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Change of Science Teachers' Use of Information and Communication Technology (ICT) Media Resources and its Pedagogical Use in Science Classrooms in a Developing Country

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ABSTRACT Using quantitative and qualitative research, the present study explores and compares the variety of information and communication technology (ICT) resources in use by high school Science teachers, and how their pedagogical and technological use of ICT in Science classrooms have changed over the years. The initial quantitative study confirmed that only a few Science teachers used ICT multimedia, but more now use PowerPoint and internet searches for procuring data as well as more regularly for teaching. The initial qualitative study suggested that Science teachers are keen to use ICT, but some lack specialized ICT technological skills and pedagogical content knowledge skills, and this was not found to have changed in the final qualitative study. The study also suggested that teachers are keen to encourage learners to engage in constructivist learning, but are constrained by the ICT infrastructure prevalent in their schools. Where software media, internet and computers are accessible, they are not pedagogically and technologically easily integrated in classroom teaching due to limited time and accessibility of computer rooms. The present study has implications for the successful integration of ICT in Science classrooms for both Science teachers and ICT management at schools.

INTRODUCTION

The introduction of information and communication technology (ICT) media in schools is considered a necessity, based on economic, social and pedagogical rationales, and many governments worldwide have launched major programs and invested substantial capital to support ICT in education projects (Abdelwahed 2014; Chai et al. 2014; Dawson 2008; Draper 2010). These initiatives are expected to aid important educational reform whereby ICT-based teaching can transform both teachers and learners into active knowledge constructors and critical thinkers – a more appropriate profile for citizens of the Information Society.

Great strides have been made in education in the United Kingdom, United States of America (USA), Japan, India, Singapore and Turkey, among others, in using and researching the effectiveness of computers and ICT in teaching and learning (Chai et al. 2014; Gulbahar and Guven 2008; Toh and So 2011). In South Africa (SA), although the government has realised the impact of the digital divide, there is still a widening gap in ICT resources: some schools have ICT technologies that is parallel to those of their counterparts globally, while the disadvantaged and rural schools lag far behind (Department of Education (DoE) 2004; Howie and Blignaut 2009). While only some teachers and learners have computers at home and some schools have computer rooms, there can be little doubt that ICT has an important role to play in accessing a range of resources and knowledge in science education. Research in ICT skills, however, suggested that teachers are not well prepared to teach with the internet as its current use is "limited in scope and substance" and they will need more support to identify subject–related internet resources (Wallace 2004: 447). Hence, the need is for more research in technological, pedagogical and content knowledge (TPACK) use of ICT in discipline areas (Chai et al. 2010; Kalogiannakis 2010). TPACK presents an active framework for describing teachers' knowledge required for "designing, implementing, and evaluating curriculum and instruction with technology. TPACK strategic thinking includes knowing when, where, and how to use domain-specific knowledge and strategies for guiding students' learning with appropriate information and communication technologies" (Niess 2011: 299).

ICT incorporated in Further Education and Training for the Grades 10-12 science curriculum in SA (DoE 2003) is intended to promote effective methodologies in teachers' learner-centred engagement in their subject specialisation, as well as to address issues of integration of knowledge and technological skills development. In the light of this intention, critical research questions must be posed to evaluate the

suitability and effectiveness of ICT technologies used for science instruction. For instance, which ICT resources were and are now being used by science teachers? What kinds of teaching strategies in ICT are now being used to teach science at schools, and what still limits science teachers' effective TPACK use of ICT? A deeper analysis of teachers' TPACK use in ICT over a period of time as new resources become available is necessary to inform us of progress.

This comparative study addresses these issues and first quantitatively examined 135 science teachers' practices of use of ICT resources in schools in a province of SA in 2007, and in a qualitative follow-up case study in 2009 explored the TPACK use of ICT by four teachers in selected secondary schools. The study was repeated in 2014, with 53 of the 135 teachers participating in the quantitative study and four of the same teachers and their schools in the qualitative study.

Science and Mathematics results are poor in SA, and researching discipline teachers' TPACK in ICT is a crucial factor to enhance teaching and learning (Mji and Makgato 2006). At present, there are hardly any comparative studies of TPACK use of ICT in the Science curriculum in Southern Africa (Draper 2010; Howie and Blignaut 2009).

Review of the Literature

In Science, computers are now used to develop a wide variety of scientific skills, from traditional drill and practice, tutorials, simulations, modelling, data-logging and CD-ROMs to presenting information and use of the internet. The use of spreadsheets and programs have made data capture and representation less time-consuming, and more time can now be spent on analysis and interpretation of data in Science laboratories.

