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Pre-service teachers' competence to teach science through information and communication technologies in South Africa

Abstract

Research suggests that there is a need for better training of prospective teachers on information and communication technologies (ICTs) in order to encourage their use for teaching and learning in schools. This paper presents findings on the self-perceptions of competence by pre-service teachers to use ICTs for teaching science content. A mixed method approach was used where 103 final year pre-service teachers completed a questionnaire on their competence to use ICTs for teaching and 21 of them participated in focus group interviews concerning their experiences with ICTs during teaching practice. Results show that pre-service teachers seem to be more competent in the non-technology related skills compared to the technology related knowledge fields and that there are significant variations in their ICT competences. These variations largely result from the uneven opportunities to learn that are provided to the pre-service teachers. More significantly, the directional trend shown by the correlations indicates that the more lecturers or mentor teachers use ICT tools to teach, the more pre-service teachers learn to use ICT tools in their own teaching. The paper concludes with a discussion on the implication of these findings for policy and practice and specifically suggests that there is a need to review the policy guidelines on the development of the teacher education programmes to be more deliberate in their inclusion of ICTs. The key recommended contribution is for teacher preparation programmes at universities to be restructured in order to improve the training of future teachers on the use of ICTs to teach science.

Key words: pre-service teachers, science education, information and communication technologies, teaching practice, teacher education, technological pedagogical content knowledge (TPACK)

1. Introduction

There is a great deal of variation in terms of how prospective teachers use ICTs to teach their subjects (Hennessy *et al.*, 2007). The variations range from some pre-service teachers who are uncomfortable and avoid using ICTs in class to those who are highly skilled and deploy ICTs with reasonable comfort and enthusiasm to the benefit of their learners. Closing the competence gap in the use of ICTs by teachers and students in general and the preparation

of teachers in using ICTs for teaching and learning remain important social justice issues in the 21st century technology driven world (Cuban & Cuban, 2009; Tarman, Baytak & Duman, 2015). Pre-service teachers' development of competence to teach science subjects using ICTs requires knowledge, skills and opportunity to learn during the teacher preparation programmes. As a result, many higher education institutions have had to redesign and redevelop their teacher education programmes, partly to include the ICT competence knowledge and skills that are required by teachers of various subjects. Thus, teacher education programmes are viewed as important vehicles for equipping a new generation of teachers with ICT skills to enable the teaching of content in the various subjects.

This paper examines the use of ICTs by pre-service teachers in one of the critical subjects in South Africa, namely, science. ICTs are not just an option for improving teaching and learning nowadays but a necessity for social justice in terms of breaking the "digital divide" (Nykvist & Mukherjee, 2016). By investigating the use of ICTs by science pre-service teachers in schools during teaching practice, the paper also seeks to provide answers to two other related questions. Firstly, whether and how the teacher education programme aligns with the national expectations for ICT usage for teaching the school curriculum and whether and how the teacher education curriculum serves the national requirement for ICTs to be considered a fundamental learning area for all pre-service teachers in South Africa.

2. Background to the study

In its recent policy guidelines for teacher education programmes, the Department of Higher Education and Training (DHET, 2013) classifies ICTs as a fundamental learning area 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 guidelines and/or national research-generated recommendations 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. There is thus a clear gap in terms of how teacher educators are expected to break the "digital divide" in their preparation of prospective teachers.

Literature suggests that even when they complete their studies and begin working, in-service teachers remain potentially unprepared to use ICT tools in the classrooms despite being trained during teacher preparation (Niess, 2005). Local researchers in South Africa have also demonstrated that although in-service teachers are trained to use ICTs in various government and non-government initiatives, many are still not competent to use ICTs in their subject teaching (Mlitwa & Kesewaa, 2013; Ndlovu & Lawrence, 2012). Collectively, the current evidence seems to point towards a disturbing conclusion that the bulk of the training of in-service teachers to teach with ICTs does not seem to contribute to competent teaching using 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.

