.68 | 0.50 | 4.00 |

The descriptive statistics of the TPACK models of opportunity to learn (OTL) is displayed in table 12 with the number of participants per TPACK model, the mean, standard deviation (SD) and the minimum and maximum values selected in the survey being displayed.

Table 12 displays the mean for TPACK models 1 which is more than 3 (M=3.07) and suggests that participants agreed that lecturers and teachers were exemplary in combining content, ICTs and different approaches. At the same time, the mean for TPACK models 2 was less than 3 (2.85), suggesting that the amount of time available for modelling is perceived as being less than ideal or perhaps even inadequate.

**Table 13:** Descriptive statistics for TPACK model 1 & TPACK model 2 questionnaire

| TPACK model 1 | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| My science education lecturer(s) is (are) exemplary in combining science content, technology skills and teaching approaches in their teaching. | 103 | 3.38 | 0.67 | 1.00 | 4.00 |
| My lecturer(s) in the education-related ICT courses is (are) exemplary in using technologies in their teaching of the course. | 103 | 3.33 | 0.71 | 2.00 | 4.00 |
| My lecturer(s) in other education courses/modules is (are) exemplary in using technologies in their teaching of the courses. | 103 | 3.06 | 0.84 | 0.00 | 4.00 |
| My mentor teachers in schools (during teaching practice) are/were exemplary in combining science content, technology skills and teaching approaches in their teaching. | 103 | 2.52 | 1.06 | 0.00 | 4.00 |
| TPACK model 2 | N | Mean | SD | Min. | Max |
| Approximately what percentage of the time (in a semester/term) have your science education lecturers provided an example of combining content, technology skills and teaching approaches in their teaching? | 103 | 3.14 | 0.83 | 1.00 | 4.00 |
| Approximately what percentage of the time (in a semester/term) have your lecturers outside of teacher education (e.g. in the Humanities/Natural Sciences/Theology Faculties) provided an example of combining content, technology skills and teaching approaches in their teaching? | 103 | 2.82 | 0.90 | 0.00 | 4.00 |
| Approximately what percentage of the time (in a semester/term) has your lecturers in education-related ICT courses combined content, technology skills and teaching approaches in their teaching? | 103 | 2.96 | 0.83 | 0.00 | 4.00 |
| Approximately what percentage of the time (during the whole duration of your teaching practice) has your mentor teachers in the schools combined content, technology skills and teaching approaches in their teaching? | 103 | 2.48 | 1.09 | 0.00 | 4.00 |

Table 13 displays further exploration of each of the questionnaire items on each modelling experience (TPACK model 1 and 2). The results in both TPACK models had mean values of more than 3 (agree) and less than 4 (strongly agree) for questions relating to whether lecturers from science education, ICT related modules and other education models are exemplary in combining content, technology skills and teaching approaches in their teaching. The results show positive feedback. On the contrary, TPACK model 1 and 2 with questions relating to whether school mentors or teachers were exemplary in combining content, technology skills and teaching approaches during teaching practice had the lowest mean of 2.52 and 2.48 with a high SD of 1.06 on TPACK model 1 and 1.09 on TPACK model 2. This is an indication of skewed results. The latter batch of results thus needs to be interpreted with caution.

The qualitative data analysis from focus group interviews was used to confirm the findings of the quantitative data analyses through the interview questions. Data that related to opportunities to learn from the models of TPACK were inferred from responses to the following question:

- What motivated/demotivated you to use any of the mentioned ICT tools?

The responses to this question revealed that lecturers from campus and in-service teachers in schools motivate most students to use ICTs. A few participants indicated that they were motivated by the ways in which their lecturers taught them at the university. Thus, lecturers seem to be effective TPACK models for combining content, technologies and teaching approaches in a lecture hall. As a result of the influence from the teacher educators, the pre-service teachers wanted to apply what was learned in class into their own teaching situation thus confirming the notion of “apprenticeship of observation” as proposed by Lortie (1975). For example, one participant argued that:

> Lecturers on campus use video for presentations which motivated us to use videos and ICT tools in our own lesson presentations during teaching practice (Group three, 1).

In another example of a participant who was motivated by a teacher at the school, he mentioned:

> My mentor was pretty much good at using the computer for everything and I had to teach like him (Group three, 4).

A number of participants in each focus group pointed out how they were motivated or demotivated to use ICTs in school by the different conditions or situations in the schools. Here is a sample of what participants from different groups had to say.

> In the school where I was placed in, I would not real like to work there again. What demotivated me…I felt it was a long procedure before you could be entrusted with an ICT tool or Internet. It was not easy to be able to get access, to get the Internet because the principal was not approachable (Group one, 3).

> My mentor encouraged me to prepare my lessons at school and provided resources. I used the school's Internet to search and show learners videos on YouTube while the learners watched on the screen. For example I showed them different types of joints from YouTube (Group two, 6).

> Plus, the teachers did not give us study guides, the ones with the answers. And I asked the teacher to like help me to set the multiple choice or something that I'm going to give the learners but she didn't help me so I had to consult the Internet and stuff and do it myself (Group three, 14).

Further discussions on the interview question, "What would you ask for that you think schools need the most with regard to ICT tools?" revealed more information on how school contexts and mentor teachers may not have helped much to improve the TPACK knowledge of some of the pre-service teachers:

> I propose internal training of teachers in each of the school on how to use ICT. For example in one of the schools which I attended, the teacher was asking me to help. The teachers should be equipped on using ICT tools and should be able to use the computers. The problem is that even though some schools have computers but the teachers are unable to use these computers. Computers will just gather dust if teachers are not trained. One newly graduated teacher had to assist the other staff members in training. Teachers can share knowledge (Group one, 2).

According to the findings, pre-service teachers perceive their competence to be largely motivated or demotivated by the role of lecturers in the teacher education programme or on how mentor teachers use ICT to teach science subject in the schools.

The next set of findings relate to the patterns of use of ICT tools by the pre-service teachers during teaching practice.

### 4.4.2 Research question two

> Which ICT tools do pre-service science teachers commonly use during teaching practice? (What are the prevailing patterns of use of ICTs during teaching practice?

In order to understand which ICT tools pre-service teachers commonly used to teach science during teaching practice, an in-depth analysis of the survey was done concurrently with the analysis of lesson plans and transcripts of the focus group interviews. As discussed earlier survey data revealed TCK to be below average with the use of digital audio and video identified as the most common tools with an above average mean score (M=3.21) and the use of a digital projector came second (M=2.98). The survey data analysis was then triangulated with participants' lesson plans and focus group interviews.

The exploration of lesson plans and focus group interviews began early during the data collection and analysis stages of the study, as suggested by literature (Krippendorff, 1989; Cohen *et al.*, 2011). The lesson plans and transcripts were examined line by line to determine which ICT tools were mentioned in the lesson plans and during the focus group discussions. When considering the categories or themes of the data in a lesson plan, cross-reference is made to the responses from the focus group interviews (see appendix B). The use of different instruments allowed for the triangulation by “examining evidence from the sources and using it to build a coherent justification” on the commonly used ICT tools (Creswell, 2014: 201).

**Table 14:** Lesson planning form analysis

| Lesson plan | Phase (Grade) | Learning Area (Subject) | Which ICT tools are commonly used (RQ2) | How ICT tool(s) was (were) to be used |
|---|---|---|---|---|
| LP1 | SP (8) | NS | PowerPoint [OVPS] | Lesson presentation |
| LP2 | SP (8) | NS | Scratch Pad [MEDIA] | Not indicated |
| LP4 | IP (4) | NS | pictures, projectors [OVPS] | Lesson presentation |
| LP6 | SP (8) | NS | PowerPoint /pictures [OVPS] | Lesson Presentation |
| LP 7 | FET (11) | LS | Worksheet [APP] | Learner engagement |
| LP 8 | IP (4) | NS | Pictures [PRINT] | Learner engagement |
| LP 10 | FET (11) | LS | Images from the textbook copied [PRINT] | Lesson presentation |
| LP 11 | FET (11) | LS | Laptop and projector, video [MEDIA] whiteboard. [OVPS] | Lesson presentation |
| LP 12 | FET (11) | LS | Video [MEDIA] & projector [OVPS] | Lesson presentation |
| LP 14* | FET (10) | LS | Laptop and projector, hand out, chart [OVPS] | Lesson presentation |
| LP 18 | FET (10) | LS | Slides [OVPS] | Presentation |
| LP 19 | FET (10) | LS | Hand outs [PRINT] | Learner engagement |
| LP 20 | FET (10) | LS | Hand outs [PRINT] | Learner engagement |
| LP21 | FET (11) | LS | Word document/worksheet [APP] | Lesson presentation |
| LP 23 | SP (8) | NS | Projector [OVPS] | Lesson presentation |
| LP 25 | FET (11) | LS | Hand out [PRINT], Projector [OVPS] | Learner engagement |
| LP 26* | FET (11) | LS | Video [MEDIA] & slides [OVPS] | Lesson presentation |
| LP 28 | SP (7) | NS | Hand outs, pictures [PRINT] | Learner engagement |
| LP 30 | FET (11) | LS | poster [PRINT] | Presentation |
| LP 31 | FET (11) | LS | N/A | - |
| LP 32 | FET (11) | LS | Hand outs [MEDIA] PRINT] | Presentation |
| LP 33 | FET (11) | LS | N/A | - |

**Lesson plans with evidence of the combination of ICT tools with content and pedagogical knowledge domains discussed in research question 1(TPACK). Two lesson plans had nothing to report on this question and were thus assumed to have not used any such ICT tools.*

Table 14 displays an in-depth content analysis of the lesson planning form submitted voluntarily as part of the textual data sources by participants who had completed the survey. Information from each of the 33 lesson plans was recorded in an Excel sheet with no name identifiers in order to maintain anonymity. A table was then created with information that directly relates to research question two (see table 14).

Table 14 displays 33 lesson planning forms with only 19 (58%) that identified varied ICT tools in terms of levels of complexity. The use of printers, which was coded as [PRINT] and a data projector or overhead projector, screen, slides and PowerPoint presentations, coded [OVPS] were found to be the most common ICT tools highlighted in both the lesson plans and the focus group interviews. Interestingly, these tools were in the second place in terms of frequency in the survey analysis. The most commonly used ICT tools [OVPS] were used by pre-service teachers for class presentations, with information displayed either in text or in pictures and text. The remaining 14 (42%) lesson plans did not indicate any type of ICT tool being used. Surprisingly, only 5 (16%) less common ICT tools were actually used for learner participation in a lesson plan and these reveal advanced knowledge of TPACK which is the combination of technologies, content and pedagogic knowledge domains.

To find the most commonly used ICT tools, further analysis was conducted on the focus group interviews' transcripts and lesson planning forms. The focus group interviews were transcribed into an MS Word document, categorised into codes, given descriptions and the occurrences were counted. The Excel word sheet was used to graphical display the counting of the occurrences in the lesson planning form and interview questions as a way of cross-referencing the data for research question 2 (Yin, 2014). The face-to-face focus group interviews provided some form of reality check with participants giving details of the ICT tool(s) that were initially identified in the TPACK survey or in the lesson plan(s) on how they were actually used during teaching practice.

Table 15 below shows the frequency in the citations of ICT tools by participants in the lesson plans and during the focus group interviews.

**Table 15:** Frequency of ICT tools per participant and per lesson plan

| ICT tools | Number of times in which ICT tools were mentioned | |
|---|---|---|
| | per participant during the focus group interviews | per lesson planning form |
| Internet | 11 | 0 |
| Mobile technology | 6 | 0 |
| Projector | 8 | 8 |
| Printer | 9 | 9 |
| Multimedia | 15 | 5 |
| Standard applications | 2 | 4 |
| Computers | 6 | 3 |
| Interactive whiteboard (IWB) | 3 | 0 |

The evidence in table 15 seems to suggest that multimedia were most frequently mentioned, followed by the Internet (as a separate tool) – both tools were mentioned in all four focus group interviews out of 18 participants. Multimedia was mentioned 15 times in the focus group interviews while in the lesson plan they were mentioned 5 times. The Internet was mentioned 11 times as a basic tool for searching information during lesson preparation but it was not mentioned at all as an ICT tool for teaching science content. The tabulated evidence also demonstrates that printers and projectors were as commonly used as described in the focus group interviews and lesson plans. Further evidence indicates that printers might be readily available even in the schools with fewer resources. For instance, one of the participants reported as follows,

> Teachers handwrote the test and the tests were then photocopied. I also made one copy on campus and made more copies at school for my class (Group two, 4).

It is interesting to note that the use of mobile technology was commonly mentioned in all the focus group interviews as a common personal device used for lesson preparation and "enhancing knowledge". They were also used for communicating with peers but they were not mentioned at all in the lesson planning forms. For example, three participants in different focus groups explained as follows,

> I use my phone, my USB cable to search using the mobile device and stored the information to print at school and also used a friend's laptop (Group one, 3).
>
> I used an iPad to record a lecturer then played the recording during a lesson about atomic bombs during teaching practice (Group two, 4).
>
> I was using my tablet when I was at school (Group three, 8).
>
> I only used the computer labs to prepare the slides and save it to my phone (Group four, 17).

Table 15 displays a comparison of different types of ICT tool usage per lesson planning form and per participant in the interviews. The resulting evidence shows ICT tool for duplication of information to be the easiest to access as participants indicated that they copied from the Internet to their personal devices or repository device at the school where copies were multiplied with a printer. As one participant exclaimed,

> I copied as well for activities from Internet for 35 grade 4s in a classroom, and printed it out for the learners. I printed pictures and students shared copies (Group one, 3).

The interactive white boards (IWBs) are coded only in the interviews, not in the lesson planning forms. IWB were not mentioned at all in the 33 lesson plans and only mentioned by three participants in two (50%) focus groups as a tool that was used during teaching practice and as a beneficial tool for future science teachers. Participants who indicated they had used IWBs had this to say,

> I was using it when maybe I wanted to explain something and I feel like I have to write it on the board, I would use the whiteboard and the marker (Group four, 15).

Similarly, another participant explained that,

> I also use it to project my slides and also to elaborate on some points (Group four, 17).

The other focus groups did not mention IWBs as a tool that they had used but only raised it as a response to the following interview question:

> Which ICT tools or resources do you envisage yourself using more frequently in future as a science teacher and why?