Research suggested that both learners and teachers benefit from the use of CD-ROMs in education (Treacy 2009). For teachers, safety and ease of gathering data using simulated experiments reduced laboratory preparation time. A number of researchers view computers as having an influential effect on the teaching and learning processes, and believe that schools would become more learner-centred and that more individualised learning would take place than ever before (Abdelwahed 2014; Warschauer and Matuchniak 2010; Webb 2005). Early ICT studies in education (Mumtaz 2000) focused mainly on tutorial work, simulations, data capture and effects of ICT on learners' learning, and the role of the teacher and problems in implementation. It is not surprising that due to the scale of investment in ICT, questions are being asked about its effectiveness and value for money. The benefits of computer instruction are many, including motivating learners when teachers use different teaching strategies to improve learning (Bennett 2003; Bingimlas 2009).

Researchers generally agree that there is a digital divide between home and school use of computers (Warschauer and Matuchniak 2010) and that computers in schools have not had the desired effect expected of enhancing Science teaching and are also not fully utilised in South African schools (Howie and Blignaut 2009). Warschauer and Matuchniak (2010) also reported that a lack of adequate training for the teachers, high-quality software and hardware, TPACK integration of ICT in Science, and the amount of time teachers need to develop lessons are problems still to be resolved.

There is a combination of many factors that teachers must consider in using ICT, such as multiple instructional strategies, the interactions between students and learners' prior knowledge, and not merely the use of a computer. In SA, a developing country, Draper (2010) in a doctoral study involving 267 Grade 8 Science teachers found that when Science teachers have access to ICT, they are able to use it effectively to add value to teaching and learning. Unwin (2011: 113) reported that there is "a gulf between the rhetoric of those advocating the use of ICT in education in Africa and the reality of classroom practice." He argued for fundamental principles of good practice that must be addressed for such programmes to be effective, such as the integration of ICT practice within the whole curriculum and appropriate educational partnerships.

However, Chai et al. (2014: 3), in a recent review, sum up the major factors that determine the success or failure of ICT integration in educational institutions, and it depends on the interaction between "teachers' attributes akin to innovating and designing, and contextual variables such as access and support for the technologies and the envisioned pedagogies". They add that teachers' perceived barriers to ICT integration include their training in technological

knowledge, availability of equipment, time constraints for lesson planning, and lack of technical support and their pedagogical beliefs.

Theoretical Framework

Of relevance to this study is teachers' pedagogical content knowledge (PCK) (Gess-Newsome and Lederman 1999; Shulman and Shulman 2004) of how ICT is integrated into Science teaching. An important factor in determining teachers' beliefs is their notion of PCK, the kind of knowledge that develops at the interface of content and pedagogy that facilitates understanding of the organisation, and representation and adaptation of themes, problems and issues related to disciplinary knowledge to suit the particular contextual challenges prevalent in a teaching and learning context (Mumtaz 2000). Science teachers often negotiate with the ICT and media teachers in planning their lessons and using ICT specialist rooms. Linn and Hsi (2000) report on pedagogical issues in Science education that use ICT, and produced a list of pedagogic principles that include social aspects such as encouraging students to learn and listen to one another, designing social activities to promote productive and respectful interactions, and employing multiple social activities while engaging in ICT/Science-related tasks.

Recently, the three basic components of knowledge essential for teaching, namely, content knowledge (CK), pedagogical knowledge (PK) and technology knowledge (TK) have been integrated into a new term called technological pedagogical content knowledge or TPACK. TPACK refers to the knowledge required by teachers for integrating technology into their teaching in any content area (Mishra and Koehler 2006). In this model described by Mishra and Koehler (2006), teachers need to have an intuitive understanding of the complex interplay between these components. For instance, when teaching content (CK) they must be able to choose the appropriate pedagogical methods as well as select the technology to effectively present the lesson. Hence, they also need to have technology knowledge (TK), which refers to the knowledge about various technologies, ranging from low-tech technologies such as pencil and paper to digital technologies that include the internet, computer simulations, interactive whiteboards, discussion forums and software programs. They need PCK, which refers to the content knowledge that deals with the teaching process and is different for various content areas, as it blends both content and pedagogy with the goal being to develop better teaching practices in the content areas. They will also need technological content knowledge (TCK), which refers to the knowledge of how technology can create new representations for specific content. Technological pedagogical knowledge (TPK) refers to the knowledge of how various technologies can be used in teaching, and to understanding that using technology may change the way teachers teach. The model helps teachers to understand that by using a specific technology they can change the way students practice and understand concepts in a specific content area.