At the schooling level, the national Department of Basic Education (DBE) in South Africa has tried to provide some guidance on the subject of ICT integration by requiring that "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 is also in line with the 2006 Council on Higher Education's (CHE) report, which recommends 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: 22). Both these arguments underscore the need to include the use of ICTs for subject teaching in the teacher education programmes. The trend in many universities is to offer special courses on ICTs for the pre-service teacher education students and/or to recommend that lecturers integrate technology in their subject method courses. While universities encourage ICT usage in their policies and the integration of ICTs in the modules offered, the barriers in the use of ICTs during teaching practice for specific subjects remain unclear. It is important, however, that student teachers 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 specifically focus on such integration of ICTs during teaching practice, in particular.

The main objective of the research is to establish prospective teachers' levels of knowledge and skills on ICT tools that are appropriate for teaching science through the examination of their TPACK competencies. Specifically, the paper seeks to understand the practices of pre-service teachers in terms of using ICT tools during teaching practice by presenting findings from an investigation of pre-service teachers' competence in the use of ICTs at one South African university by asking the following questions:

1. What are the pre-service teachers' perceived competencies with respect to their technological pedagogical content knowledge (TPACK)?

2. How can the pre-service teachers' competencies be understood and explained?

3.   Review of relevant literature and theoretical framework

This review of literature seeks to answer the question on what is known about the preparation of pre-service teachers to use ICTs for subject teaching in order to present a theoretical framework for examining the use of ICTs to teach specific subjects. Many universities seek to enforce the integration of technology through policies and investment in various ICT infrastructures (Valtonen *et al*., 2015). For instance, most South African universities include ICTs across all courses offered within the teacher education programme. Yet, there are no defined stipulations on the required competence levels and/or required usage criteria by pre-service teachers during teaching practice. Thus, teaching practice is regarded as a useful platform to provide a training ground for pre-service teachers to build their confidence and competence in the use of ICTs. This paper presents data from a survey and interview study of the ICT competencies of final year pre-service teachers after completing their final or last teaching practice placement in their teacher education programme.

Teaching practice exposes pre-service teachers to a number of experiences that are designed to promote the integration of theory and practice. Those experiences include coherence of theory from the university-based modules offered in the teacher education programme and the practical application of ICT skills to teach school subjects such as natural sciences, life sciences and physical sciences. Since ICT and methodology courses are part of the theoretical preparation of teachers during teacher education, it is important for pre-service teachers to practise the skills taught and be evaluated not only on the theory but also in terms of their actual performance and/or application during teaching practice. Kabilan and Izzaham (2008: 87) argue 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. However, Liu (2012) argues that teacher education modules fail to mentor the use of computers in the classroom during teaching practice. Therefore, it is important for teacher education programmes to facilitate what is learned in these programmes and the practical application of ICTs in schools.

It is the responsibility of teacher education programmes (TEP) 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) highlights the quality and quantity of ICT courses in TEP, the training of the mentor teachers in schools and the availability of ICTs for use by pre-service teachers during teaching practice in schools as factors that are important in influencing the development of competent teachers. The present study, therefore, sought to triangulate all known obstacles and opportunities that have the potential to shape the competence of pre-service teachers by examining their university-based ICT training while at the same time examining their in-school experiences and mentoring support.

