THE PEDAGOGICAL USE OF ICTS IN GRADE 8 MATHEMATICS IN SOUTH AFRICAN SCHOOLS[2]

Verona Cassim[a], A. Seugnet Blignaut[a], HJ Nieuwoudt[b] & CJ Els[a]

[a] School of Continuing Teacher Education, Potchefstroom Campus, North-West University

[b] School of Curriculum-based Studies, Potchefstroom Campus, North-West University

This paper presents the findings of secondary data analysis of the South African dataset of SITES 2006 (Second Information Technology Education Study), the latest of three ICT in Education studies of the IAE. The aim was to determine to what extend ICT contributed towards the pedagogical use of ICTs in schools across the world. The study comprised three survey instruments aimed at the mathematics teachers, science teachers, school principals, technology coordinators, and the National Research Coordinators of the participating 22 countries and education systems. The international data became available in 2008 for participating country's in-depth analysis. The current analysis takes into account the ICT aims as set out in the e-Education Policy that aims to have ICT's integrated at all levels of the education system, i.e. management, teaching, learning and administration, by 2013.

INTRODUCTION

The technological era demands that learners develop higher order thinking skills (HOTS) during school education. Mathematics one of the foundation learning areas of the curriculum and has an important role in the development of HOTS to accomplish the tasks relevant to achieving the outcomes and developing skills like conceptualising, abstraction, generalisation, problem solving and information-processing (Nieuwoudt, 2006). The South African education system should adapt to the change and use information and communication technology (ICTs) to enhance the development of HOTS through integrated ICT teaching and learning (Republic of South Africa, 2004). The problem-centred approach (PCA), which is also a socio-constructivist approach, is proposed as the best practice for mathematics education at school level (Nieuwoudt, 2006). Through PCA activities, mathematics is not based on drill and practice exercises, but relates to the active engagement of learners in mathematical problems and activities relating to their immediate environments. Two cornerstones of PCA are problem-solving contexts and social interaction (Nieuwoudt, 2006). According to Murray *et al*. (1998) social interaction creates opportunities for learners to talk about their own thinking which is essential for meta-cognition and reflective thinking. Reflective thinking is an important requirement for effective learning (Du Plessis & Webb, 2008). Learners learn from the knowledge they construct during social interaction with their peers. Meaningful problem solving and HOTS occur within learner-learner and teacher-learner relationships which develop during such social constructivist interaction.

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e-EDUCATION WHITE PAPER

In accordance with the National Department of Education's (NDoE) obligation to deliver on public expectation, growth as well as the assurance that every learner in the General Education and Training (GET) and Further Education and Training (FET) band will be ICT literate by 2013, a three phase implementation model with specific priorities and actions, creates alignment with the capacity and national educational budget. Phase I (2004-2007) focuses on the enhancement of system-wide and institutional readiness to use ICT in teaching and learning. Phase II (2007-2010) focuses on the system-wide integration of ICT's into teaching and learning and Phase III (2010-2013) ICT's integrates ICT at all levels of the education system—management, teaching, learning and administration (Republic of South Africa, 2004).

SITES 2006 IN SOUTH AFRICA

During 2004-2006 South Africa participated in large scale survey Second International Information Technology in Education Study (SITES 2006) conducted by the International Association for the Evaluation of Educational Achievement (IEA) supplying the 22 participating systems with an extended view on the pedagogical practices of ICT across the world (Pelgrum & Law, 2008). The study constructed four questionnaires that were administered to school principals, ICT coordinators at schools, mathematics and science teachers, and the research coordinators of the participating countries in a probabilistic sample of more than 400 schools per country or education system whereby respondents in 504 non-computer using and computer using schools in South Africa completed the survey.

SITES 2006 focused on the role ICT play in the teaching and learning of mathematics in schools and examined how it can contribute towards the development of 21st century skills. ICT usage in general in grade 8 encountered the lowest usage level in South Africa, which was only 18% for mathematics and 15.9% for science. Even though South Africa has an ICT policy in place and acknowledges that certain changes within the systems need to take place. South African data frequencies indicate that the majority of South African mathematics and science teachers in grade 8 are not confident in performing some of the most basic ICT functions.