Participants in group one supported a participant who explained the benefit of IWBs as follows:

> A white board replaces a blackboard/chalkboard and it much more… It is easy to clean and it makes the student feels like there are moving to somewhere into life, IWB makes them feel they are entering a new dimension and now can learn better and they are easy to use. It makes them feels they learn better. A white

> board can also act as a white screen projection. The old blackboard cannot be multipurpose, serve as a projector and also has health risks such as dust for asthmatic people because of the use of chalk. Cleaning chalkboard is a mission. Sometimes you can see it hard to remove yellow colour. Green colour can also affect eyesight for leaners (Group two, 6).

Despite IWBs being identified as more useful by the few in the focus groups others did not mention it as either available to use or as a future tool to be used in their teaching of science. The use of standard ICT tools such as MS Word documents and Excel sheets was used exclusively to prepare a lesson and for administrative purposes. The standard applications were pointed out as mostly used by mentors when the researcher specifically asked participants whether they have ever used the specific data management tools and how they have used them. Participants reported as follows:

> I have seen teachers use Excel to record information like test results. I used the Word document once that is when I was displaying the rules of the lab, I wrote them on the Microsoft Word and then I print them out and I displayed it in the class (Group four, 17).

> I used a Word document to set up the multiple-choice quiz and to assess the learners. Teachers used Excel for the attendance register (Group three, 7).

Notably, none of the ICT tools that were identified in lesson plans and focus group interviews was specifically for teaching science. It is also interesting to note that the use of multimedia such as videos, audio and YouTube were mentioned a number of times in the conversations in the focus groups and is mostly related to the teaching of specific topics. On the other hand, the use of other ICT tools such as the Internet was the second most commonly used tool (see figure 3). For example, these students pointed out in their focus group:

> I also used I used the school's Internet to search and show learners for videos on YouTube while the learners watched on the screen. For example I showed them different types of joints from YouTube (Group two, 6).

> I also used Internet and watched a video on YouTube on the process of photosynthesis. I was using my tablet when I was at school (Group three, 7]).

The use of videos to deliver science content seems to be a common ICT tool among pre-service teachers to enhance their knowledge. Therefore, the use of videos and audio can offer exciting opportunities for pre-service teachers in meeting their needs and those of learners during teaching practice (Hartsell & Yuen, 2006). This raises another question on whether multimedia such as video is the best ICT tool for teaching science content. I will return to this discussion in chapter 5.

### 4.4.3 Research question three

> How are the ICT tools used for teaching science during teaching practice? (For what purposes are they used and what are the methods of use)

The data sources for answering research question three were the participants' lesson plans, and narratives from focus group interviews. In the analysis of lesson plans, an Excel spreadsheet was used to record relevant details of each of the 33 lesson plans submitted by the participants. The question on "How ICT tool(s) were to be used" was added on the lesson plan matrix analysis as a theme to determine the (planned) use of ICT tools during teaching practice. Furthermore, the researcher considered it relevant to add a column with comments as part of detailing first impressions on each lesson plan in the initial coding (Creswell, 2014). The coding and categorising of themes in each lesson plan and among all the lesson plans was done several times hand-in-hand with coding and categorisation of explanations from the focus group interviews (Creswell, 2014). The lesson planning forms required pre-service teachers to “indicate which methods, activities, sources and educational media will be used with examples attached to the back of the lesson plan”. The types of ICT tools could thus be identified from the lesson plan documents under the headings of “source or educational media”. Then, the analysis of the examples that were attached to the lesson plans together with the narratives on how the “media” were to be used in the lesson gave a sense of how the tools were used by the pre-service teachers. Details on how the ICT tools or educational media were to be used varied and were described in different parts of the lesson planning forms.

In the four face-to-face focus group interviews, I used the following interview question to explore answers for research question 3:

> Could you describe how you used ICT tools to support your science teaching during lesson preparation, during lesson presentation, for class activities or homework during the teaching practice?

In addition, I posed questions that required of the participants to elaborate on how each of the ICT tools that were mentioned in the lesson plans or during the interviews were used during teaching practice specifically (see appendix B for the interview protocol).

The data revealed that most of the pre-service teachers used ICT tools to present information to the learners. The presentation of information to learners was either done digitally on an overhead projector or using a low level ICT such as a printer to make copies. From the lesson plans, only 58% of the lesson plans identified an ICT tool while all participants in the focus group interviews indicated that they had used either a low level or high level ICT tool. Participants in each focus group reported as follows:

> I used the Internet mostly for examples where I can come up with greater lessons, information and make posters to supplement the lesson (Group one, 3).

> The reason I used videos was when it came to the experiments there were no resources, so at least you had to go with them to make them see what happens, what affects photosynthesis and the amount of carbon dioxide how does it affect photosynthesis rates and those kind of stuff because we could not do it hands on (Group three, 7).

> When I arrived at school I saw that most of their resources for practical work were not enough. They did not have a Bunsen burner which they could use and also the beakers for all the learners. So I used the videos so that it would better their understanding, rather than if I was going to explain to them (Group four, 17).

In summary therefore, the lesson plans seemed to confirm the data from the focus groups that pre-service teachers still rely on traditional methods to teach even though they may draw on ICT tools for preparation before class. This resonates with the findings by other researchers who have argued that teaching in many classrooms has not changed much in recent decades (Cuban, 1986; 2013; Hiebert, & Stigler, 2000; Twenge, 2009). The findings of the present study reveal that what may have changed is the preparation for class, where pre-service teachers are competent in the use of ICTs to improve their understanding of science content to be taught but perhaps not the teaching itself.

### 4.4.4 Research question four

> How can the competences on ICTs and patterns of use be understood and explained?

Research question four was answered by first studying the correlations between TCK, TPK, TPACK, and competence to teach. I used the quantitative analyses to construct an explanation for the observed data on the pre-service teachers' perceived competences to teach through ICTs and the patterns of use that were discussed in the previous section. The analyses were performed using descriptive and inferential statistics. To understand and explain the patterns of use of ICTs in schools by the pre-service teachers, I investigated the extent to which the teachers' knowledge and skills or what I have referred to as 'perceived competence' could be explained by their opportunities to learn (OTL) that are offered to them in the pre-service teacher education programmes. Thus,, I examined the relationships between the pre-service teachers' OTL and their perceived competence to use ICTs for teaching science with the proposition that the better the OTL, the higher the perceptions of competence to teach using ICTs among the pre-service teachers will be. Therefore, the higher the chances that they will use the ICT tools in their own teaching of science during teaching practice.

The Pearson product moment correlation was used to determine possible relationships between the four variables (TCK, TPK, TPACK and competence to teach) where each item was examined individually and then correlated with the others to look for relationships between the variables. The Pearson's product moment correlation was used to determine the relationships between the dependent and/or independent variables to explain the pre-service teacher's use of ICTs to teach science during teaching practice instead of the Spearman rank-order correlation coefficient. The Spearman rank-order correlation coefficient is a non-parametric measure of association based on the ranks of the data values. It is robust to outliers and assesses how well the relationship between two variables can be described using a monotonic function. The Pearson correlation coefficient on the other hand assesses how well the relationship between two variables can be described using a specific monotonic function, namely a linear function. In the case of the present questionnaire, data gross outliers are not possible because the responses must lie between 0 and 5. Furthermore, because of the relatively high sample size, the Spearman and Pearson correlation coefficients were generally close to each other, so it was decided to report using the conventional Pearson correlation coefficient.

The exploration of the research question on the development of the necessary competence for pre-service teachers' to teach science subjects using ICTs through the teacher education preparation programme was measured by two aggregate variables in the questionnaire: viz. "modules taken" and by the variable "Models of TPACK" (lecturers and school-based mentors). The dependent variable or the concept of perceived competence to teach subject matter using ICTs is defined and measured by three sets of outcome variables: viz. competence on: TCK, TPK and TPACK. These are the three key components that according to the TPACK framework relate directly to ICT competence.

#### 4.4.4.1 Models for TPACK

The first set of specific questions used to explore correlations from the data is labelled as (a) follows:

- To what extent does the variable "Models of TPACK" (lecturers and school-based teachers) explain the pre-service teachers' perceived "competence to teach their subjects using ICTs" (i.e. competence on TCK, TPK and TPACK together)?
- To what extent do the "Models of TPACK" (lecturers and schoolteachers) explain the pre-service teachers' competence on each of the individual components of the composite concept of "competence"; i.e. TCK, TPK and TPACK?

**Table 16:** Pearson correlation coefficients (P-values), N=103. Models of TPACK exemplary

| Independent Variables | Dependent Variables | | | |
|---|---|---|---|---|
| | TCK | TPK | TPACK | Competence to teach |
| **V052** Science education lecturer(s) are exemplary in combining science content, technology skills and teaching approaches in their teaching | 0.15161 (0.1263) | 0.21409 (0.0299) | **0.32941 (0.0007)** | 0.28271 **(0.0038)** |
| **V053** Education-related ICT courses lecturer(s) are exemplary in using technologies in their teaching of the course | 0.14456 (0.1452) | **0.30960 (0.0015)** | **0.30192 (0.0019)** | **0.30787 (0.0016)** |
| **V054** Other education courses/modules lecturer(s) are exemplary in using technologies in their teaching of the courses | 0.11986 (0.2278) | 0.07551 (0.4484) | **0.30180 (0.0019)** | 0.20142 (0.0413) |
| **V055** Mentor teachers in schools (during teaching practice) are/were exemplary in combining science content, technology skills and teaching approaches in their teaching | **0.30349 (0.0018)** | **0.29213 (0.0028)** | **0.30154 (0.0020)** | **0.37008 (0.0001)** |
| a. Models of TPACK_1_Exemplary | **0.29779 (0.0023)** | **0.34961 (0.0003)** | **0.47859 (0.0001)** | **0.46039 (0.0001)** |

* Significant at $p < 0.05$

The values presented in tables 16, 17 and 18 display Pearson correlation values with p-values indicated in brackets. The results presented in table 16 indicate that in general there were moderate to moderately strong positive correlations between the TPACK exemplary variables and the four dependent variables of TCK, TPK, TPACK and competence to teach science with technology which define the aggregate of the TCK, TPK and TPACK together. The correlation between responses to the first variable (V052) (lecturer(s) being exemplary in combining science content, technology skills and teaching approaches in their teaching) and TCK was not statistically significant. The correlation between V055 (mentor teachers in schools [during teaching practice] are/were exemplary in combining science content, technology skills and teaching approaches in their teaching) with TCK is significant ($p<0.05$). The correlation between teachers' mentoring (V055) with all variables, TCK, TPK, TPACK and competence to teach was moderately high and had very low p-values. These correlations seem to suggest that pre-service teachers value the mentoring from teachers more during teaching practice even though they are less likely to observe the use of ICTs for teaching science from mentor teachers than from lecturers at university. The TPACK p-value was also very low which suggests that the integration of pedagogy, content and technology was rare from all TPACK models (i.e. university lecturers and school-based teacher mentors).

#### 4.4.4.2 Computer modules taken

The second specific set of questions for exploring correlations (labelled b) is as follows:

- To what extent do the "modules taken" explain the pre-service teachers' perceived "competence" to teach their subjects using ICTs" (i.e. competence on TCK, TPK and TPACK together)?
- To what extent do the "modules taken" explain the pre-service teachers' perceived competence on each of the individual components of the composite concept of "competence", i.e. TCK, TPK and TPACK separately?

**Table 17:** Pearson correlation coefficients, (P-values), N=103.Computer modules taken

| Independent Variables | Dependent variables | | | |
|---|---|---|---|---|
| | TCK | TPK | TPACK | Competence to teach |
| ICT111 module | 0.01606 (0.8721) | -0.18394 (0.0629) | -0.11496 (0.2476) | -0.11311 (0.2553) |
| ECL122 module | 0.08565 (0.3897) | -0.02831 (0.7765) | -0.02946 (0.7677) | 0.01436 (0.8855) |
| BRS111 module | 0.05028 (0.6140) | 0.01403 (0.8881) | 0.07993 (0.4222) | 0.05902 (0.5537) |
| Other module | 0.00837 (0.9332) | 0.07559 (0.4479) | -0.01185 (0.9055) | 0.02989 (0.7644) |
| b. Completed computer related module | -0.09519 (0.3388) | -0.03089 (0.7568) | -0.08316 (0.4036) | -0.08681 (0.3833) |

* Significant at $p < 0.05$

The modules taken displayed in table 17 shows that there were no significant correlations between computer modules taken and the variables TCK, TPK, TPACK and competence to teach. The modules taken by the pre-service teachers do not appear to tell us much about whether they are likely to be competent to use the ICT tools for teaching science. Conceivably, they can take and pass all the ICT related modules and still not be competent to use them during teaching (practice).

#### 4.4.4.3 Time taken

The following third group of questions were used to determine correlations with the amount of time involved in providing the required OTL and are labelled as (c):

- Does the amount of time spent on modelling by the "Models of TPACK" matter in terms of explaining the pre-service teachers' perceived "competence to teach their subjects using ICTs" [i.e. competence on TCK, TPK and TPACK together]?
- Does the amount of time spent on modelling by the "Models of TPACK" matter in terms of explaining the pre-service teachers' perceived competence on each of the individual components of the composite concept of "competence"; i.e. TCK, TPK and TPACK separately?

Pearson's correlations between each of the dependent and each of the independent variables allows one to assess ("one-variable-at-a-time") the association between potential predictors and pre-service teachers' perceived competence to teach science subjects using ICTs.