Many studies have used the technological pedagogical content knowledge (TPACK) framework to study the integration of ICTs by in-service teachers and/or to examine the theoretical knowledge of pre-service teachers on ICTs (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. Moreover, the use of TPACK instruments in South Africa is still in its infancy as it has only been successfully used in a secondary data analysis study investigating the level of TPACK for grade 8 mathematics in-service teachers (Leendertz *et al*., 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. The current study opted to use the TPACK instrument, which has been successfully tested and validated in other international studies. TPACK is a framework that has been articulated by several researchers in the field of ICT integration in schools (Mishra & Koehler 2006; Schmidt, Cogan & Houang 2011). 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 (1986) is that TPACK begins to describe additional and specific dimensions of knowledge that subject specialists need in order to integrate technology successfully into their teaching. 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. Lin *et al*. (2013), who have used the TPACK framework to study the integration of ICTs in Singapore, advocate for more such studies across the world. This paper thus responds to this call and uses the TPACK framework 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. 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 (e.g. during teaching practice and with content such as science).
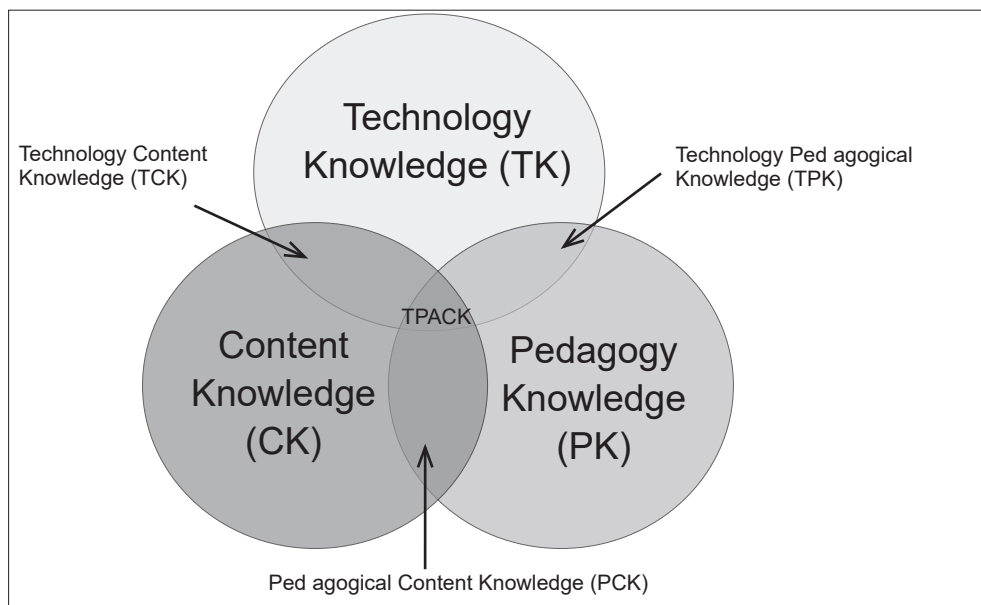

Figure 1: TPACK model for pre-service teachers' use of ICTs

(Adapted from Mishra & Koehler, 2006: 1025)

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 also represents the application of specific knowledge of science content, practical use of ICT knowledge and the art of teaching. Thus, it demonstrates the interactions among the TPACK concepts that can provide a measure of competence on the use of ICTs by pre-service teachers. TPACK thus gives a solid theoretical framework with which to examine many of the issues that arise when learning to combine technology, content and pedagogy in the teaching of science.

4. Methodology

This paper reports on findings from an in-depth case study of one university, with two campuses, where a TPACK survey was administered together with semi-structured focus group interviews. The case study "presents and represents reality" of teaching specific content with ICT tools in different teaching and learning environments for different content topics in different grades and phases of education (Cohen, Manion & Morrison, 2011: 129). The case study design was better placed to provide rich insights on a specific teacher education programme and a group of final year pre-service teachers. A mixed method approach was

chosen for the study. A concurrent, triangulation mixed methods design was adopted where data from the TPACK survey was triangulated with data from the focus group interviews (Creswell, 2014). The TPACK survey for pre-service teachers consisted of 59 close-ended questionnaire items adapted for the South African context, to assess the ICT competencies for teaching science (Schmidt *et al.*, 2009). The researcher administered the TPACK survey, with assistance from one of the methodology course teacher educators, during and after the students' return from a teaching practice period of two consecutive weeks in schools. The questionnaire included items on the demographic information of the students, while the rest of the questions centred on the sources of ICT skills, the seven TPACK domains (TK, CK, PK, PCK, TCK, TPK, TPACK) and the models of TPACK. The items were rated on a five-point Likert scale scored from zero for "strongly disagree" to four for "strongly agree". The information was captured in an Excel sheet and analysed using the South African Statistics (SAS) software.