PEDAGOGICAL USE OF ICT

The pedagogical use of ICTs consists of two main components, namely the application of pedagogy and the use of ICTs. Mishra (2008) refers to the importance of having a sound technological pedagogical content knowledge (TPCK) to ensure the effective integration of ICTs in schools. Pedagogy is an active method of teaching with confidence using certain techniques, strategies and technologies to attain pedagogical goals within a specific environment, as well as assisting learners through interaction and activity in the ongoing academic and social events of the classroom

(BlogSpot, 2008; Farlex, 2009). It is also known as the study or scientific method of teaching where the teacher has to acquire relevant pedagogical knowledge and techniques to be able to teach competently and confidently (BlogSpot, 2008). Besides having adequate pedagogical knowledge, teachers should be knowledgeable about the content of their subject (content knowledge) as well. The third important element in the TPACK (Baran *et al.*, 2011), a strand at the Society for Information Technology and Teacher Education (SITE) and American Educational Research Association (AERA) conferences (Mishra, 2008), represents technological knowledge. Technological knowledge is the ability to use the ICTs in teaching and learning of content knowledge to learners. ICTs are characterised as artificial and symbolical technologies implemented in schools to facilitate the teaching and learning process (Bosco, 2004). Technological tools such as graphing calculators, geometric software, multimedia tools and the Internet are useful tools in teaching and learning mathematics (Jarred, 1998).

THEORETICAL FRAMEWORK

The conceptual framework which all these factors are embedded known as *Technological Pedagogical Content Knowledge* (TPACK) and not merely a basis of technology, pedagogy, content and teaching with technology but the foundation of this research (Mishra & Koehler, 2006).

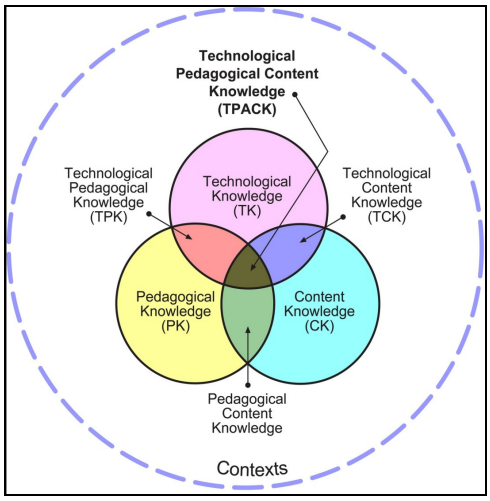

Fig. 1: Technological Pedagogical Content Knowledge Framework (Mishra, 2008)

RESEARCH DESIGN AND METHODOLOGY

The study followed a basic secondary data analysis (SDA) using the data of the stratified sample of the 504 computer using and non-computer using schools in South Africa which participated in SITES 2006; representing the data from 640 mathematics teachers' questionnaires. The dataset allowed the researcher to explore different themes and correlations between variables that were not calculated and reported by the main study, without any further data collection. In order to determine whether TPACK knowledge in grade 8 mathematics contributes towards more effective mathematics teaching

in schools, Question 21 J (from Part VII of the SITES 2006 *Teachers' questionnaire* on the pedagogical use of ICT (I know in which [K] teaching and learning[PC] situation to use ICT [T] was used as the main variable, then correlated with as many possible other variables within the same teachers' questionnaire, to answer the main research question: *To what extend can knowledge of the pedagogical use of ICT's in grade 8 mathematics contribute towards more effective mathematics teaching in* schools*?* (SITES, 2006b).

In order to address the first research question: *What is the pedagogical use of ICTs for the teaching and learning of grade 8 mathematics in South African schools?,* the frequency tables of the dataset for mathematics teachers were used to identify how grade 8 mathematics teachers use ICTs for teaching and learning. To address the second research question: *To what extend can knowledge of the pedagogical use of ICT's in grade 8 mathematics contribute toward more effective mathematics teaching in schools?,* descriptive statistics and cross tabulations are calculated. In many cases it is important to know whether there is a relationship (correlation) between two variables.
For random sampling, statistical relationships (correlations) between variables were determined with Chi-square tests and effect sizes but what was imperative is whether the relationship is large enough to be important (Ellis & Steyn, 2003). In such cases the statistical significance tests (e.g. Chi-square tests) were used to show that the result was practically statistically significant. Chi-square is a sampling distribution that gives probabilities about frequencies (Spatz, 2008). An effect size $V \leq 0.2$ is considered a small effect with no or very little significance. An effect size $0.3 \leq V \leq 0.4$ is considered a medium effect that tends towards a practically significant correlation. For the purpose of this investigation, an effect size $V \geq 0.5$ (preferably $V \geq 0.8$) is considered a large effect which indicates a practically significant correlation. In order to complete the SDA for the second research question, the Statistical Consultation Service of the North-West University assisted in the cross tabulation analysis using SPSS® 16.0 for Windows (SPSS, 2007). Only medium and large effect sizes (Phi and V values ≥ 0.3) are reported. Both phi coefficient and Cramer' V can be considered as effect sizes (Ellis & Steyn, 2003)