**Table 18:** Pearson correlation coefficients, (P-values), N=103. Time spent

| Independent Variables | Dependent variables | | | |
|---|---|---|---|---|
| | TCK | TPK | TPACK | Competence to teach |
| **V056** Approximately what percentage of the time have your science education lecturers provided an example of combining content, technology skills and teaching approaches in their teaching? | 0.2312 (0.0188) | 0.2098 (0.0334) | 0.3396 (0.0004) | 0.31980 (0.0010) |
| **V057** Approximately what percentage of the time (in a semester/term) have your lecturers outside of teacher education (e.g. in the Humanities/Natural Sciences/Theology Faculties) provided an example of combining content, technology skills and teaching approaches in their teaching? | 0.27035 (0.0057) | 0.20458 (0.0382) | 0.26486 (0.0069) | 0.30548 (0.0017) |
| **V058** Approximately what percentage of the time (in a semester/term) have your lecturers in education-related ICT courses combined content, technology skills and teaching approaches in their teaching? | 0.22338 (0.0233) | 0.24547 (0.0124) | 0.27716 (0.0046) | 0.30645 (0.0016) |
| **V059** Approximately what percentage of the time (during the whole duration of your teaching practice) have your mentor teachers in the schools combined content, technology skills and teaching approaches in their teaching? | 0.34328 (0.0004) | 0.19644 (0.0467) | 0.32503 (0.0008) | 0.35761 (0.0002) |
| c. Models_TPACK_2_Time scores | 0.36384 (0.0002) | 0.28373 (0.0037) | 0.40384 (<0.0001) | 0.43310 (<0.0001) |

*Significant at $p < 0.05$

Pearson's correlations in table 18 presents estimations of the "Models of TPACK" relationships with four dependent variables (TCK, TPK, TPACK and competence to teach) against five independent variables of time taken to model the use of ICTs to teach science. The Pearson correlation coefficient, r, can take a range of values from +1 to -1. Table 18 shows r-values with low to medium positive correlations with all values above 0, which is an indication that the association between dependent and independent variables does exist. They range between the highest value of r=0.35761 for V059 with “competence to teach” and the lowest correlation value of r =0.19644 for V059 with TPK. These results indicate a small (r=0.19644) to medium association (r=0.43310) that is closer to 0.5. R-values greater than 0 but less than 1 indicates a small positive correlation between pre-service teachers’ competence to teach and the time taken by “Models of TPACK” (lecturers and mentor teachers) to set examples on how to combine content, technology skills and teaching approaches.

The p-value results for the correlation between dependent variables (TCK, TPK, TPACK and competence to teach) and independent variables are all less than the significant level of 0.05 ($p<0.05$), which confirms that the correlation coefficients are significant. The highest p-value between V059 and TPK is (0.0467) while the lowest value is (0.0004) between V056 and TPACK. The results indicate that it is significant for lecturers and mentor teachers to take time to combine content, ICT skills and teaching approaches.

In summary, the analysis of the data shows that:

(a) There is a small positive correlation between pre-service teachers’ competence to teach and the “Models of TPACK” (see table 16),

(b) There was no correlation between dependent variables and modules taken (see table 17) and

(c) The correlation between dependent variables and the “Models of TPACK” time scores were all significant (see table 18).

The directional trend shown by the correlations indicates that the more lecturers and teachers use ICT tools to teach, the more pre-service teachers learn to use ICT tools in their own teaching. The ICT related modules taken have no significance in teaching them to use technology to teach science subjects.

#### 4.4.4.4 Multiple linear regression (MLR) analysis

Further analysis was done through multiple linear regressions in order to determine the relationships between the perceived competences of pre-service teachers to teach science subjects using ICTs and their OTL. Cohen *et al.* (2011: 663) describe multiple linear regressions as a statistical tool that "enable prediction and weighs the relationship between two or more explanatory independent variables and dependent variable" (TCK, TPK, TPACK and "competence to teach"). This was done through the measurement of the average scores of the questionnaire domains TCK, TPK and TPACK, which are regarded as dependent variables. Furthermore, the average of these three average domain scores was calculated and labelled "competence to teach". These four variables were considered as our dependent variables. Then, the joint relationship of three sets of independent variables with the abovementioned dependent variables was investigated.

The three sets of independent variables were defined as follows:

1. The "Models of TPACK" (scores for questions V052-V055 of the questionnaire and their average score labelled "Models of TPACK1").
2. "Modules taken", which are the binary variables ICT111, ECL122, BRS111 and Other (module taken "yes" versus "no").
3. The "Models of TPACK" time scores (scores for questions V056-V059 of the questionnaire and their average score labelled "Models of TPACK2").

Linear regression models were fitted with TCK, TPK, TPACK and "competence to teach" as dependent variables and the above three sets of independent variables to address the following specific questions that emerged from the primary question:

- To what extent do the “Models of TPACK” (lecturers and school-based teachers or mentors, together and separately) explain the pre-service teachers’ perceived “competence to teach their subjects using ICTs” (i.e. competence on TCK, TPK and TPACK)?
- To what extent do the “Modules taken” together with “Models of TPACK” (lecturers and teachers) explain the pre-service teachers’ perceived “competence to teach their subjects using ICTs” (i.e. competence on TCK, TPK and TPACK)? In addition, which of the two (when taken together) has stronger effects?
- Does the amount of time spent on modelling by the “Models of TPACK” matter in terms of explaining the pre-service teachers’ perceived “competence to teach their subjects using ICTs”?

The detailed results of the multiple linear regressions are presented in tables 16 to 18 for the four dependent variable (TCK, TPK, TPACK and competence to teach). Results from these linear regression models allow one to assess to what extent the independent variables are jointly associated with the pre-service teachers’ perceived competence to teach their subjects using ICTs.

Data analysis of each of the specific questions is presented in its own table and an explanation will be provided at the end of the table. SAS output (SAS, 2013) presents multiple linear regressions using the following:

- Pr>|t| – to represent the significance of the results. For this study, “statistically significant” is at a p-value $<0.05$. A p-value of $<0.05$ indicates there is a >95% probability the results are not due to chance.

**Models of TPACK on perceived competence to teach science**

The first multiple regression analysis investigated the relationship between "Models of TPACK" and all independent variables, V052, V053, V054 and V055 with the following question:

To what extent do lecturers and school-based teachers or mentors (together and separately); explain the pre-service teachers' perceived "competence to teach their subjects using ICTs" (i.e. competence on TCK, TPK and TPACK)?

**Table 19:** Models of TPACK_1_Exemplary as predictors of perceived competence to teach: Regression coefficients (p-values) for independent variables from multiple linear regression model

| Independent variables | Dependent variables | | | |
|---|---|---|---|---|
| | TCK | TPK | TPACK | Competence to teach |
| **V052** Science education lecturer(s) are exemplary in combining science content, technology skills and teaching approaches in their teaching | 0.06632 (0.4845) | 0.08617 (0.3132) | 0.14716 (0.0648) | 0.09989 (0.1384) |
| **V053** Education-related ICT course lecturer(s) are exemplary in using technologies in their teaching of the course | 0.06959 (0.4345) | 0.21160 (**0.0093*)** | 0.12606 (0.0913) | **0.13575 (0.0329*)** |
| **V054** Other education courses/modules lecturer(s)are exemplary in using technologies in their teaching of the courses | 0.02119 (0.7742) | -0.04928 (0.4585) | 0.10161 (0.1011) | 0.02451 (0.6391) |
| **V055** Mentor teachers in schools (during teaching practice) are/were exemplary in combining science content, technology skills and teaching approaches in their teaching | **0.15841 (0.0045*)** | 0.13913 **(0.0054*)** | 0.11976 (**0.0096*)** | **0.13910 (0.0005*)** |

*p<0.05,

The results presented in table 19 show variables V053 (education-related ICT course lecturer(s) to be statistically significant for TPK (p=0.0093) and "competence to teach" (p=0.0329). This suggests that a high score on V053 (education-related ICT courses lecturer[s]) predicts a high TPK score since the regression coefficients in the question are positive and the p-values indicate significance. Therefore, education-related ICT course lecturer(s) (V053) is a predictor of perceived competence to teach science with ICT. This seems to suggest that pre-service teachers learn more on using ICT from computer related module lecturers on how to combine technology and pedagogical knowledge (TPK) and thus have a better chance to contribute to the competence to teach. The results showed variables V055 regression coefficients with higher scores for TCK (p=0.0045), TPK (p=0.0054), TPACK (p=0.0096) and competence to teach (p=0.0005). All the dependent variables revealed statistically significant p-values for the V055 (mentor teachers in schools during teaching practice). This suggests that pre-service teachers are more likely to learn how to use ICTs to teach from mentor or in-service teachers in schools during teaching practice.

**Computer related modules as predictors of perceived competence to teach**

The second multiple regression analysis investigated the relationship between "computer related modules" as independent variables, ICT111, ECL122, BRS111, other modules and Models of TPACK with similar dependent variables of TCK, TPK and TPACK and "competence to teach". The following specific question was used for the analysis:

To what extent do the "modules taken" together with "Models of TPACK" (lecturers and teachers) explain the pre-service teachers' perceived "competence to teach their subjects using ICTs" (i.e. competence on TCK, TPK and TPACK)? Moreover, which of the two (when taken together) has stronger effects?

**Table 20:** Computer related modules as predictors of perceived competence to teach: Regression coefficients (P-values) for independent variables from multiple linear regression model

| Independent variables | Dependent variables | | | |
|---|---|---|---|---|
| | TCK | TPK | TPACK | Competence to teach |
| ICT111 module | 0.08955 (0.6949) | -0.36364 (0.0825) | -0.09382 (0.6208) | -0.12264 (0.4511) |
| ECL122 module | 0.28218 (0.2958) | 0.24530 (0.3181) | 0.11464 (0.6083) | 0.21404 (0.2655) |
| BRS111 module | 0.11750 (0.4874) | -0.12908 (0.4023) | -0.01805 (0.8976) | -0.00988 (0.9346) |
| Other modules | 0.07099 (0.7044) | -0.00451 (0.9789) | -0.07477 (0.6304) | -0.00277 (0.9834) |
| Models_TPACK_1 | **0.35276 (0.0022*)** | **0.35014 (0.0009*)** | **0.48628 (<.0001*)** | **0.39639 (<.0001)** |

*p<0.05 is significant

Table 20 displays the results with all independent variables for modules (ICT111, ECL122, BRS111 and Other modules) and does not show a statistically significant relationship for the perceived competence to teach with technology with all p-values being above 0.05. The results for the independent variable "Models of TPACK" had an opposite effect where the results reveal a statistically significant relationship for all the dependent variables. This suggests that "Models of TPACK" (lecturers and teachers) are exemplary in developing competence to teach with ICTs for pre-service teachers.

**Models_TPACK_2_Time scores as predictors of perceived competence to teach**

The third multiple linear regression analysis investigated the relationship between "Models of TPACK 2" with these independent variables, V056, V057, V058 and V059. The analysis focussed on the following question:

Does the amount of time spent on modelling by the "Models of TPACK" matter in terms of explaining the pre-service teachers' perceived "competence to teach their subjects using ICTs"?

**Table 21:** Models_TPACK_2_Time scores as predictors of perceived competence to teach: Regression coefficients (p-values) for independent variables from multiple linear regression model

| Independent variables | Dependent variables | | | |
|---|---|---|---|---|
| | TCK | TPK | TPACK | Competence to teach |
| **V056** Approximately what percentage of the time (in a semester/term) have your science education lecturers provided an example of combining content, technology skills and teaching approaches in their teaching? | 0.0357 (0.6795) | 0.0667 (0.4256) | 0.1484 (0.0528) | 0.0836 (0.1930) |
| **V057** Approximately what percentage of the time (in a semester/term) have your lecturers outside of teacher education (e.g. in the Humanities/Natural Sciences/Theology Faculties) provided an example of combining content, technology skills and teaching approaches in their teaching? | 0.0759 (0.3983) | 0.0015 (0.9861) | -0.0196 (0.8030) | 0.0193 (0.7720) |
| **V058** Approximately what percentage of the time (in a semester/term) have your lecturers in education-related ICT courses combined content, technology skills and teaching approaches in their teaching? | 0.0427 (0.6179) | 0.1152 (0.1667) | 0.0905 (0.2307) | 0.0828 (0.1933) |
| **V059** Approximately what percentage of the time (during the whole duration of your teaching practice) have your mentor teachers in the schools combined content, technology skills and teaching approaches in their teaching? | **0.1503 (0.0074*)** | 0.0605 (0.2577) | **0.1106 0.0240*** | **0.1071 (0.0098*)** |

*p<0.05 is significant

The results in table 21 had only one variable, V059, which significantly contributed to pre-service teachers' competence to teach their subject with ICTs for TCK, TPACK and competence to teach. This suggests that mentor teachers in schools are perceived as the models for the combination of technology and content knowledge (TCK), combination of the integration of technology, pedagogy and content knowledge (TPACK) and competence to teach.

#### 4.4.5 Research question five

What suggestions for improvement can be made regarding the development of competence and use of ICT tools for the teaching of specific subjects, for example science?

An important part of answering the stated research question was addressed through structured focus group interviews to give an opportunity for pre-service teachers to express themselves in their own words, specifically sharing insights on their practical experiences during their teaching practice in schools. The pre-service teachers had experienced teaching practice for at least four weeks in each of the four years in the teacher education programme (B.Ed.) or for four weeks in the one year teacher education programme (PGCE). The data emerging from the analysis of transcripts with pre-service teachers' suggests a way forward for the development of competence and future use of ICT tools for the teaching of science content in particular. The ideas shared across the four focus groups are summarised into four major themes namely:

- ICTs communities of practice
- Mentoring
- Lack of learner engagement
- Curriculum alignment

#### 4.4.5.1 ICTs communities of practice

This theme concerns the use of ICTs to share information and communicate with one another in order to support the effective teaching of science content. It is interesting to note that one emergent theme is about how ICTs can be used to promote collegiality among pre-service teachers. The suggestions and recommendations about ICTs more often involved reference to shared ideas and common experiences. There were no conflicting ideas in any of the focus group interviews and across the different focus groups. However, individual opinions were expressed but much of the talk centred on the opportunities and challenges experienced during teaching practice and the contributions of ICT use.

One aspect that all interviewees agreed on was that they all use ICTs for communication amongst themselves and with their mentors. They all agreed that ICT tools are most effective in engaging through concept clarification or for providing additional information on difficult science topics and for the sharing of resources in general. Several participants provided some examples to illustrate the use of ICTs for communication and/or building and sustaining learning communities among themselves and their mentors:

> I also emailed or SMS (instant messaging) one of my peers to answer some of the questions I did not understand (Group two, 4).

One participant further credited the considerable capacities of email as a tool that can be used to communicate with “oneself” as a form of backing up information:

> It is also useful to email yourself the information as a form of storage (Group three, 8).

Across all focus group interviews, the participants agreed that WhatsApp was the best and most commonly used tool amongst them during teaching practice. One participant put it as follows,

> I remember we created a WhatsApp group of which we called it Lebohang* Secondary, where we discussed issues like, how was your lesson today, things that you experience (Group four, 17).

Equally, the use of social media ICT tools can also contribute to collegiality and the development of competence among pre-service teachers. For example, one participant shared this scenario where they learned from each other:

> A student posted a picture of a learner sleeping while he was presenting physical science. There were comments like "Teacher, you are not doing very well, which approach is that?" and others gave positive comments about the content he was presenting and importance of class activities" (Group four, 15).