A pilot study was conducted with newly graduated science teachers (N = 5) to test the reliability of the TPACK instrument. The pilot study helped me to modify the final survey items and the focus group questions (Creswell, 2014). The adaptations to the survey included the removal and restructuring of a few questions and some of the wording changed to reflect the familiar South African terminologies better. It also enabled the use of language with which the participants would be familiar. In Cohen *et al.* (2011), it is argued that it is important to have more structured interview questions to provide reliability to the study.

Ethical clearance for the study was obtained from the university's ethics board, the necessary permission was obtained from the faculty management and the science teacher educators involved. The study selected a cohort of final year science pre-service teachers doing either the Bachelor of Education (B.Ed.) qualification or Postgraduate Certificate in Education (PGCE), with specialisations in physical sciences, natural sciences and/or life sciences. One hundred and three participants had engaged 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 103 pre-service science teachers who participated in the study gave their informed consent prior to completion of the survey and again at the beginning of the semi-structured focus group interviews. Assurances were provided to the participants that their contribution was voluntary and that they could withdraw at any time during the study should they wish to do so, without influencing their marks in either the methodology modules and/or ICT modules. The pre-service teachers were invited to participate in a focus group interview after completing a survey and through an online announcement in their methodology subject platform on Blackboard. The invitations resulted in 21 volunteers who participated in the four (4) focus groups 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. In the next section, I first explore the perceived competencies of the pre-service teachers from the survey before providing a possible explanation from interview discussions.

5. Results

The first research question is "what are the pre-service teachers' perceived competencies with respect to the technological pedagogical content knowledge (TPACK)?" The TPACK survey was used to examine sources of ICT skills, knowledge areas and the opportunities to learn for pre-service teachers. The analysis used the SAS program to identify and average a number of variables for each knowledge domain (Schmidt *et al*., 2009).

Table 1 below presents descriptive statistics for the seven TPACK scales showing mean scores, standard deviations, minimum and maximum values. The mean scores show differences in the three non-technology related and four technology-related scale scores. The mean scores of the non-technology related domains were the highest with mean values above three, that is CK (M=3.32) and PK (M=3.18). This is an indication that the participants regard content knowledge (CK) and pedagogical knowledge (PK) as more important than technology-related knowledge domains' mean scores such as TK (M=3.02), which had the lesser mean score. This implies that pre-service teachers' knowledge on technologies is lower than the content and pedagogical knowledge required to teach science. The standard deviation for all seven TPACK scales were less than one and varied between 0.44 to 0.60, which indicate that data points were all relatively close to the mean and remarkably consistent.

Table 1:   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

Additionally, a paired t-test was performed to determine whether there was a statistically significant mean difference between the non-technology related domains (CK and PK) and technology related domains (TK). Table 2 below confirms with the paired t-test results that the difference in mean values above are statistically significant and are not due to chance. The p value results (Table 2) show content knowledge with technology knowledge (<.0001) and pedagogical knowledge with technology knowledge (0.0053).

Table 2: Paired t-test analysis of technology and non-technology knowledge

Paired knowledge areas	Paired differences					t	df	p
	Mean	Std. Deviation	Std. Error	95% confidence interval for mean difference				
				Lower	Upper			
TK -CK	-0.2906	0.5285	0.0521	-0.3939	-0.1873	-5.58	102	<.0001
TK-PK	-0.1534	0.5466	0.0539	-0.2603	-0.0466	-2.85	102	0.0053

The interview data provided further evidence of competency on the non-technology related domains, with a lack of competency on the application of the technology knowledge for teaching science specifically. When participants were asked to describe how they used ICTs during teaching practice, all of the pre-service teachers provided examples on how they used ICTs for lesson preparation and specifically to enhance their knowledge of the science concepts they were going to teach. The use of various ICT tools by the pre-service teachers for lesson preparation and presentation was mentioned several times during the interviews but did not include details on how learners were to engage with ICTs during the teaching of the science subject. Here is an example of how one pre-service teacher articulated the point,

> *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 (Group one, 2).*

The emphasis in the quote is clearly on the use of ICTs for preparation and personal development and less on actual use with learners during the lessons. Furthermore, when asked about how they used each specific tool identified in the TPACK survey to teach science during teaching practice, it was evident that the pre-service teachers did not take the ICTs into the classroom for student engagement per se. The following extracts from two of the participants exemplify the perspectives on the use of ICTs in the classroom.