RESULTS

Pedagogical use of ICT

Table 1 gives a summary of the pedagogical use of ICTs for the teaching and learning of grade 8 mathematics in South African schools.

Use of ICT	Findings from the SITES 2006 and the SDA of this study
General use of ICT	• Mathematics teachers (42.22%) used word-processing with confidence to create documer (e.g. tests and exams) • Respondents were less confident in the use of emails, electronic filing, and spreadsheets • Few teachers (13%) had email accounts • Some schools (67%) had access to the Internet for teachers
Pedagogical use of ICT	• Most respondents (48.96%) had no confidence in knowing in which teaching and learning situation to use ICT

Use of ICT	Findings from the SITES 2006 and the SDA of this study
	• Teachers struggled (46.02%) to find curriculum resources on the Internet • Teachers struggled (52.59%) to monitor learners' performance using ICT • Teachers were not confident in the pedagogical use of ICT • Few teachers used ICTs in planning, monitoring, supporting and conducting pedagogical activities
Learners' competence with operating skills	• Few learners (44.59%) could use word-processing • Few learners (54.71%) could access database software • Almost no learners (60.62%) could operate data-logging tools
Impact of ICT on teachers	• Little or no (39.21) change in teacher's ICT skills • Teachers struggled with confidence to operate ICT and software • Many of teachers (32.70%)did not use ICT to monitor learners' progress • Teachers acknowledged (61.57%) ICT did not make than less effective teachers • Few teachers (34.70%) shared ideas with colleagues outside their own schools
Barriers of ICT for teaching and learning	• Insufficient (42.77%) ICT skills all around • Not time (41.30%) to develop and implement ICT-related activities • Little support to develop ICT-related skills • Little confidence (41.25%) to try new approaches

Table 1. Executive summary of the pedagogical use of ICT for teaching and learning of grade 8 mathematics in South African schools

The use of ICT is trivial to most mathematics teachers in South African schools. Mathematics teachers do not have pedagogical knowledge [PK], content knowledge [CK], and technological knowledge [TK] which is central to ICT integration in teaching and learning. South African teachers experienced difficulties to represent concepts with the assistance of ICT. They do not have the pedagogical techniques to use ICT in constructive ways to teach mathematical content to learners and build new concepts from their existing knowledge. The insufficient TPACK contributed to the level of confidence in ICT when planning, teaching and communicating in grade 8 mathematics classrooms.

Fig. 2 gives results from the correlation study between the main variable (i.e. I know which [K] teaching and learning situations [PC] are suitable for ICT [T] use) and other variables in the SITES 2006 teachers' questionnaire. The main variable relates to TPACK (Fig. 1). Three main clusters (themes) of TPACK were identified, i.e. impact, teacher practices, and barriers.

Impact of ICT

The items pertaining to impact (grouped into two sub-categories, i.e. (i) insufficient ICT knowledge and (ii) learners' knowledge and skills) correlated to a medium effect ($0.3 \leq V \leq 0.4$) and a large effect ($V = 0.47$) with TPACK, which indicates that mathematics teachers had insufficient ICT knowledge to provide individualised feedback to learners using ICT. They were not able to use the ICT to incorporate new ways of learning, to monitor learners' progress, and to collaborate with peers outside the school to gain some knowledge to enhance their teaching practices. Many indicated that using ICT increased their workload and work pressure but if ICT are used effectively it can speed up and enhance work production (Osborne & Hennessey, 2003). Teachers' subject matter knowledge increased, indicating that even though they did not have sufficient