All participants agreed that the use of social media indirectly contributed to their development and even pointed out that their mentors also used these tools to interact with them and with their learners. One participant gave the following example:

> My mentor posted pictures of class activities, life science models and important notices on Facebook. Though, he needed to repeat those announcements, by telling them in class again that "I have placed a picture or notice like this and this on Facebook, since some of the learners don't have access to Facebook" (Group four,14).

In summary, although not all the participants engaged in the ICT learning communities, they all appreciated the way ICT tools helped develop their competence in teaching science content and the potential for building communities of learning. This resonates with what other researchers have suggested; that the use of ICTs depends on affordance and competence to engage in communication acts (Cleaves & Toplis, 2008; Garrison, 1993; Wang, 2009). In this case, pre-service teachers needed to have data bundles, personal devices or access to ICT tools such as Internet and personal interest to engage with others in these communities of learning.

In contrast, communities of practice can develop through the approach used by pre-service teachers to present their lessons with ICT tools through the involvement of others such as learners, subject colleagues, peers and school colleagues. In the discussion on research question two, it emerged that the most commonly used ICT tools were mainly those for the presentation of information. Most participants regarded the presence of these ICTs in schools as an indication of whether a school is well equipped. One participant stated that her teaching practice school "was basically chalk and talk" and further pointed out that she had to,

> Use the university resources to get posters because the school had no Internet access, no overhead projector… (Group two, 4)

The discussion in the focus groups often involved reference to individual use of ICT, not so much the shared experiences with the learners. Participants used "I" throughout their response in description of how ICT tools were used during teaching practice. There was no identity of "I and the learners" or "we during the lesson in class". The individualistic and teachers-led approach to the use of ICT tools is revealed from the beginning of the planning stage in the lesson planning forms throughout the reflections. For example, one participant mentioned that,

> If I am preparing a lesson, and don't have much knowledge for the subject I used the Internet to research information for more knowledge using a phone and the university computers about different topics to enhance my knowledge. I copy, as well, activities

> from Internet for 35 grade 4s in a classroom, information and printed it out for the learners. Printed pictures and students shared copies (Group one, 2).

All participants reflected on how they use ICTs to prepare for a lesson and none of them pointed out the description of how they teach science lessons with ICTs. It was either they use a projector or distributed copies of papers to the learners while they seemingly continued with the use of traditional methods of teaching (Cuban, 1986; 2013; Hiebert, & Stigler, 2000; Twenge, 2009). Explanations were mostly based on the use of mobile technology and personal data preparation of lessons and using university resources to enhance their teaching. Even in well-resourced schools, ICT usage in schools mostly involved learners observing from projectors and computers while ICTs such as the Internet was for the exclusive use of the teachers. Thus, the patterns of use seem to be lacking in the aspect of community engagement and all learners seem not to be active participants in their own learning. Even in their suggestions, pre-service teachers opposed the idea of giving ICT access to learners. One participant argued as follows,

> The only disadvantage that I saw with us as learners (when she was still in school) was that while the teacher was teaching CAT, we had access to the computers so, I would open anything that I wanted and when the teacher came, I would close it. So, I don't think it is wise to give the learners full access. They should restrict or have an overhead projector so that only the teacher can access the computer because, if you have your own computer it is then that you are going to play games while the teacher is teaching (Group three, 13).

One participant from a different focus group had a similar view about giving learners access to the devices:

> We do not really have to give them individual resources such as tablet. Eish! It is not safe for children to own tablet, there are criminals out there (Group one, 1).

Only one participant, out of 21 interviewees, shared a scenario where learners could use ICTs to learn. The participant relayed an instance where s/he advised learners to:

> take photos of scientific apparatus or models used in class so that they can use pictures to recall concept learned and to record notes on their cell phones when preparing for a test and maybe listen to them on their way to school (Group three, 7).

This example supports the many arguments made by other researchers that ICT tools can contribute to the improvement of learning in critical subjects such as science (Cleaves & Toplis, 2008; Holden *et al.*, 2008; Kisalama & Kafyulilo, 2012; Van Rooy, 2012).

#### 4.4.5.2 Mentoring capabilities

The analysis investigated the environment in which pre-service teachers do their teaching practice and their relationship with mentors. Do the schools and mentors during teaching practice render opportunities for contributing to the development of ICT competence for the teaching of science subjects? The discussion on this theme raised the issue on the importance of a conducive physical classroom environment, socio-economic status and educational contexts for the usage of ICTs in schools. This discussion was driven by the following interview questions:

- Briefly, tell us about the ICT situation in the teaching practice schools?
- Were there ICT resources in the schools where you did your teaching practice?
- Were there any restrictions on teachers or student teachers on the use of these resources?

Science lessons typically take place in well-resourced laboratory areas where science resources such as models, apparatus and chemicals will be stored including ICT tools such as overhead projectors and computers. This could lead to a better quality education where learners have a conducive learning space. All pre-service teachers dream of such a teaching practice environment but only a few get to work in such ideal environments. Many of the pre-service teachers indicated their disbelief regarding the reality that hit them during teaching practice. Participants shared their experiences on the ICT access issues in the teaching practice schools. For example, one participant explained as follows,

> In terms of ICT, ehh, I'm not sure, because the places I've been to was only the staffroom and the classes. So, I've never used any ICT. They said they have a laboratory but I'm not sure if they have computers. They did mention that they have a science lab, because by the time I wanted to use the models, I was able to access the models, but I have never seen the lab or the computer labs. The models were collected for me (Group three, 11).

In contrast, there were schools in the same province that had no access problems at all:

> The resources were similar to that of student 5 school, each classroom is also fitted with a smart board. Well resourced. For example, we had a full digital skeleton model that could be assembled (Group two, 6).

In many schools, ICT tools such as an overhead projector were not easily accessible for them to use in the classroom. They had to go through a process to be able to access the ICT tools. As one participant in another focus group reported,

> They said that there was a computer lab but I have never saw it. In the life sciences lab there is not even a single computer in there. So, I only used the class to present a lesson to the learners and I didn't even use a computer (Group three, 11).

In contrast, three participants out of 21 had done teaching practice in the past four years in well-resourced schools and could not imagine what it would be like to work in an unfavourable environment. It is striking to note that some pre-service teachers understand that it is the norm to work in an unfavourable environment, as one participant noted,

> You know what, I think it…is difficult for township schools to get access to ICTs because they are government schools, they do not pay school fees and parents have no money. Everything they depend on the government and government take time to fund. There was no ICT tools for the learners and teachers but they were available for the administration staff (Group two, 4).

Differences between science lessons in a conducive environment with ICT tools compared to those that were characterised by “chalk and talk” could be clearly identified in the voices of pre-service teachers’ suggestions regarding the conditions that contribute to their competence in the use of ICTs. Most participants suggested that schools with access to the Internet would be more conducive to learning and developing expertise to use ICTs for teaching. Equally, other participants had to put in extra effort in creating a conducive environment despite all the odds by using their personal devices. As a participant remarked,

> Though there were limitations, with the use of Internet or ICT resources, it kept me going because at the end of the day I was for doing it for the learners (Group one, 1).

All participants in the study had their teaching practice in public schools but the situation analysis of schools differed and how individual participants handled the situation also differed. For example, one participant’s experience was as follows:

> The situation was very much bad in that other school because they do not have much resources comparing to the last school I did my teaching practice. They do have a computer lab but it is not accessible, it is always locked. They do have

> projectors but they said to us we will not be able to use projectors, since their walls are a little bit darker and also there are some stuff on the walls, so they say we must rely only on the textbooks and some additional sources. My friend used his own projector but when he was projecting nothing appeared there. It was disruptive or distracting to the students (Group Four, 17).

It seems that improvement in the development of pre-service teachers' use of ICTs to teach science during teaching practice is one task that still needs to be prioritised in teaching practice and in engagement with the school situation. Analysis is needed in order to ensure that all pre-service teachers get equal opportunities to learn or practice ICT skills in a conducive environment.

Equally important in the explanation and understanding of how pre-service teachers use ICTs is the mentoring relationship in the schools. Most of the conversations with pre-service teachers centred on the relationship with mentors or in-service teachers during teaching practice. Two participants had positive reports regarding their mentors.

> In my situation, I just consulted the mentor and I had all the access, even the Internet, everything to prepare for my lessons (Group three, 13).

> My mentor was pretty much using the computer for everything. I had to do the same (Group four, 15).

Much of the talk centred on how mentors did or did not give them access to ICTs at the school. It became clear from the conversations that the relationships with mentors can either motivate or demotivate pre-service teachers and contribute to explaining how ICTs are used (or not) during teaching practice. According to some of the participants, the relationship with a mentor can affect personal reputation and contribute to the poor presentation of subject content. One participant shared the following experience:

> The mentor should tell me or give me orientation on how to use a pointer for example, not in front of the learners because that would make me feel inadequate for the rest of the class presentation and I would not want to use that thing again. Learners would be like you are going to teach us but you do not know how to use that? (Group two, 6).

In summary, pre-service teachers' use of ICTs seems to be shaped by the nature of the relationship with their mentors and the teaching practice school environment. As argued by other researchers, pre-service teachers are mostly native immigrants of ICTs but there is a change when they have to teach, they become dependent on others such as mentors (Wentworth, Graham & Tripp, 2008).

#### 4.4.5.3 Lack of learner engagement

Learner engagement focuses on the extent to which ICT usage is linked to specific subjects and accommodates learners of different abilities to participate in the activities. Teaching science using ICTs is acknowledged for addressing difficult science concepts and for being able to address learners' challenges in understanding complex experimental work. The participants addressed the issue of engaging learners in the lesson when they were asked what motivated them to use ICT tools when teaching. Most of the participants' responses were centred on the delivery of effective lessons that not only benefitted individual learners but also included learners of different abilities. One participant highlighted how teaching with ICTs benefits learners with disabilities. The participant explained as follows:

> Remember we have visual, auditory learners, learners who see things when there is movement. So with the computer and a projector, all of those things are incorporated; the movement, the sound, the visuals. If I teach learners maybe about matter, for example, you can call learners to come and select solid, gas, liquid from the pictures they see on the screen with an audio, maybe to enforce

> performance in a computer, we can have cartoon, games in a computer. You can call Thabo, Sipho to come to touch the screen or use a mouse as a pointer. Computers can be used as modem with CDs and DVDs even without Internet (Group two, 4).

Teaching with ICT tools also helps learners visualise practical work that would have been difficult or impossible to conduct in a classroom and more difficult for pre-service teachers to organise within the teaching practice period. For example, one participant explained as follows,

> I think for me what motivated me the most was, I was teaching about blood circulation but before you start you were supposed to do a practical on dissecting a sheep's heart, now because we couldn't get hold of a sheep's heart and what not I decided to download a video where they were showing how to dissect a sheep's heart (Group four, 15).

In this case, it would be very expensive and messy for a teaching practice school to kill an animal for an experiment in life sciences and perhaps for some it would be a case of cruelty to animals. The use of videos to teach such an intense topic helps learners to visualise a real situation that would have just been narrated if only traditional teaching methods were used. The use of ICT tools such as videos to teach science content could even be shared with learners for later viewing in order to enhance their individual learning beyond the classroom experience. Learners could then be able to engage with the lesson at their pace and even accommodate learners with different disabilities.

Participants also raised their concerns about the lack of apparatus in the teaching practice schools where the use of ICT tools came in handy for conducting experiments. One participant shared his views as follows,

> The other challenge is because I was doing practical work, learners were supposed to do science not observe science. I think that this is the first challenge

> because they will not have that much background on how to conduct an experiment for themselves (Group four, 17).

Hartsell and Yuen (2006) maintain that the primary advantage of multimedia such as videos is the ability for learners to self-pace their learning, especially when used to support and enhance science learning. Videos can provide an active support when used for activities such as demonstrations on how to conduct an experiment while learners perform hands-on in their own classrooms. The hands-on practical work will then support and be supported by what is viewed in the video, instead of it being used as an alternative approach to practical work. Participants argued that the use of ICTs has contributed to deepening the learning of science content with some real engagement during lesson preparation and lesson presentation.

#### 4.4.5.4 Curriculum alignment

There are many examples of ICT tools that can be used for teaching science content such as natural sciences, life sciences and physical sciences. The various ICTs however, need to be modelled for pre-service teachers in the teacher education programme and at the teaching practice schools. In the current study, the TPACK model survey revealed that methodology lecturers were exemplary in the use of ICTs to teach methodology course content including the lecturers of computer related courses and other modules in the Faculty of Education. The modelling of TPACK by lecturers or teacher educators was also supported by the mean scores of more than a value of 3 (table 12 [M=3.07] and detailed analysis in table 13). The response to the interview questions continued to confirm a similar notion reflecting pre-service teachers' high confidence in teacher educators (lecturers) at the universities as exemplary in their use of ICTs. When asked, what do you think prepared you more to start using ICT tools or resources in the first place?

Participants highlighted that the university has contributed to their learning to use ICTs by providing resources such as exemplary lecturers, computers and data bundles. For example, two participants in different groups stated the following,

> I only started working on computers when I got to the university because of a lack of resources at my schools (Group one, 2).

> I just want to put an emphasis on what student #9 said, even the majority of us we came into the university without having the skills on how to use computers (Group three, 7).

In contrast, participants expressed reasons for not using ICT tools such as a lack of resources in schools and a lack of knowledge among in-service teachers or mentors on how to use ICTs. A few argued that the situation during teaching practice is similar to the experiences they had as high school learners just a few years prior (approximately 4 years prior). The other participants argued that many ICTs were available in their mentoring school but the in-service teachers and they themselves as pre-service teachers faced a dilemma of not knowing how to operate them and thus had no interest in attempting to try. For example, one participant reported her experiences at school as follows,

> I think the other thing is that teachers do not have an interest in using computers at the school or they are not well informed about IT (technology) (Group three, 12).

One participant even suggested that the teachers needed more training when saying

> I propose internal training of teachers in each of the school on how to use ICTs. For example in one of the schools which I attended, the teacher was asking me to help. The teachers should be equipped on using ICT tools and should be able to use the computers. The problem is that even though some schools have

> computers but the teachers are unable to use these computers. Computers will just gather dust if teachers are not trained. In one of the schools where I did teaching practice, learners were provided with tablets but teachers did not know how to use them (Group two, 4).