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

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

Consistent with the TPACK survey results, where the items that focused specifically on the TPACK knowledge dimension yielded the second lowest mean score of M=2.97, pre-service teachers' TPACK knowledge was inadequate. Participants in the focus groups also confirmed being unable to implement TPACK due to constraints experienced in the teaching practice schools, such as a lack of ICT resources or a lack of mentor support. Some of the participants in the different focus groups shared their views as follows,

> *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).*

The point of the argument is that mentors are not always necessarily knowledgeable about how to use the available ICT resources either. Another participant corroborated the point about the lack of support or guidance from mentors by saying,

> *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).*

This is one indication that the pre-service teachers had expected to be guided and supported by their mentors on the use of ICT resources for teaching. The guidance and support on the use of ICTs was however not always forthcoming, as suggested by the preceding quotes.

In summary, the data seems to suggest that the pre-service teachers were not skilled in the technology-related knowledge domains that are a pre-condition for using ICTs to teach. Thus, it was perhaps not surprising that the pre-service teachers did not use ICTs extensively for classroom activities as opposed to their use for planning purposes. How then do we begin to understand and explain the pre-service teachers' weaknesses in the technology-related knowledge domains and the lack of ICT usage for classroom teaching? The next section presents data to explore this second research question.

To understand and explain the findings, I first examined the two possible sources of ICT competence for student teachers in general, viz. from the teacher educators (lecturers) and from the mentor teachers (in schools during teaching practice). That is, I asked the following question: what or how are the opportunities to learn (OTL) about ICTs for the pre-service teachers in the TEP and then specifically during the in-school experience. Results from pre-service teachers' opportunities to learn provided answers on the development of competence in terms of the opportunities to learn that are available to the pre-service teachers first from the teacher educators (lecturers) and second from the mentor teachers in the teaching practice schools. The survey results on TPACK modelling 1; examine how science content, ICTs and teaching approaches are applied practically by lecturers and by mentor teachers in order to model good practice for the pre-service teachers. TPACK modelling 2; on the other hand, reports on the amount of time involved in the modelling by the various role models, in order to estimate the quantity of modelling that may lead to improved learning on the use of ICTs by the pre-service teachers.

Table 3:   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 results in table 2 suggest that participants agreed that lecturers and teachers were exemplary in combining content, ICTs and different approaches to the teaching of science and thereby role modelled for them on how to use ICTs for teaching the subject. In contrast, the mean for TPACK models 2 was low, thereby suggesting that the amount of time available for

role modelling is perceived as being less than ideal or perhaps even inadequate for the pre-service teachers to acquire the necessary competence to use ICTs on their own.

Qualitative data relating to opportunities to learn from the models of TPACK was used to confirm the findings of the quantitative data analyses through the following interview questions:

What motivated/demotivated you to use any of the mentioned ICT tools, if at all?

The responses to this question revealed that the campus-based lecturers and the school-based mentor teachers motivated most students to use ICTs. A few of the participants, for instance, indicated that they were motivated by the ways in which their lecturers taught them at the university. Thus, lecturers seem to be effective TPACK role models for combining content, technologies and teaching approaches in their lectures. 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: 61). For example, one participant argued,

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).

Similarly, the school-based mentors also played an important role as described by two other participants who were motivated by their mentor-teachers.

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 good at using the computer for everything and I had to teach like him (Group three, 4).

These statements provide support to the quantitative evidence, which suggests that the teacher educators and the school-based mentor teachers have the potential to model for pre-service teachers how to use ICTs for teaching the subject.

Despite the positive effects of mentoring and campus based lectures, a larger number of participants felt demotivated by their school-based mentors and did not want to use ICTs. Here is how one participant described the latter situation,

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).