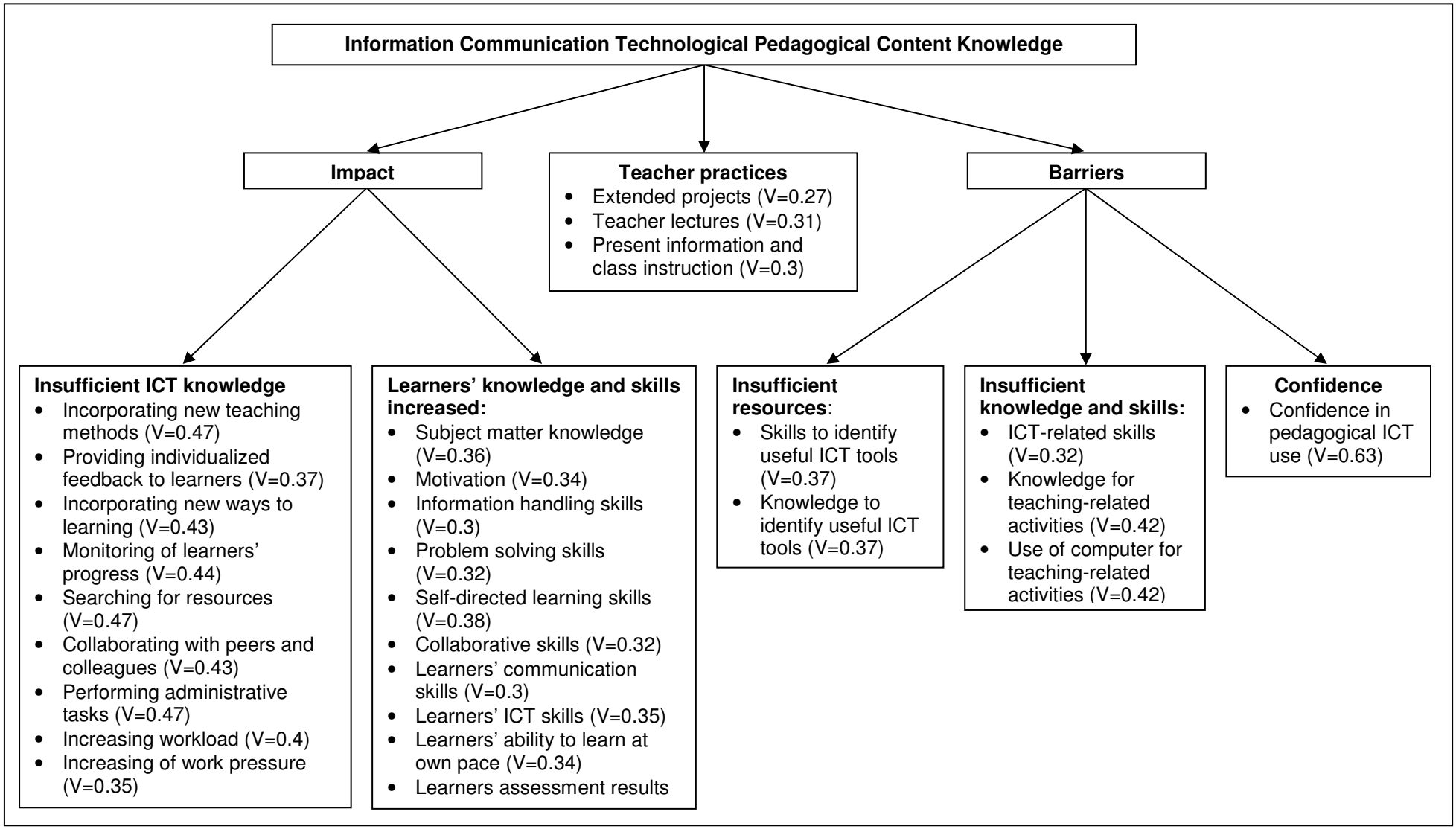

Fig. 2 Summary of the correlations study between the main variables and other variables from the SITES 2006 teachers' questionnaire

TPACK, ICT gave them the opportunity to explore with different ICT mediums to develop their mathematical content knowledge. An increase in motivation, information handling skills, problem solving skills which enable learners to be actively engaged in mathematical problems and activities relating to their immediate environment. Additionally learners' were able to work more independently as their self-directed learning skills increased. An enhancement in collaborative skills and learner communication as social interaction creates opportunities for learners to talk about their own thinking, essential for meta-cognition and reflective thinking. As learners' ICT skills developed they were able to learn at their own pace (Balanskat *et al.*, 2006). Overall learners achieved better results in their assessment. All the above tend towards practically significant correlations with TPACK.