Previous research has also revealed that ICTs are good for enhancing learning across all curricular subjects and that pre-service teachers therefore need to demonstrate competence and skills in ICTs (DoE, 2004; Wilson-Strydom & Thomson, 2005). Furthermore, we know that even while many teachers have been trained to use ICTs modelling their use in teaching critical subjects such as science has not been as successful (Niess, 2005; Mlitwa & Kesewaa, 2013; Ndlovu & Lawrence, 2012; Luan *et al.*, 2005). The point therefore is not that more training is required but a different kind of training that involves modelling the actual use of the ICTs and alignment with the curriculum. An approach should focus on aligning curriculum with teacher training for both pre-service teachers in the teacher education programmes and in-service teachers in schools.

## 4.5 Summary of the chapter

The chapter on the findings provided a presentation of the results from the mixed methodology case study research. The purpose of the study was to determine the pre-service teachers' competence in teaching science using ICT tools during teaching practice. The design allowed for in-depth analysis and findings on the five major guiding research questions. The results suggest that the use of ICT tools during teaching practice in schools is dependent on a number of factors including the pre-service teachers' competency levels and their opportunities to learn, especially from their subject methodology lecturers. The amount of time spent on modelling good practices by their school-based mentors also influences their competency levels.

Chapter 5 discusses the findings in some greater depth by exploring some of the literature presented in chapter two. The next chapter will also explore the implications of the findings, the recommendations and the suggestions for further research.

# 5. CHAPTER 5 – DISCUSSION OF FINDINGS AND CONCLUSIONS

## 5.1. Introduction

The final chapter begins with a summary of how the study was conducted, followed by a discussion on the significance of the findings, the implications and concludes with the recommendations for further research and conclusions of the study. It is important to outline the discussion on the methodological approach used as this is the first study of its kind in South Africa that employs mixed methods approaches to examine issues of ICT competence with reference to preservice teachers. It is also the only study in the country to date that uses teaching practice as a context for exploring the pre-service teachers' competences. It is thus useful to capture this methodological contribution of the study in order to enable other researchers to test and/or extend the methodologies required for such an investigation. The interpretation and discussion of the findings is related to the literature review discussion that was presented in chapter 2, while the research methodology relates to the discussion on methods and processes as described in chapter 3. Finally, recommendations for future studies and conclusions of the study are presented together with a synthesising statement that is aimed at capturing the main thesis of the current study.

## 5.2. Summary of the research

The study examined how pre-service teachers teach science using ICTs, by investigating their competences during teaching practice. The study explored pre-service teachers' competences on the use of ICT tools to teach science subjects and whether they feel that the skills and knowledge learned in the teacher preparation programme can be effectively implemented in the teaching of science during teaching practice in schools.

The study began from four premises to which it sought to contribute insights:

a. Most teachers are unprepared to use ICT tools despite being trained in higher education institutions (Luan *et al.*, 2005; Mlitwa & Kesewaa, 2013; Ndlovu & Lawrence, 2012; Niess, 2005). The literature thus seems to suggest that the bulk of pre-service teachers' training does not appear to contribute to the competence of teaching using ICTs.

b. Yet, many international and national studies see it as imperative for all teachers to have adequate ICT skills (Chikasha, *et al.*, 2014; Jung, 2005). The higher education institutions are called upon to fast track the process of providing pre-service and in-service teachers with these ICT skills for teaching subject matter (Hindle, 2007).

c. Furthermore, local higher education institutions have invested heavily in ICTs and recurriculation to include ICTs in teacher education programmes (Chikasha *et al.,* 2014, UFS, 2012). The question therefore is whether the investments in ICTs and the recurriculation processes have been adequate to develop the required competencies in the pre-service teachers. With new ICT modules and policies introduced that require integration of ICTs in methodology courses such as science and teaching practice modules, for example at the university being studied, do the changes go far enough? No studies have been done on the integration of ICTs in teacher education programmes, especially in South Africa, and none have been done using the context of teaching practice and/or with the focus on specific subjects, for example natural sciences.

d. Lastly, there has been some recent research on what is commonly referred to as the "digital identities" of university students (Nykvist, & Mukherjee, 2016; Prensky, 2002; Wenger, 1998). What seems to be missing from the studies on digital identities is the disaggregation of the data to focus on specific groups of students; for example the pre-service teachers, especially those who specialise in the sciences for the context of the present study. What are the “identities” of these students in terms of their competences to use ICTs for teaching their subjects?

The study employed mixed methodology (quantitative and qualitative approaches) to unpack the issues of interest using questionnaire responses, analysis of lesson planning forms and focus group interviews. Eclectic theories and the Technological Pedagogical Content Knowledge (TPACK) influenced the data collection and analysis. Eclectic theories that included the cognitive theory, connectivism, constructivism and behaviourism helped me to interpret the experiences of pre-service teachers during teaching practice (Ertmer & Newby, 1993). The TPACK framework, on the other hand, was used to understand the levels of competence of pre-service teachers to teach science content (Chai *et al.* 2011; Harris *et al.* 2009; Koehler & Mishra 2009; Mishra & Koehler, 2006; Schmidt *et al.* 2011).

The collection of data through mixed methodology provided for an in-depth analysis of the pre-service teachers’ perceived competence in the use of ICT and helped in exploring the patterns of use for subject teaching. The quantitative approach consisted of a modified version of the TPACK survey questionnaire, which prompted participants to respond to a variety of close-ended questions related to skills, knowledge and opportunities to learn. The TPACK survey questionnaire was limited to final year science pre-service teachers who had completed their final teaching practice session. One hundred and three (103) participants completed the questionnaire at the beginning of the second semester during and after a two-week period of school visits for teaching practice in 2015. Lesson planning forms used during teaching practice were immediately submitted to the researcher after the completion of the questionnaires and other volunteers brought theirs along during the scheduled focus group interviews.

Overall, the purpose of the study was to answer the primary research question: What are the competences of pre-service teachers for using ICTs to teach science content during teaching practice? In addition to the primary research question, the study addressed the five secondary research questions. The mixed methods instruments for collecting the data are summarised in the table below (table 22).

**Table 22:** Secondary research questions

| Research question | Research Instrument |
|---|---|
| 1. What is the competency of science education pre-service teachers with respect to the various tools that are applicable for teaching science content in schools? | Survey(closed) |
| | Focus group interview |
| 2. Which ICT tools are commonly used by pre-service science teachers during teaching practice? | Content analysis (Lesson plan) |
| | Focus group interviews. |
| 3. How are the ICT tools used for teaching science during teaching practice? | Content analysis (Lesson plan) |
| | Focus group interviews |
| 4. How can the competences on ICTs and patterns of use be understood and explained? | TPACK survey |
| 5. What suggestions for improvement can be made regarding the development of competence and use of ICT tools for teaching of specific subjects, for example science? | Focus group interviews |

Table 22 displays each of the five secondary research questions with the research instruments used to unpack the study. The study used the quantitative approach; with the TPACK instrument to answer research questions one, and four which related to knowledge, skills and opportunity to learn on the usage of ICTs. The qualitative approaches using lesson planning forms and focus group interviews were mainly used to answer research question two, three and five. In the final analyses, all answers to the research questions triangulated both approaches, which was an innovation for a study of (pre-service) teacher competence to teach subject matter using ICTs.

The next section discusses the findings and explores their theoretical significance and implications for policy and practice.

In this study, the researcher opted to use eclectic theories without restrictions. This combined approach to theorising the study helped to provide a comprehensive set of explanations for the data collected: For example, to explain the choices on a variety of ICT tools used and the methodological decisions for deploying these ICT tools during the lessons, I used the cognitive theory. Similarly, to explain how pre-service teachers connect science content with the selection of an ICT tool, the theory of connectivism was helpful. The expected behaviours arising from the courses taken were explained using behaviourism, whereas to understand how knowledge is constructed by the pre-service teachers from their varied experiences (at university and in schools), I used the theory of constructivism. A blended theoretical framework enabled the researcher to gain an in-depth understanding of the issues being studied, since there was a single theory could not provide a complete picture to explain the pre-service teachers' competence in the use of ICTs to teach a specific subject. A key conceptual framework that influenced this study was the TPACK framework which is widely adopted by the ICT research community (Chai *et al.* 2011; Harris *et al.* 2009; Koh, & Chai, 2011; Koehler & Mishra 2009; Schmidt *et al*., 2011). The TPACK framework was used as the basis for this research to enable the measurement of competence, through identification of domains of competence using the TPACK instrument. Mishra and Koehler's (2006) TPACK framework has been adopted by many studies and fitted this study well as it sought to measure and analyse pre-service teachers' competence in teaching science through ICTs.

This study expected pre-service teachers at one selected university to self-assess their technological, pedagogical, and content knowledge (TPACK) through the completion of the survey. More specifically, the study compared and contrasted the TPACK results from the survey with lesson plan analysis and focus group interviews together with the exploration of previous literature on the subject. In discussing the key findings of this study, I also seek to examine their significance by responding to the practical question on whether the teacher education programme seems to be properly aligned with the ICT integration goals proposed in the national curriculum. These goals are in terms of ICT being a fundamental learning for all pre-service teachers in order to produce teachers who have the necessary competence to teach using ICTs.

## 5.3. Key findings and their significance

The use of ICTs in daily life and the economy has led to major developments and changes across the world. Yet, the use of ICTs remains a significant challenge for many teachers in schools, which creates a "digital divide" that threatens social justice and democracy in general and presents a challenge to future teachers as they graduate and compete for jobs. Therefore, this study aimed to establish the levels of knowledge and skills by prospective teachers on ICT tools that are appropriate for teaching science and mapped out their patterns of use during teaching practice, This was done with the view of clarifying the role of teacher education in supporting prospective teachers to be adept users of appropriate technologies for teaching their subjects, specifically science. It is hoped that an understanding of pre-service teachers' competence levels for using ICTs to teach science will help to facilitate the design or redesign of teacher education programmes in order to provide better platforms and opportunities for practice and deployment of these skills during the school placement experience.

The discussion of the significance of the findings from this study will be addressed in sections that align to each research objective of the study, i.e.

a. Identifying competencies of pre-service teachers on ICT tools for teaching science in particular,
b. Exploring the practices of pre-service teachers in terms of using ICT tools during teaching practice,
c. Identifying patterns in the use of ICT tools for teaching science as a subject by pre-service teachers,
d. Explaining the competence levels and patterns of use of ICTs by the different groups of pre-service science students,
e. Making suggestions and recommendations for improvements in the education of pre-service teachers on the use of ICTs for subject teaching.

### 5.3.1 Competence to teach science through ICTs

The competences of pre-service teachers to teach science using ICTs during teaching practice were examined through research question one and research question four. Research question one sheds light on the self-perceptions of competence as measured by the TPACK survey while research question four focused on the practical applications during the preparation of the lessons as captured in the lesson planning forms. The focus group interviews where pre-service teachers shared their teaching experience of teaching science during teaching practice in the classroom also provided the data to answer research question four.

Overall, the measurement and analysis of the data in this study found that there were significant variations in the competence of the final-year science pre-service teachers at university.

The first of the five overarching questions that measured and analysed competence in this study asked:

What is the competency of science education pre-service teachers with respect to the various tools that are applicable for teaching science content in schools?

There are three ways to examine the results on pre-service teachers' competency with respect to the various tools. Firstly, I looked at competency on ICT skills. Secondly, I looked at competency on the various knowledge domains of ICT competence and finally competency development through opportunities to learn (OTL).

The findings suggest that the teacher education programme plays a key role in developing the competence on ICT skills for pre-service teachers. The frequency results on computer related modules showed 96.12% of the participants as having taken modules that equipped them with ICT skills with approximately 74.75% having completed the prescribed basic and general computer skills module (BRS11) offered by the university being studied. Furthermore, the overall mean results for the sources of ICT skills was higher for "university" than for any of the other sources listed in the questionnaire, which confirms that competence levels on ICT are developed mostly within the teacher education programme. The narratives from the focus group interviews further supported the positive contribution of the teacher education programme to their ICT skills and knowledge where participants identified "university" as the source of development for their competence on ICT skills. However, in the "Guidelines for Teacher Training and Professional Development on ICT", Hindle (2007: 8) proposes that the standard should be "adoption level in ICT skills development for student and practising teachers" which remains the question in this case. The teaching and learning of ICT skills within the teacher education programme supports the findings from an earlier study which specifically targeted the competence of ICT skills in 17 developed (European) countries (Ananiadou & Claro, 2009). These studies confirm that pre-service teachers who have adequate ICT skills developed their competency mostly from their teacher training during their teacher preparation as required by their national curricula.

The second examination focused on whether the ICT skills competence of the pre-service teachers is “subject-specific and relevant to the learning area” content such as science (Hindle, 2007: 4). Descriptive statistics were used to examine results of competency on the TPACK knowledge domains (CK, PK, PCK, TK, TCK, TPK and TPACK) followed by in-depth analysis of all technology related knowledge areas (TK, TCK, TPK and TPACK). The study then examined the use of the ICTs to teach science content during a specific phase of teacher training (teaching practice) and looked at the significant role of ICTs when pre-service teachers practise teaching science in the classrooms during teaching practice.

The study found that pre-service teachers perceive themselves as competent on the non-technology related (CK, PK and PCK) knowledge domains. This supports a common view from other scholars that mentions positive levels of competence on content knowledge (CK), pedagogical knowledge (PK) and pedagogical content knowledge (PCK) areas relative to the technology related knowledge domains (Koh & Chai, 2011; Lin *et a*l., 2013). Another set of studies conducted in New Zealand and Spain also support the findings of this study that pre-service teachers seem to be more competent in the non-technology related fields compared to the technology related knowledge fields (Nordin, Davis, & Ariffin 2013).

Having established the pre-service teachers’ perceived competence on the non-technology domains, the present research was also aimed at quantifying the existence and extent of the competence on the four technology related knowledge domains (TK, TCK, TPK and TPACK) and measuring the opportunities to learn (OTL) such skills. An important twist on the technology related knowledge domains (TK, TCK,TPK, TPACK) was the finding that pre-service teachers seem to be aware of overall technology-related ICT tools but lack knowledge of subject specific ICT tools and experience challenges in how to use various ICTs during teaching practice to teach science subject content. From the researcher's perspective, one of the most significant contributions of this concurrent mixed methods study was its exploration of the connection between the teaching practice in schools and the teaching of science content – which is concerned with how various ICT tools can be used for improving teaching and learning of science content, specifically in South African schools. From the finding that indicates awareness of ICT tools but inability to use them for subject teaching during teaching practice, the study thus recommends the need to incorporate specific units or modules in the methodology training (and/or modules) to address ICT tools and their use for subject teaching. That is, in addition to the general ICT modules, specific subject related ICT content is needed in the teacher education programmes.