METHODOLOGY

Teachers in this study came from both an urban and rural community setting in the broader district region of the KwaZulu-Natal province in SA. Most schools have at least a few computers in the office and a fair proportion offer Computer Literacy, with most urban schools offering Computer Science. Teachers in the province come from different cultural backgrounds; most speak English and Zulu (isiZulu). A quantitative research design in 2007 followed by a qualitative in 2009 were undertaken, and followed up in 2014. The study is structured into four groups, A, B, C and D (Table 1). Permission to conduct the study was obtained from all authorities, namely the DoE, principals and teachers. The quantitative study (group A) formed part of a large quantitative ICT study undertaken to examine ICT resources available at schools in the selected province in SA (Govender 2006), and the results of this research are not reflected in this study. The time-lines for the studies are presented in Table 1.

In the 2007 quantitative research design, an extraction of data from the larger study was conducted (group A), where all 135 secondary Science teachers in the district region of the province were purposefully selected to form group B sample. These data formed the quantitative aspect of this study that investigated their current practices of use of ICT resources. This was followed by observations of ICT resources of 10 schools (group C) conveniently selected from

Table 1: Time-line structure of the study

Groups	*Year*	*Schools*
Group A	2006	191 High schools (alternate sampling from 382 schools) in Ethekwini, KwaZulu-Natal, and 1222 questionnaires received from teachers
Group B	2007	135 schools from group A and 135 Science teachers' questionnaires purposefully selected
	2014	53 Science teachers' questionnaires obtained from group B
Group C	2009	Observation visits in 10 schools conducted and schools selected from group B in a convenient sample
Group D	2009	4 schools selected from group C in a purposeful sample and interviews with 4 Science teachers conducted on school site
	2014	Same schools and teachers participated in interviews on school site

group B due to travel distance from the researchers' university. Finally, four schools (group D) were purposefully selected from group C due to facilities and use of ICT in Physical Sciences. Three males and one female teacher volunteered for classroom observations and for informal interview discussions held after their lessons. Data were recorded as field notes during classroom lessons and informal interviews with teachers, as they were reluctant to be digitally or voice recorded.

In the follow-up study in 2014, 53 teachers from the group B sample provided new quantitative data and the same four teachers from the same schools from group C were once again interviewed.

RESULTS

The Quantitative Study (Group B)

The following analysis of data (Tables 2-7) was based on extraction of data from questionnaires from a larger study where 1222 secondary teachers from 191 schools in the district region of KwaZulu-Natal province in SA were surveyed. Based on the new technology initiative in South African education (DoE 2004), this quantitative aspect of the study explored the use of ICT by 135 high school Science teachers. The study explored and compared the use of the internet by Science teachers in 2007 (Table 2) and in 2014 (Table 3), Science teachers' proficiency in ICT in 2007 (Table 4) and in 2014 (Table 5), and Science teachers' use of technology in the classroom in 2007 (Table 6) and in 2014 (Table 7).

Table 2 indicated that in 2007 the most common use of the internet was for a weekly search for educational materials and communicating via email, followed by use for teaching in class by approximately 13% of teachers, and by 8% only for class teaching. This was not alarming, given the lean distribution of access to internet in KwaZulu-Natal schools in this period. It is also evident that the majority (74.1%-97.8%) of these Science teachers did not use the internet for teaching. There are several reasons for the lack of use of the internet, which are discussed later.

A comparison of Table 3 with Table 2 displayed that there was a higher rate of internet usage in 2014 on a daily and weekly basis, and that 78% of teachers now use the internet. The 12% difference is possibly due to teachers living in rural areas; they have no need to use the internet and are still using traditional textbooks and chalkboard only. At least 42% of teachers are now using the internet on a weekly basis to search for education materials (up from 13.3%). Eighty per cent are using the internet for email on a daily and weekly basis and 78% for downloads. There has been an increase in the use of the internet on a monthly basis, possibly due to teachers paying monthly bills via the internet.