Teachers' insufficient ICT knowledge to incorporate new teaching methods, to search for resources, and to do administrative tasks, which are imperative to teaching in general show practically significant correlations with TPACK.

Teacher practices

The items pertaining to teacher practices (one category) correlated to a medium effect (V = 0.3) with TPACK, which indicates that extended projects, teacher lectures and class instruction tend towards practically significant correlations with TPACK. As seen from the descriptive statistics and the correlation study, the majority of mathematics teachers did not have TPACK with regard to teacher practices. A total of 88.70% of the grade 8 mathematics teachers did not make use of ICT for extended projects. More than ninety percent (91.40%) of the grade 8 mathematics teachers indicated insufficient TPACK to use ICTs specifically in teacher lecturing. An interesting finding was that 62.50% of the grade 8 mathematics teachers who had adequate TPACK did not make use of ICT when teaching and learning. Only 29.90% of the grade 8 mathematics teachers had the TPACK and were able to present information, provide demonstrations, and facilitate a class using ICT. Only the teachers who had adequate ICT knowledge, made use of ICT in the various teacher practice activities.

Barriers

Figure 2 illustrates the items pertaining to barriers (grouped into three sub-categories, i.e. (i) resources, (ii) knowledge and skills, and (iii) confidence) correlated to a medium effect ($0.3 \leq V \leq 0.4$) and a large effect (V = 0.5) with TPACK. Teachers' had insufficient skills to identify ICT useful tools to transfer mathematical conceptual knowledge to their learners. They were unable to identify ICT useful tools, insufficient ICT related skills, insufficient knowledge for teaching-related activities, and insufficient use of computers for teaching-related activities. As only 15% of the 640 mathematics teachers in the SITES 2006 study were ICT pedagogically trained and

more than 60% of the respondents indicated they lacked knowledge about ICT use in teaching and learning and they did not incorporate new teaching methods using the multiple ICT's at their disposal (SITES, 2006a). Many barriers tend towards practically significant correlations with TPACK. The most practically significant correlation was the confidence in pedagogical ICT use with TPACK. The fact that teachers do not believe in the ability of ICT to enhance learning, have confidence in their learners and the contexts of schools, and their reluctance to change their deep-rooted teaching methods will require much effort to change (Handal, 2004; Ward, 2003). As seen from the descriptive statistics and the correlation study, teachers did not have adequate ICT skills and their insufficient TPACK to use ICT was a major barrier identified.

Conclusions

South Africa has to confront many challenges regarding integration of ICT in schools, eventually, making it impossible to compete with other systems in all areas relating to education, but in order for us to compete within a global society we have to deal with the inequalities within our system. An aim of the research was to determine the pedagogical use of ICT's is within the teaching and learning of grade 8 mathematics in South African schools, and to determine to what extend knowledge of the pedagogical use of ICT's is in grade 8 mathematics contribute toward more effective mathematics teaching in schools. If all these disparities are coherently dealt with it will ensure the level of teachers' TPACK increase, allowing South Africa to have an acceptable standard of ICT integrated education in a global society.

At system level South Africa firstly need to address the shortcomings within the e-Education policy. The Department of Education should deal with the social and economic disparities within the system. Nongovernmental schools must assist the NDoE in training teachers for in achieving the TPACK required for ICT integration. For the stages an integrated ICT curriculum program must be developed to assist teachers in knowing which ICT devices and software are applicable for the content taught. Even tough OLSET, Thutong Portal and other websites are available to assist managers and teachers in ICT integration these provisions are not adequate to address the shortcomings at system level, therefore more websites must be created specifically to assist schools in ICT integration.

School managers and SMT members must make ICT qualifications a prerequisite in all new staff appointments. SMT members must motivate teachers to attend ICT training to ensure teachers have a sound TPACK.

The four areas influencing the use of ICT of teachers need to be addressed: confidence, time, access to resources and adequate professional development. To raise the level of confidence of teachers they have to be exposed to sufficient professional development to increase TPACK. In order to raise the level of confidence of our mathematics teachers in South African schools from 30% to 100%, each stakeholder in education (system, school and teacher) must contribute to ensure teaching and learning with ICT in South African schools become part of the daily practices.

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