Thirdly, the study examined how teacher educators (lecturers) and in-service teachers are perceived as exemplary on TPACK modelling 1 for combining content, pedagogy and ICT to teach science and TPACK modelling 2 which explored the amount of time involved in the use of ICTs by lecturers and mentor teachers. The results suggest that participants agreed that lecturers and teachers were exemplary (TPACK modelling 1) in combining content, ICTs and different teaching approaches. Furthermore, the results also suggest that pre-service teachers perceive the amount of time spent on the use of ICTs to teach science, as being less than ideal or perhaps even inadequate. Some caution, however, needs to be exercised when interpreting the findings on the mentor teachers for TPACK model 1 and 2 questions regarding combining content, technology skills and teaching approaches during teaching practice, as some of the results were rather skewed and showed a negative impact. The results of the focus group interviews confirmed the twisted results as pre-service teachers considered their competence largely motivated or demotivated by how their assigned mentor teachers use ICTs to teach science subjects in the schools.

### 5.3.2 Common ICTs during teaching practice

The second and third research questions addressed the issues of which ICT tools the pre-service teachers are familiar with and the manner in which they used them to facilitate their teaching of science during preparation and presentation of lessons during school placement. The survey instruments, lesson plans, and focus group interviews gathered data to describe the commonly used ICT tools for teaching science and how they were used, by asking the following research questions:

> Which ICT tools are commonly used by pre-service science teachers during teaching practice?
>
> and
>
> How are the ICT tools used for teaching science during teaching practice?

The present study found that the most commonly used ICTs by pre-service science teachers are “simple skill-based” and not specifically related to science subjects. The present findings support similar observations in the studies by Jimoyiannis (2010) and those by Haydn (2014). Despite there being many possible ICTs available for use in teaching science and that there have been various recommendations from other researchers for the incorporation of ICTs in science teaching (Cleaves & Toplis, 2008; Holden *et al*., 2008; Kisalama & Kafyulilo, 2012; Van Rooy, 2012), there are still variations in terms of the access to ICT tools for teaching subject specific content. Many future teachers appear to rely on the same ICT tools that were used by their own teachers four or five years prior to them being seniors at university, many of which teachers have been using for over 50 years(Cuban, 1986; 2013; Hiebert & Stigler, 2000; Twenge, 2009). The study specifically found digital audio and videos to be the most commonly cited tools in the survey data while the data projector or overhead projector, screen, slides and PowerPoint presentations were the most commonly cited in the lesson plans and the focus group interviews. Multimedia only came up as a dominant ICT theme in the focus group interviews where it was cited a number of times by the participants. These tools also had the highest mean score, which was above 3 in the survey. The study also revealed that printers for reproducing papers for class activities and class notes were commonly cited in the lesson plans and focus group interviews.

Overall, the study thus found that the variations in the commonly used ICT tools ranged from low-level printers to high-level multimedia ICTs such as videos. Based on the literature review and the results of the lesson plan and focus group interview analysis, the variations in the commonly used ICTs may be a result of the lack of standard requirements on ICTs in the lesson plans and the lack of appropriate ICT resources in the teaching practice schools. It could also result from poor mentoring by the school-based subject teachers and/or personal choices by the pre-service teachers (Cleaves & Toplis, 2008, Goktas *et al.,* 2009; Meyer & Xu, 2007; Teo *et al.,* 2008). For example, out of the 33 lesson plans analysed only one pre-service teacher used an MS Word document to type it. When participants were asked in the focus groups why their lesson plans were not typed, all mentioned that it was because they were given a hardcopy by the teaching practice office and that there was no requirement for ICT integration in the teaching practice assessment forms. Further analysis of the lesson plans found that there were also variations in how pre-service teachers include ICTs in the lesson planning forms. Most lesson plans indicated multimedia such as videos for lesson introduction, PowerPoint for lesson presentation and Word documents and printers for class activities. It is also interesting to note that the study found that all participants used mobile technology to prepare for their lessons, as McHaney (2011) also previously found, even though they did not mention that in the lesson plans themselves. Part of the reason, which is itself an interesting finding, is that even though all participants own mobile technology devices, none of them considered using them to teach science or to engage learners in a lesson. The ICTs that were used for learner participation were generally low level, in the form of paper and none of the high order tools such as games, online practical work and/or experiments. This raises an important question, if mobile technology is more accessible to pre-service teachers and most learners, why has there been no direct encouragement for the pre-service teachers and the learners to use it for teaching and/or learning or to install science related content such as periodic tables, scientific formulae, etc.? This is a question for other researchers interested in ICTs and teacher education to consider.

Regarding the question of how ICTs are used by pre-service teachers during teaching practice, the study revealed that how ICT tools are used by many pre-service teachers during teaching practice is highly dependent on at least two major factors namely, the school's ICT situation and the support or lack thereof from the mentor teachers. Previous studies have recommend the need to establish good working relationships between schools and the teacher education programmes, forming what is sometimes called communities of practice (Vandeyar, 2013; Wenger, 1998). These recommendations become relevant when we consider the fact that some of the teacher education participants felt that they were not welcome in the schools and could not be trusted with the passwords or simple access to some of the ICT tools. The support of school-based mentors was an important factor in such cases. In some of the schools, there were no ICT tools or facilities to enable teaching through ICTs by the pre-service teachers. In the context of the present study, the opportunities to learn from university programmes and the patterns of ICT usage during teaching practice in addition to the lack of practise (to teach science) with ICTs in some of the schools during teaching practice raises serious issues about equity and social justice in the training of teachers. If allocations to the teaching practice schools are done based on the luck of the draw, then it cannot be guaranteed that all pre-service teachers will have equal opportunities to learn about the use of ICTs for teaching science. This is regardless of the fact that they may all be enrolled in the same programme and will ultimately graduate with the same degree at the same university. Previous studies have confirmed the observation that many universities generously invest in ICTs, partly to prepare their students to be globally competitive and relevant for 21st century careers (Goktas *et al*., 2009; Haydn, 2014; UFS, 2012; Valtonen *et al*., 2015). The findings in this study thus go beyond the general findings about the state of readiness by universities and the various opportunities to learn about the use of ICTs created within the teacher education programmes. The present study has thus shown that opportunities to learn about the use of ICTs for subject teaching is not only limited to on-campus readiness and faculty resources but includes the need to pay attention to the resources and opportunities created for learning about the use of ICTs during school placement or teaching practice outside of the university campus. If teaching practice is an important component of the teacher education programme, then the findings call for a deliberate and careful choice of teaching practice schools to enable equitable training opportunities and spaces for the pre-service teachers to practise.

The study also found that among the commonly used ICTs none are specifically designated for science. Pre-service teachers mostly use Internet to access exemplary science lessons but mostly in order to enhance their own content knowledge. There is no evidence that points to the use of any of the technologies commonly recommended by other scholars such as multimedia simulations and data logging tools for specifically engaging learners in actively learning science (Haydn & Barton, 2007; Hennessy *et al.,* 2007). In teaching science content, pre-service teachers used ICTs to display subject content from the projectors, PowerPoint or videos with no learner engagement in terms of accessing the ICTs themselves. This runs counter to the suggestion by the CAPS science document that called for teachers “to ensure that children acquire and apply knowledge and skills in ways that are meaningful to their own lives” (Department of Basic Education, 2011: 4). Commonly, the learners were mere observers, watching teachers who were using ICTs to teach, if they used ICTs at all. The study also found no instances of use of ICTs for teaching science to engage learners in scientific investigation based on observations from real-life in their own communities and thus develop them to be able to make connections to their everyday world.

### 5.3.3 Development of competence to teach science with ICTs

The fourth research questions in the study sought to answer the question:

> How can the competences on ICTs and patterns of use be understood and explained?

The short answer to this major research question of the study is that the results show that the more lecturers in the teacher education programme and the mentor teachers in schools use ICT tools to teach science, the more pre-service teachers learn to use these same ICT tools for their own teaching of the subject. That is, the richer the quality of opportunities to learn, as defined by the university-based and the school-based opportunities to learn regarding the use of ICTs, the better the chances for developing competence to use ICTs for subject teaching by the pre-service teachers. In the section below, I provide an expanded discussion of this thesis as developed from the findings presented in chapter four. There are three parts to my discussion of the explanation of the competences and patterns of use of ICTs by pre-service teachers.

1. First, I discuss the extent to which Models of TPACK (lecturers and teachers) are exemplary in the use of ICT (see table 16) followed by the
2. Modules taken in the teacher education programmes at institutional level (see table 17) and finally the
3. Time spent by Models of TPACK using ICTs to teach science (see table 18).

Teaching is a profession where knowledge and expertise are built up incrementally over time through what has been called the “apprenticeship of observation” (Lortie, 1975). Pre-service teachers thus begin learning about how to be “good teachers” from parents, former teachers, lecturers, mentors etc. This study opted to review the formal opportunities to learn that are structured as part of the teacher education programme, which involve learning to teach science from knowledgeable others such as teacher educators (lecturers) and subject matter expert teachers (mentor teachers) during teaching practice in schools. The study thus explored the extent to which lecturers and teachers play a role in the growth and development of pre-service teachers’ competence. Previous studies have offered important insights on the exploration of the relations of opportunity to learn (OTL) with a specific subject. For example, a comparative study on mathematics teacher education programmes from eight different countries found that there is variation in the preparation of teachers and thus in their opportunities to learn (Schmidt *et al.*, 2011). The variations were observed even within the teacher education programmes from the same country (Schmidt *et al*., 2011). Similarly, it was not strange to find such variations in the current study within one teacher education programme in one country and at one institution. The variations could be explained by the differences in terms of the capacity of TPACK models (university-based lecturers and school based mentor teachers), ICT modules taken in the teacher education programme and the time spent by TPACK models on “modelling” the use of ICTs for the pre-service teachers.

The study explored the opportunity to learn through a combination of the analysis of the TPACK survey and analysis of focus group interviews in order to seek explanations for the observed variations in the pre-service teachers’ competence to use ICTs for teaching. The findings from the TPACK survey suggest that pre-service teachers value the mentoring from teachers more during teaching practice, even though they were less likely to observe the use of ICTs for teaching science from mentor teachers than from lecturers at university. From table 12 (on page 116), it can be seen that the pre-service teachers rated themselves above three on a five-point scale of (0,1,2,3,4) for TPACK models 1as exemplary, which indicates a fairly high level of confidence in teachers and lecturers as TPACK exemplary models on the use of ICTs for teaching. In terms of time spent on ICTs by teachers and lecturers as TPACK models 2, pre-service teachers were less confident with a mean score less than 3 (M=2.85) (see table 12). The subsequent descriptive analysis found that there was an imbalance between the two predictors of pre-service teachers' competence, viz. TPACK models 1 as exemplary and TPACK models 2 for the time spent, leading to the expressed variations of perceived competence by the pre-service teachers. Furthermore, the variation on the use of ICTs to teach science during teaching practice also varied across schools by mentor and by pre-service teacher. The following section provides a possible explanation for these variations based on the results presented in chapter four of this thesis:

**Mentorship capabilities**

Many researchers have made strong recommendations for ICT integration in schools and in the teaching of specific subjects (Haydn, 2014; Leendertz *et al.,* 2013; Zelkowski *et al.,* 2013). In this study, the survey and interviews were used to examine understanding and patterns of how pre-service teachers become competent in using ICTs to teach science through their mentor capabilities. The mentorship of lecturers and in-service teachers was investigated through the survey, which focused on understanding how pre-service teachers' perceptions differed with various levels of mentorship. In other words, mentorship from the lecturers of science methodology courses, the lecturers of ICT related courses, the lecturers for education studies courses, the lecturers for courses outside the teacher education programme and from the mentor teachers in schools. The study, further explored the patterns of the results with focus group interviews.

The pre-service teachers' opportunities to learn from mentors as lecturers and in-service teachers varied. The descriptive analysis revealed that mentor teachers are perceived to be more exemplary than the lecturers in combining science content, technology skills and teaching approaches in their teaching. In contrast, the correlation analysis and focus group interviews ranged from nothing learned from the mentor teachers to many opportunities to learn the use of ICTs for teaching science. Based on the overall inferential analysis correlation score (table 16) for the TPACK models as exemplary, the Pearson correlation for Models of TPACK_1_ Exemplary ranged from low to medium values indicating a small positive relationship with teacher educators and mentors in modelling the use of ICTs. Further analysis of the focus group interviews also showed findings that varied widely among the participants. There were those who were extremely excited with their opportunities to learn from mentors and who gave them access to laptops and time to prepare for lessons using ICTs. Others were extremely disappointed to find that some mentors have no competence to use ICTs to teach and tended to discourage them from using ICTs by either locking the facilities and/or not making the required passwords available. Previous studies, conducted in the South African context, have pointed out the lack of competence of mentor teachers in using computers to teach content in spite of being trained (Mlitwa & Kesewaa, 2013; Ndlovu & Lawrence, 2012). This study therefore confirms these results. Even though teachers may be trained in ICTs, some of them continue to struggle with their use and especially to become mentors on their use for teaching science to pre-service teachers during teaching practice.

**Curriculum alignment**

The study revealed that the ICT related modules taken by the pre-service teachers do not appear to tell us much about whether they are likely to be competent to use the ICT tools for teaching science (see table 17). Conceivably, they can take and pass all the ICT related modules required in their programme and still not be competent to use them during teaching (practice). The findings of this study were thus similar to those by Downes (1998) in Australia who concluded that there was no connection between the modules taken at the university and the use of computers in the classroom during teaching practice. The study had participants who did not take any of the ICT related modules but the variation in the use of ICTs had no relation with whether pre-service teachers had taken any ICT related modules. Thus, teaching practice experiences seem to contribute more to the competence on the practical application of ICTs for science subject teaching with practical coherence of theory from the teacher education programme and school curriculum. ICT related modules taken at higher education institution thus seem not to be closely aligned with the curriculum in schools regarding the use of ICTs.