Table 2: Use of internet by Science teachers in 2007 (%)

Statement	*Daily*	*Once or twice a week*	*Once or twice a month*	*Less than once a month*	*Never*
Use internet for teaching	3.0	8.1	8.9	5.9	74.1
Use internet for educational material	2.2	13.3	14.1	8.1	62.3
Use internet for email	7.4	14.8	9.6	5.2	63.0
Use internet for downloads	0.7	3.0	5.9	2.2	88.2
Use internet for other purposes	0.0	0.0	1.5	0.7	97.8

Table 3: Use of internet by Science teachers in 2014 (%)

Statement	*Daily*	*Once or twice a week*	*Once or twice a month*	*Less than once a month*	*Never*
Use internet for teaching	34	34	8	12	12
Use internet for educational material	28	42	12	18	0
Use internet for email	38	42	8	12	0
Use internet for downloads	28	50	22	0	0
Use internet for other purposes	18	24	46	12	0

Table 4 reflected that 71.8% of the teachers consider themselves (moderate to high) proficient in using a computer. However, their proficiency seems to lack experience in the use of the internet, and about 40% lacked a more sophisticated use of computer software packages like PowerPoint. Between 47.5% and 83.7% have little or no proficiency in electronic resources, discussion groups, e-mail and internet searches. It is also evident that 79.3% of teachers have no or little proficiency in use of software specific to Science teaching.

A comparison of Table 5 with Table 4 revealed that 100% of the sampled teachers in 2014 are now using computers, data projectors, word-processing and emails (moderate to high). The application aspects such as databases, software use, web design, electronic resources and discussion groups are still minimally used or not at all.

Table 4: Science teachers' proficiency in ICT in 2007 (%)

Proficiency in using	*None*	*Little*	*Moderate*	*High*
Computers	9.7	18.5	45.9	25.9
Digital cameras	22.9	28.2	37.0	11.9
Scanners	38.5	22.2	26.7	12.6
Data projectors	59.2	23.1	13.3	4.4
Word processing	19.3	11.9	31.9	37.0
Spreadsheets	23.0	15.6	32.6	28.8
Databases	32.6	20.0	32.6	14.8
Graphics programs	45.2	27.4	14.8	12.6
PowerPoint	48.9	20.0	15.6	15.5
Software specific to subject	61.5	17.8	14.1	6.6
Website development	72.6	15.6	8.1	3.7
Electronic references/resources	45.9	17.8	22.2	14.1
Discussion groups / List-servers	70.3	13.4	12.6	3.7
Email	34.8	12.6	29.6	23.0
Internet searches / search engines	33.4	14.1	25.2	27.3

Table 5: Science teachers' proficiency in ICT in 2014 (%)

Proficiency in using	*None*	*Little*	*Moderate*	*High*
Computers	0	0	46	54
Digital cameras	0	32	34	34
Scanners	8	24	30	38
Data projectors	0	12	42	46
Word processing	0	0	50	50
Spreadsheets	8	24	26	42
Databases	55	30	12	3
Graphics programs	55	34	8	3
PowerPoint	0	0	54	46
Software specific to subject	88	0	4	8
Website development	84	8	4	4
Electronic references/resources	72	16	4	8
Discussion groups/List-servers	76	16	4	4
E-mail			73	27
Internet searches/Search engines			73	27

Table 6 confirmed that in 2007 the majority of these Science teachers did not use a computer in their teaching (69.7%). It is quite possible that teachers do not use discussion groups, email and internet searches because they do not have internet access. However, it is surprising to find that 82.2% and 94.8% of teachers respectively do not use electronic resources and software specific to the subject, who do not require internet access or a networked environment, since stand-alone PCs and CDs can be used. These findings are supported by our qualitative study in Science classes in four secondary schools in this region in 2009.

A comparison of Table 7 with Table 6 reveals that in 2014 about 50% of the sampled teachers are now using the internet and PowerPoint in classroom teaching, whereas in 2007 69.7% did not use these in their teaching. While internet access has increased (as evident in Table 3), other aspects such as software, email and electronic references are still hardly used (in the range of 68%–98%).

The Qualitative Study

General Observations of Media Resources in 10 Selected Schools in KwaZulu-Natal (Group C)

As teacher educators we had opportunities to visit 10 schools in the sample in the district region in 2009 and observe the kind of resources that were being used. The 10 schools were purposefully selected due to close proximity to the university, and as these teachers also volunteered to participate in the research. The researchers also interacted informally with the teachers and made field notes. Textbooks and notes are still used as the main source of information for learning and teaching in Science teaching in these schools. All 10 schools had video machines and televisions, and due to lack of easy access and media management this resource becomes a task to manage for most teachers. Only four schools had a media teacher. Five schools did not have adequate educational video resources, which created problems for teachers. A few teachers borrowed materials from a Science resource centre. In SA the television channels SABC beams out school programs in Science and Mathematics. These are useful to Grade 11 and 12 learners for revision in examinations. Unfortunately, teachers reported that these are not accessed during school times due to lack of access to a media room and the compressed Science curriculum.