The results suggest that pre-service teachers' opportunities to learn from lecturers and in-service teachers varied and seem to be shaped by the nature of the relationship with their mentors. As argued by other researchers, most of the pre-service teachers can be expected to be native immigrants of ICTs but there seems to be a change when they have to teach, they become dependent on others such as mentors (Wentworth, Graham & Tripp, 2008). These findings appear to point towards one important factor that shapes the ICT competence of pre-service teachers, namely, the mentorship capabilities and opportunities in schools during teaching practice. The variations in the use of ICTs for teaching science among the pre-service teachers can thus be understood in the context of and explained by the differences in opportunities to learn, especially as set out in the schools where teaching practice takes place.

6. Discussion

The main research question for this paper was "what are the competences of pre-service teachers to teach science using ICTs during teaching practice?" The findings 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). Lin *et al.* (2013), among others, informed the research and call for further research to assist science teacher educators in the review of methodology courses to prepare competent pre-service science teachers. Descriptive statistics were used to examine the results of competency on the TPACK knowledge domains (CK, PK, PCK, TK, TCK, TPK and TPACK). This was followed by in-depth analysis of all technology related knowledge areas (TK, TCK, TPK and TPACK) with the purpose of examining the data on the use of the ICTs to teach science content during teaching practice and looked at the significant role of ICTs when pre-service teachers teach 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. These findings are in line with the view of Koh and Chai (2011) who found that there are positive levels of competence on CK, PK and PCK areas relative to the technology-related knowledge domains. 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). The present research went even further by disaggregating the level of competence on the four technology-related knowledge domains (TK, TCK, TPK and TPACK) and tracking the OTL of such skills. An important twist in the analysis relating to the technology-related knowledge domains (TK, TCK, TPK and TPACK) was the finding that pre-service teachers seem to be aware of many ICT tools available for teaching but lack the knowledge of subject specific ICT tools and experience challenges on how to use various ICTs during teaching practice to teach science content. This is an important finding because it suggests that awareness of ICT tools is inadequate to enable their use for subject teaching during teaching practice. To explain the variations in the use of ICT tools for teaching science, the paper suggests that there are two major explanatory variables. First are the 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, especially with respect to the technology domain of the TPACK knowledge. The differences in ICT module requirements for the various groups of pre-service teachers account for some of the variation in the technology knowledge domain competence. For example, the curriculum for the intermediate and senior phase (middle and senior primary) pre-service teachers includes a compulsory ICT related module, which is not the case for the further education and training phase (high school) group. Notwithstanding the differences in the coursework requirements that may account for variations in competence, the bulk of the explanation seems 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. Pre-service teachers can also be assigned to mentors who are themselves not adept users of ICTs, let alone being able to mentor them in the use of ICTs for teaching. The second variable thus points to the uneven distribution of opportunities to learn that are provided to the pre-service teachers during the teaching practice period. These findings call for a more carefully considered and structured TEP, 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 practise with cutting edge ICTs for teaching science. They should also 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 notion of this paper is that the richer the quality of opportunities to learn, as defined by the university-based coursework and the in-school-based opportunities for practise in the use of ICTs, the better the chances for developing competence among all pre-service teachers to use ICTs for subject teaching.

7. Conclusion

This study was limited by the fact that it was conducted at one university and with only one group of final year science pre-service teachers. 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 using ICTs, caution should be exercised in doing so. A larger scale study that compares data from different programmes and universities is recommended.

Although there are variations in the ICT competence of pre-service teachers for teaching science, teaching practice remains an ideal platform for students to learn through practise and it provides a platform for the application of knowledge for teaching or what is called craft knowledge. As part of developing competent pre-service teachers, an establishment of the support systems focusing on subject-specific use of ICTs during teaching practice is recommended. Collaboration and better communication with curriculum developers, teaching practice schools, teacher-educators and mentors is thus called for in this regard. All stakeholders need to play a role in the development of competence by pre-service teachers in order to bridge the digital divide and address the social justice issues on the use of ICTs for teaching and learning in schools. This is particularly vital in the context of South Africa, where there are no clear performance standards for teachers in schools and/or assessment guidelines for teacher educators on ICT competence.

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