## 5.4. Limitations for the study

The data collection for the current study was limited, in terms of time. The data could only be collected during the second semester of the final year of study for the pre-service teachers and after the last teaching practice period. The challenge with this data collection is that it did not allow for a comparison of results from other semesters, or for insights developed over an extended period during pre-service training. Additionally, the beginning of the final semester can be a busy time for pre-service teachers as they finalise their teaching practice portfolio for assessment and begin preparing for their job search. A similar study in the future could consider beginning data collection early in the beginning of the academic year (first semester) and perhaps target third year science pre-service teachers as participants and continue to their final year in order to increase the period for data collection.

Another limitation is that the study aggregates the teaching practice experiences of the participants who were completing the final year in the four-year B.Ed. programme with participants who were enrolled in the one-year PGCE programme. The PGCE pre-service teachers had little teaching practice experience, limited to only 4 weeks, while the undergraduate participants had more teaching practice experience, of approximately 2-4 weeks in each of the 4 years in the programme. A comparative study on the differential influences of the two types of programmes and/or cohorts may provide a more nuanced set of insights than is possible in this study.

Furthermore, the results from the current study are limited to understanding the differences that are attributable to the teacher education programme, with the understanding that the overall differences in the ICT knowledge, skills and opportunity to learn of the participants may be attributable to many other factors outside of the teacher education programme. It is not possible, within the limits of present day correlational methods to account for all the possible variables in any one study.

This study was also limited by the fact that it was conducted at one university and with only one group of final year science pre-service teachers from across two campuses in South Africa. These findings therefore apply directly to this group of final year students at one university. While the results may be extended to other pre-service teachers, lecturers, mentor teachers and teacher education programmes that are similar, and seek to prepare pre-service teachers to teach science through ICTs, caution should be exercised in doing so. A larger scale study that compares data from different programmes, universities and campuses is recommended.

Finally, unforeseen circumstances such as student protests on campuses (e.g. the #Feesmustfall movement in 2015) limited the potential number of participants completing surveys, submitting copies of lesson plans and volunteering for focus group interviews.

## 5.5. Implications and recommendations for practice, policy & further research

The results of this study have possible implications in three areas: (a) teaching practice, (b) curriculum policy, and (c) future research, which are discussed below:

### 5.5.1 Implications and recommendations for practice

As their communities and location mostly define South African schools, different challenges and opportunities concerning teaching science with ICT tools during teaching practice should have been expected. For example, teaching practice in urban and rural schools should be expected to vary by school and by mentor in a school, and individual pre-service teacher who has to adapt to the school situation also shapes the differences. One of the challenges pre-service teachers face in schools during teaching practice is adapting to in-school situations they encounter during the short period (two weeks) of teaching practice. There is a need to establish support systems to mitigate the challenges faced by pre-service teachers in using ICTs during teaching practice. The university-based lecturers and school-based mentor teachers can assist the pre-service teachers in the implementation of ICTs during teaching practice by broadening the scope of exploration for various ICTs for each science concept or topic in the university and schools. More collaboration and better communication with all the schools, teacher-educators and mentors is thus called for in this regard.

The collaboration between schools and universities could also involve the training of mentor teachers, the provision of facilities and ICT tools by mentors and schools, as well as the joint assessment of pre-service teachers and post-assessment discussions by university-based lecturers and the school-based mentor teachers. All practitioners, pre-service teachers, in-service mentors and lecturers will need to learn by doing; and reflecting on effective strategies in technology integration with content and pedagogy in school settings as a regular part of their ongoing capacity building in response to the challenges pointed out in this study of ICT integration during teaching practice.

The findings may also be useful in the implementation of the South African national curriculum with respect to the integration of ICTs across subjects in schools (DoE, 2004, Wilson-Strydom & Thomson, 2005). This study found that many pre-service teachers struggle to implement ICTs in the teaching of science subjects in schools. The same struggles can be expected to prevail at least in the first years of their teaching. Thus, national curriculum developers can help to close the gap by providing teachers with concrete examples of how to use ICT tools for teaching specific science topics.

The present study also has implications for the practice of teacher education in universities programmes in general. For example, the study suggests the need for methodology courses within the university programmes to consider topics on subject specific ICTs prior to placing pre-service teachers in schools for teaching practice. In addition, it may be useful for the general ICT-module in the teacher education programme to focus their content and assessment on issues of subject specific integration using classroom vignettes, among others.

Furthermore, a crucial implication for university-based teacher education programmes is the need to develop specific criteria for selecting teaching practice schools, which would include, among others, the availability of opportunities for pre-service teachers to access and practise using ICTs for teaching their subjects. Support by mentors who are themselves able and willing to use ICTs for subject teaching should also be one, among many, important considerations.

### 5.5.2 Implications and recommendations for policy

The findings of the study have several implications for policy on teacher education, school curriculum implementation and higher education in general. Curriculum developers, especially in the Department of Basic Education have to be more deliberate and overt about the need for integration of ICTs in the curriculum policy for schools and for teacher education. Alignment between the two policy provisions – for schools and for teacher education programmes – is required including the development of specific objectives and assessment criteria for the integration at each level.

A set of implementation guidelines should be developed for both in-service and pre-service teachers to enable a substantive and broader integration of ICTs in teaching and learning. It would be preferable for the implementation guidelines to be subject-specific in order to take advantage of the emerging technologies in each field of expertise. Guidelines on the levels of competence required for different stages of pre-service teacher education and for in-service teachers are also required. An accelerated programme of capacity building in schools and universities should accompany these guidelines.

### 5.5.3 Implication for future research

In addition to the recommendations that were made in the section on limitations of the present study, a longitudinal study is recommended to allow for a longer and more differentiated collection of data. Possibly fewer participants should be included to eliminate between-phases variation, (intermediate phase, senior phase, and FET) and between science subject variation (natural sciences, life sciences and physical sciences) and also to provide information regarding individual changes over time and changes in different schools. The present study relied on a cross-sectional survey over a one-semester period (3 months). The cross-sectional study allowed for the examination of knowledge, skills and opportunities to learn of same population of pre-service teachers using the same survey, and the same lesson plans over at similar teaching period. Changes over-time may be explored through a longitudinal study.

The present study was based on the TPACK conceptual framework and used eclectic theories to make sense of the data. We now know more about how TPACK works as a tool for measuring ICT competences of pre-service teachers and what the relevance of the various theories are in such studies. However, more research focusing specifically on the practical application of the TPACK framework in the context of developing countries such as South Africa is required. To date, there is a lot more research that is located in developing countries with better ICT resources and training. Although useful, insights from the developing world may be more relevant to the majority of the world population that lives in less ideal conditions in terms of ICT resources and use.

The study found that there was no statistically significant relationship between ICT related modules taken in the teacher education programmes and the use of ICTs to teach science. Various factors may account for this inconsistency. A deeper analysis of the ICT modules taken might need to be done to determine the actual ICT content of these courses and its relevance to teaching science subjects or to the school curriculum in general. Furthermore, a more detailed qualitative study of the experiences of the pre-service teachers in the various teacher education modules and in schools for teaching practice may help to unpack some of the issues generated in the present research.

## 5.6. Conclusions

By all accounts, many universities and many teacher education programmes seem to have invested plenty in the area of information and communication technologies (ICTs) in order to produce competent teachers who will make a difference in their future places of work including schools. Furthermore, developing countries such as South Africa, have in recent times, worked progressively to improve their school curricula and particularly introduced policies and innovations that focus on bringing in and using new technologies for teaching and learning in various subjects.

The introduction of ICTs in teacher education programmes and in schools is generally expected to shift classrooms practice from “chalk and talk” to more authentic and innovative classes (Cuban, 1986; 2013; Hiebert, & Stigler, 2000; Twenge, 2009). However, as the findings in the present study suggest, change in the use of ICTs is more dependent on each pre-service teacher’s “digital identity”. The digital identities of many science pre-service teachers appear to be made up of ‘“simple skill-based” ICT tools that are not specifically related to teaching and learning of science. That is, in spite of some knowledge of common ICTs by pre-service teachers, one great weakness is the lack of ICT skills to engage learners actively in specifically learning science.

Helping pre-service teachers to be competent in teaching science using relevant ICTs is something that will need specific focus in the teacher education programmes and especially during the teaching practice period. As part of developing the digital identities of pre-service teachers, a deliberate focus on subject-specific ICT tools is required. Mentor teachers in schools and university-based teacher educators therefore need to be aware of these challenges in respect of the variety of ICT skills that are required by pre-service teachers who wish to be effective and innovative in their teaching.

As a teacher educator, and being responsible for the ICT training of the pre-service teachers at the university, the study has provided me with useful insights on how to (re) think my own practice in this regard. I am much more aware of the challenges involved in structuring better opportunities to learn for pre-service teachers in the areas of subject-specific ICTs. I am persuaded by the argument for a more subject specific approach to ICT training in order to enable pre-service teachers to be in a position to integrate ICTs in their own teaching during teaching practice. In addition, that support and scaffolding is required to enable this integration during teaching practice while the school-based mentors and university-based teacher educators need to play complementary roles in the support and scaffolding processes. To ensure success and sustainability in the required changes, the assessment of teaching practice needs to include aspects on ICT integration by pre-service teachers.

It is encouraging to see that not all is lost with the current cohort of pre-service teachers. Some of them are already making strides with respect to the integration of ICTs in their own teaching of science in schools during teaching practice. It would be interesting to follow these young innovators into their first years of full-time teaching to explore the kinds of support they receive in schools, together with the challenges and opportunities that exist for more substantive integration of ICTs in science teaching.

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# APPENDIX A: SURVEY

**RESEARCH STUDY ON THE USE OF ICTS DURING TEACHING PRACTICE**

My name is Thuthukile Jita and I am a lecturer and PhD student at the University of the Free State. As part of my doctoral programme, I am doing research on the following topic:

*Pre-service teachers' competences to teach science through Information and Communication Technologies during teaching practice.*

The purpose of the research is to examine how pre-service teachers learn to teach science through the use of Information Communication Technologies (ICTs). Specifically, I wish to investigate the competences and practices of pre-service teachers during teaching practice. The study has potential to benefit future teachers on the use of ICTs, teacher educators on how to integrate ICTs in teacher education programme and universities on assessing the level of competence of their prospective teachers.

I hereby invite you to participate in this investigation. If you agree to be a participant in this study, you will be asked to:

1. Complete the attached **survey** which will take about 20minutes in a face-to-face class.

2. Submit at least ONE of the four **lesson plans** used for assessment during teaching practice in schools, at your earliest convenient time.

3. Be part of a 45-minutes **focus group interview** to be held on a mutually agreed upon date, time and venue over a cup of tea/coffee.

Your identity, as a participant in this study will remain confidential and no names of participants or institution shall be used in any reports about this study. Only the researcher and her supervisor(s) will have access to all material used for this study.

You are free to participate or to withdraw your participation at any time during the study. While your responses to all questions are important to me, you may choose not to answer some of the questions in the survey or during the interviews should you wish.

If you have any questions, comments, and/or suggestions, please feel free to contact me at (051)-401 7441/ 0718729795 or jitat@ufs.ac.za **or my supervisor Prof (MG) Mahlomaholo at** MahlomaholoMG@ufs.ac.za **or +27514017521.**

Thank you for your kind consideration of my request.

✂- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

*Pre-service teachers' competences to teach science through Information and Communication Technologies during teaching practice.*

If you agree to participate in the research study, please complete the attached consent form

Printed name of participant: ____________________________________________

Cell Number: ____________________________________________________

Email address: ___________________________________________________

Participant's Signature: ______________________________ Date: ____________

**TPACK SURVEY FOR PRE-SERVICE TEACHERS**

Thank you for taking time to complete this questionnaire. Please answer each question to the best of your knowledge. Your thoughtfulness and candid responses will be greatly appreciated.

Your individual name or identification number will not at any time be associated with your responses. Your responses will be kept completely confidential and will not influence your course grade.

**DEMOGRAPHIC INFORMATION**

1. Gender
   a. Female
   b. Male

2. Age range
   a. 18-22
   b. 23-26
   c. 27-32
   d. 32+

3. Program of study
   a. Bachelor of Education (B.ED)
   b. Postgraduate Certificate in Education (PGCE)

4. Area of Specialization
   a. Foundation Phase (FP)
   b. Intermediate Phase (IP)
   c. Senior Phase(SP)
   d. Further Education and Training (FET)

5. Science teaching subject
   a. Physical Science
   b. Natural Science
   c. Life Science

6. Second teaching subject(s) is/are:
   a. Mathematics
   b. Languages, e.g. English, Afrikaans or Sotho
   c. Life Orientation or Life Skills
   d. Agriculture
   e. Arts & Culture
   f. Geography
   g. History
   h. Accounting
   i. Economics
   j. Business Economics
   k. Social Studies
   l. Other, please list below

______________________________________________

7. Have you completed any of the computer related modules in your program?
   a. Yes
   b. No

8. If yes, choose the year completed next to the course or give the name of module not listed:

| **Module**<br>**Year completed:** | **2015 or 2014** | **2013 or 2012** | **2011 & 2010** | **2009 or Before 2009** |
|---|---|---|---|---|
| ICT111 (Information Communication & Technologies) | | | | |
| ECL122 (Use of computers in the teaching context) | | | | |
| BRS111(Basic computer skills) | | | | |
| Other:______________________________ | | | | |