Although a variety of Science education CD-ROMs are available and now affordable, few schools with computers are using CDs in Science, except encyclopedias like Encarta. The principals cite low budget as the main problem.

Table 6: Science teachers' use of technology in the classroom in 2007 (%)

Used the following in teaching	*Daily*	*Once or twice a week*	*Once or twice a month*	*Less than once a month*	*Never*
Computer	13.3	7.4	4.4	5.2	69.7
Data projector	3.0	0.0	0.7	3.7	92.6
PowerPoint	2.2	1.5	0.0	6.7	89.6
Software specific to subject	2.2	0.7	1.5	0.7	94.8
Electronic references/resources	2.2	4.4	3.7	7.4	82.2
Discussion groups	0.7	2.2	0.0	1.5	95.6
Email	5.2	4.4	2.2	5.2	83.0
Internet searches	5.2	4.4	3.0	8.1	79.3

Table 7: Science teachers' use of technology in the classroom in 2014 (%)

Used the following in teaching	*Daily*	*Once or twice a week*	*Once or twice a month*	*Less than once a month*	*Never*
Computer	22	12	12	4	50
Data projector	22	12	8	4	54
PowerPoint	20	12	8	4	56
Software specific to subject				8	92
Electronic references/resources	12	4			84
Discussion groups	4	4			92
Email	16	12	4		68
Internet searches	16	8	4		72

Visiting schools and observing the limited use of computers for teaching (as evidenced also from Tables 2, 4 and 6) suggested that computers at home may play a more significance role in developing teachers' ICT skills than those at school. Teachers report that their proficiency in ICT was acquired through self-training, formal ICT courses and from the tertiary curriculum. Four teachers of the 10 from semi-rural poor communities were not familiar with computer skills. A major review study also showed that ICT skills are less accessed by teachers in schools of lower socio-economic status (SES) (Warschauer and Matuchniak 2010).

A detailed description of the use of ICT in four selected secondary schools for the qualitative study is given below. Science teachers and principals were interviewed and observations were made in Science classrooms. The schools' names have been changed to ensure confidentiality. The case studies report general ICT facilities in the schools, teachers' Science content lessons using ICT and teachers pedagogical use of ICT in class. These four case studies describe in a qualitative way how ICT multimedia, namely textbooks, videos, televisions, CDs, computers and the internet are used in teaching Science in these selected secondary schools and how the socio-cultural setting of the school impacts on Science teaching.

Case Studies of ICT Use in Four Selected Secondary Schools

Wellington Secondary

Wellington Secondary is a well-resourced school of middle SES in the Durban South region and was visited in 2009. This school has launched its multimedia room with much fanfare from the DoE and community. There are 40 computers in the computer room for Computer Science learners. Teachers have internet access to four computers in a boardroom and another 12 computers are for learners' use with internet facilities in a secured media centre. This computer room is also available to learners during lunch times and before and after school. Learners pay minimum amounts for printing and use of the internet. The media teacher controls the centre.

The school has purchased CDs in Science, Maths and Languages for the high school curriculum. The head of department (HOD) was initially reluctant to embrace ICT use in Science for Grades 11 and 12 as she was syllabus-bound and had little time. At the following week's visit we were pleasantly surprised when the HOD and her Science teachers were more enthusiastic, and she requested more support in ICT and use of CDs and said that she would welcome assistance from the researchers. The principal welcomed the Science lecturers to explore how the internet was used in classroom Science teaching. An HOD remarked during an interview that these were new fads and that one needs someone to sustain the use of ICT in schools, which they cannot afford.

Carol, a young female Science teacher in this school, was keen use the internet in her teaching. We gave some advice on accessing data and a site was found on chemical reactions. She explored the site and planned to teach learners how to search the internet and access sites. However, the media room was locked in spite of prior arrangements, which caused some delay to the start of her lesson. The learners (40) were excited and half the class was ask to sit in front of computers, with groups of four to each computer (two sitting and two standing behind). The teacher requested learners with internet skills to be the leaders in each group. By this time some of these learners had already accessed sites with cars, etc., and minimised the screen when the teacher glanced at them. About 15 learners had used the internet before. Others were taught how to access Google search engine and type in the key words (chemical reactions + high school).