*Information and Communication Technologies (ICTs) is a broad concept that can mean a lot of different things. For the purpose of this questionnaire, ICTs refer to digital technology/technologies. That is, the digital tools we use such as computers, laptops, iPods, handhelds, interactive whiteboards, software programs, online tools, etc. Please answer all of the questions and if you are uncertain of your response you may ask the researcher or select "Neutral".*

| **ICTs (Information and Communication and Technologies (ICTs) skills**<br>9.To what extent do you think you learned ICT skills from these sources: | Very great deal | Great Extent | Some extent | Little bit | Not at all |
|---|---|---|---|---|---|
| From a school class or schoolmate. | | | | | |
| From a university/college class. | | | | | |
| From a friend, and /or family members | | | | | |
| On my own. | | | | | |
| Other, please list: ______________________ | | | | | |
| **TK (Technology Knowledge)** | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
| 10.I can learn technology easily. | | | | | |
| 11.I keep up with important new technologies | | | | | |
| 12.I frequently play around with technology. | | | | | |
| 13.I know about a lot of different technologies. | | | | | |
| 14.I can teach with the use of technology. | | | | | |
| 15.I am aware which ones of the technologies would work better for my science teaching | | | | | |
| 16.I can specifically teach science with the use of technology | | | | | |
| **CK (Content Knowledge) Science** | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
| 17.I have sufficient science knowledge to teach the subject. | | | | | |
| 18.I can use a scientific way of thinking. | | | | | |
| 19.I have various ways and strategies of developing my own understanding of science. | | | | | |
| 20.I am familiar with the science content that is prescribed by the CAPS | | | | | |
| 21.I can explain the concept of "global warming" | | | | | |
| 22.I have sufficient knowledge to answer most high school students' questions on science | | | | | |
| **PK (Pedagogical Knowledge)** | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
| 23.I know how to assess learners' performance in a science lesson. | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 24.I am able to adapt my teaching based-upon what learners currently understand or do not understand. | | | | | |
| 25.I am able to adapt my teaching style to different learners. | | | | | |
| 26.I know how to assess student learning in multiple ways. | | | | | |
| 27.I can use a wide range of teaching approaches in a classroom setting. | | | | | |
| 28.I am familiar with common student understandings & misconceptions in science. | | | | | |
| 29.I know how to organize and maintain classroom management. | | | | | |
| 30.I am familiar with the science textbooks that are used in most South African schools. | | | | | |
| **PCK (Pedagogical Content Knowledge)** | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
| 31.I can select effective teaching approaches to guide student thinking and learning in Science. | | | | | |
| **TCK (Technological Content Knowledge)** | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
| 32. I know how to teach science using **Clouds** e.g. google drive, iClouds, draw box. | | | | | |
| 33.I know how to teach science using **digital boards** e.g. Smartboard, digital projector. | | | | | |
| 34. I know how to teach science using **Learning Management Systems** e.g. Moodle, Blackboard. | | | | | |
| 35. I know how to teach science using **Mobile devices** e.g. Cell phones, Tablet, IPad. | | | | | |
| 36.I know how to teach science using **online educational sites** e.g. Mastering Biology, Big Brother series. | | | | | |
| 37.I know how to teach science using audios, and videos e.g. YouTube. | | | | | |
| **TPK (Technological Pedagogical Knowledge)** | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
| 38.I am able to choose technologies that enhance my teaching approaches for a lesson. | | | | | |
| 39.I am able to choose technologies that enhance students' learning for a lesson. | | | | | |
| 40.I always think critically about how to use technology in my classroom. | | | | | |
| 41.I am able to adapt & use the technologies that I am learning about at university to different teaching activities. | | | | | |
| **TPACK (Technology Pedagogy and Content Knowledge)** | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
| 42.I am able to teach lessons that appropriately combine science content with technology skills. | | | | | |
| 43.I am able to teach lessons that appropriately combine science content with different teaching approaches | | | | | |
| 44.I am able to teach lessons that appropriately combine science content, technology skills and my teaching approaches. | | | | | |
| | | | | | |

| **Models of TPACK (Lecturers & Teachers)** | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 45.My science education lecturer(s) are exemplary in combining science content, technology skills and teaching approaches in their teaching. | | | | | |
| 46.My lecturer(s) in the education-related ICT-courses are exemplary in the use of technologies in their teaching. | | | | | |
| 47.My lecturer(s) in other education courses/modules are exemplary in the use of technologies in their teaching of the courses. | | | | | |
| 48.My mentor teachers in schools (during teaching practice) are/were exemplary in combining science content, technology skills and teaching approaches in their teaching. | | | | | |
| **Models of TPACK (Lecturers & Teachers)** | 76-100% | 51%-75% | 26%-50% | 11%-25% | 0%-10% |
| 49.Approximately what percentage of the time (in a semester/term) have your **science education lecturers** provided an example of combining content, technology skills and teaching approaches in their teaching? | | | | | |
| 50.Approximately what percentage of the time (in a semester/term) have your **lecturers outside of teacher education** (e.g. in the Humanities/Natural Sciences/Theology Faculties) provided an example of combining content, technology skills and teaching approaches in their teaching? | | | | | |
| 51.Approximately what percentage of the time (in a semester/term) have your **lecturers in education-related ICT courses** combined content, technology skills and teaching approaches in their teaching? | | | | | |
| 52. Approximately what percentage of the time (during the whole duration of your teaching practice) have your **mentor teachers in schools** combined science content, technology skills and teaching approaches in their teaching? | | | | | |

## APPENDIX B: INTERVIEW PROTOCOL



Just introduce yourself briefly: Your name and what are you current doing for living and what grade and subject do you teach or you last taught or you last enjoyed teaching.

**Information about Informant.** Warm-up Questions: These questions focus on the interviewee's background on teaching science, and his/her experience in using ICT tools.

1. In which schools did you do your final year of teaching practice (2012/2010/2009) and briefly tell me about the ICTs situation in those schools? [Take note of the availability of ICT's in each school and their quantum/district/ situation analysis]

2. Which grade(s) did you teach science and which science subject did you teach? [refer to the table in page 1 for specific subject and grades for each student label e.g. A,B,C,&D]

3. Were there ICT resources in the schools wherein you did your teaching practice? Were there any restrictions on teachers or student teachers on the use of these resources? [e.g. needed password or teacher access code to use].

B. **General Questions.** These questions focus on how the pre-service teacher used ICT tools to support teaching of science during teaching practice.

4. Could you describe how you used ICT tools to support your science teaching during lesson preparation or during lesson presentation or for class activities or homework during the teaching practice?

5. What motivated/demotivated you to make or not to use of the ICT tools mentioned (Listen for peer influences/personal influences/teacher education program & teacher educator or teacher monitor push etc.)

6. Which ICT tools or resources do you envisaged yourself using more frequently in future as a science teacher and why? If you had to go back into TP

7. Let's talk about each specific ICT tool (these tools were collected from lesson plans that indicated the use of ICTs). Did you use these tools, are you aware of them and how did use it for if you did use it (Explain how was it used). [Researcher goes through the list one by one asking and noting how ICT is used in the teaching of science and what are the reasons of not using ICT's].

   - Data management tools: e.g. MS Word, MS excel, MS power point presentations.
   - Digital Tools: Multimedia CDs/DVDs, Videos, Electronic Whiteboard, Digital projector
   - Educational sites: e.g. mastering biology, big brother sites
   - Web-based Tools: e.g. internet, emails, google search, LMS (Moodle)
   - Content-specific Learning Software: e.g. games, simulations, tutorials
   - Repository tools: e.g. usb, clouds, drawbox, external drive, CD.DVD,

- Emerging technology: podcast, i-pod, chat, mobile technology (phone or tablet)What were the current technologies during your TP

C. **<u>Pre-service teacher Learning</u>:** These questions focus on what motivated the use and how challenges and opportunities are/were handled.

8. What do you think prepared you more to start using ICT tools or resources in the first place? Right at the beginning when you first used that specific ICT tool (It can be at the lecture hall, micro teaching or experimental teaching)? (Listen for class attendance and/or lecturing or observation from peers or lecturers or observation of experienced teachers in the schools).

9. For each one of the ICTs you have used or not used, what were the challenges you experienced or that led you to use or not use it? (Ask them to specify the tool and give reasons for either use or non-use)

10. Now, let us turn to the opportunities and advantages you see when using these ICT tools and resources: For each of the tools that you are using, tell me about the advantages or opportunities that you see in using them. (Ask them to specify the tool and give reasons for either use or non-use)

D. **<u>Wrap-up Questions:</u>** These questions focus on thanking the interviewee and for any additional information to be added by either an interviewer or interviewee. Give the interviewee a big Thank You! Inform her/him on what is will be next step, if any follow-up has to be done.

11. Is there anything else regarding the use of ICT tools/resources to teach science that happened during teaching practice that we did not cover maybe and you would like to add?

# APPENDIX C: LESSON PLANNING FORM

[redacted]

**FAKULTEIT OPVOEDKUNDE / FACULTY OF EDUCATION**

**LESBEPLANNINGSVORM: INTERMEDIêRE, SENIOR EN VERDERE ONDERWYS- EN OPLEIDINGSFASES**

**LESSON PLANNING FORM: INTERMEDIATE, SENIOR AND FURTHER EDUCATION AND TRAINING PHASES**

[redacted]

| | | | | | | |
|---|---|---|---|---|---|---|
| **1.** | **Student:** | | | | | |
| **2.** | **Studentenommer / Student number:** | | | **3.** | **Datum / Date:** | |
| **4.** | **Skool / School:** | **5.** | **Graad:**<br>**Grade:** | **6.** | **Duur van Periode:**<br>**Duration of period:** | |
| **7.** | **<u>Vak:</u>**<br>**Subject:** | | | | | |
| **8.** | **Lestema / Lesson Theme:** | | | | | |
| **9.** | **Spesifieke doelstelling(s) vir les:**<br>**Specific Aim(s) for lesson:** | | | | | |
| **10.** | **Situasie-analise: Gee slegs veranderlikes vir hierdie les (leerders, onderwyser, gemeenskap, leerinhoude, klaskameromgewing). Gee die volledige situasie-analise vir skool in leêr aan dosent.**<br>**Situation analysis: Give only variables for this lesson (learners, teacher, society, learning contents, classroom environment). Give the full situation analysis for school in file to lecturer.** | | | | | |

**11.** ***Watter van die 7 Algemene Doelstellings aangespreek in les? / Which of the 7 General Aims addressed in lesson?***

**Mark (with a X) MOSTLY TWO applicable General Aims that this lesson can equip learners with for life.**

**Merk (met 'n X) HOOGSTENS TWEE Algemene Doelstellings waarmee hierdie les leerders vir die lewe kan toerus.**

| 1. Identifiseer en oplos van probleme – kreatiewe denke. / Identify and solve problems – creative thinking | 2. Effektiewe samewerking in groepe. / Work effectively with others | 3. Bestuur jouself op 'n verantwoordelike wyse. / Organise and manage oneself responsibly | 4. Versameling, analisering, organisering, evaluering van inligting. / Collect, analyse organise and critically evaluate information. | 5. Effektiewe kommunikasie op verskillende wyses. / Communicate effectively | 6. Die effektiewe aanwending van wetenskap en tegnologie. / Use science and technology effectively and responsibility | 7. Openbaar begrip vir die wêreld. / Understand the world as a set of related systems |
|---|---|---|---|---|---|---|
| | | | | | | |

**12.** **<u>Lesdoelwit(te)</u>: Wat spesifiek moet die leerders teen die einde van die les met die inhoude kan doen (doel van les) (dui die aksies met aktiewe werkwoorde aan: *nie* ken, weet en verstaan nie)?**

**<u>Lesson Objective(s)</u>: What specifically should the learners be able to do with the contents by the end of the lesson (purpose of lesson) (indicate actions with active verbs: *not* know and understand)?**

| | | | | |
|---|---|---|---|---|
| 13. | Volledige lesinleiding / Complete lesson introduction: | | | |
| 14. | Lesinhoude (struktureer die inhoude van die les volledig onder toepaslike hoofopskrifte). *Voeg ekstra blaaie met kolomme agteraan hierdie lesplan by indien meer ruimte benodig word.* Lesson Contents (structure the contents of the lesson fully under appropriate headings). *Add extra pages with columns at the back of this lesson plan if you need more space.* | Dui aan watter metodes, aktiwiteite, bronne en onderwysmedia gebruik gaan word. (Voorbeelde agteraan lesplan geheg.) Indicate which methods, activities, sources and educational media will be used. Examples attached to the back of lesson plan | Lesinhoude (struktureer die inhoude van die les volledig onder toepaslike hoofopskrifte). *Voeg ekstra blaaie met kolomme agteraan hierdie lesplan by indien meer ruimte benodig word.* Lesson Contents (structure the contents of the lesson fully under appropriate headings). *Add extra pages with columns at the back of this lesson plan if you need more space.* | Dui aan watter metodes, aktiwiteite, bronne en onderwysmedia gebruik gaan word. (Voorbeelde agteraan lesplan geheg.) Indicate which methods, activities, sources and educational media will be used. Examples attached to the back of lesson plan |
| | KOLOM 1 / COLUMN 1 | | KOLOM 2 / COLUMN 2 | |
| | Vervolg in kolom 2 / Continue in column 2 | | | |

<table>
<tr><td rowspan="2">15.</td><td colspan="4">Assessering / Assessment</td></tr>
<tr><td><u>Hoe assesseer? / How Assess?</u></td><td colspan="2"><u>Wat? (kennis van…/ Vermoë om…)<br>What? (knowledge of … / Ability to…)</u></td><td><u>Deur wie? / By who?</u></td></tr>
<tr><td>16.</td><td colspan="4">Op watter wyse maak u voorsiening vir Diversiteit (leerderverskille) en leerhindernisse in hierdie les?<br>How do you make provision for Diversity (learner differences) and barriers to learning in this lesson?<br><br><u>Diversiteit / Diversity</u>:<br><br><u>Leerhindernisse / Barriers to learning</u>:</td></tr>
<tr><td>17.</td><td colspan="4">Kreatiwiteit: Wat doen u in die les wat kreatief is?/Creativity: What do you do in the lesson that is creative?</td></tr>
<tr><td>18.</td><td>Vaardighede, Houdings en Waardes aangespreek (sien KABV, maar lei ook self af uit les en gee voorbeelde by elk):<br>Skills, Attitudes and Values addressed (see CAPS, but also derive from lesson yourself and give examples in each case):<br><u>Vaardighede (fisiese, kognitiewe en sosiale)</u><br><u>Skills (physical, cognitive and social)</u>:<br><br><u>Houdings / Attitudes</u>:<br><br><u>Waardes / Values</u>:</td><td>19.</td><td colspan="2">Tuiswerk / Homework</td></tr>
<tr><td colspan="3">Assessed by:</td><td colspan="2">Date:</td></tr>
</table>

## APPENDIX D: ETHICAL CLEARANCE LETTER

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS·UV
EDUCATION
OPVOEDKUNDE

**Faculty of Education**

30-Jun-2015

Dear Mrs Thuthukile Jita

**Ethics Clearance:** Pre-service teachers' competences to teach science through Information and Communication Technologies during teaching practice

**Principal Investigator:** Mrs Thuthukile Jita

**Department:** School of Education Studies (Bloemfontein Campus)

With reference to you application for ethical clearance with the Faculty of Education. I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence is:

**UFS-HSD2015/0268**

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours Sincerely

Dr M.M. Nkoane
Chairperson: Ethics Committee
Faculty of Education