The site was selected and instructions were given by the Science teacher for learners to follow each section of notes. The first site covered chemical reactions in the home and simulated reactions of vinegar and baking powder; the learners soon realised that a 'kitchen is a whole chemical laboratory'. The second site covered combustion and safety issues. The discussion went on to a clip of the space-shuttle Discovery and fuels used to propel rockets. The exploded space shuttle Columbia was mentioned and how the gases oxygen and hydrogen combined and reacted, destroying the shuttle and its occupants, one being a school teacher. Carol indicated that the next session would take place in the laboratory, where some chemical reaction practicals will be done.

As learners were excited, Carol often had to raise her voice to gain control of the class. Each

group had to respond briefly on what they read and understood in chemical reactions. The class was busy, with some groups isolated as their computers failed to access the internet. Carol then joined the groups with unwieldy numbers. When the buzzer when off, reluctant learners dragged their feet -and the internet boffins quickly went back to their car sites. As we left the class, we could hear pleas from learners for the teacher to take them back to the media room for their next Science lesson.

Carol was clearly motivated by this experience and wanted to plan further lessons using the internet. She reported that she had not thought about using the internet to add to the everyday Science experiences of learners (for example, the space shuttle, which was current in the news, included combustion science). She felt that the site extended her own knowledge, and expressed the ease at which this knowledge could be obtained. She wanted notes for her own reflection to find out how her learners reacted, and asked them to summarize the Science ICT lesson and their experiences in a single page.

In 2014 a visit back to the school and an interview with the teacher showed more confidence in the use of internet and software, and the school now has wireless internet applicable to all classes, with limited code access as a safety device. The teacher was using PowerPoint, a data projector and simulation software to teach her Science lessons. When I visited the teacher, she was using smart-board technology with color electronic pens to teach a lesson on electricity. She also used a webcam to reflect students' work directly onto the smart-board and discussed conceptual errors made by learners to the entire class.

Seadoone Secondary

In 2009, Seadoone Secondary, a newly established private school in an upper economic area, with only four learners in Grade 11, had computer facilities in the laboratory. The Science teacher, Sam, in a first lesson, used the internet in class to access notes on redox reactions from a South African site. The notes were a simplified version of the textbook and contained examples, exercises and problems. Sam informed learners about the source of data. Towards the end of the lesson the class walked to the media centre which had been booked prior. There were computers connected to the internet, and the learners accessed the periodic table. Sam showed learners that by placing the cursor on the Hydrogen symbol in the periodic table, all the chemical data about the elements could be obtained. This intrigued the learners. Properties of the periodic table were briefly discussed. The learners were asked to explore this and other sites at home. The learners had to complete their homework using the internet at home.

The researchers interviewed learners informally about their first experience of using the internet in Science lessons, and they were amazed at the amount of data that could be obtained in Science from the internet. Up until now they had used the internet at home only for general surfing but not for Science learning.

In the second lesson (a week later), Science teacher Michael immediately took the class to the media centre as another class left. The researchers were amazed at the ease in which this class could walk from the laboratory into the media centre in an almost open-space set-up. Michael had planned this lesson, on sulphur chemistry, in advance, using a number of sites. Learners were asked to search for the element sulphur. One group typed 'sulphur chemistry', the other 'sulphur'. The 'sulphur chemistry' group immediately found some interesting sites and explored the images of types of sulphur and information on it. They were excited about the rhombic and monoclinic color images of sulphur. The 'sulphur' group found sites related to sulphur research, and got lost in a maze of information, and were brought back to the sulphur chemistry site by the teacher's intervention.

Compounds of sulphur were discussed using another site, and hundreds of sulphur compounds were quickly glanced over. Learners were amazed at the enormous amount of combinations of sulphur. A learner chose an interesting site of sulphur stars with spectra. Michael discussed how these stars were identified through line spectra and how in Astronomy atomic spectra play a crucial role in analysis of distant objects. He then took learners back to the laboratory to demonstrate the formation of plastic sulphur.

During interviews, learners were asked whether it was better to perform the practicals first or use the internet on sulphur practical simulations and theory. The learners unanimously

replied that seeing the final product first via simulation and then performing the practical was more effective in their understanding. The learners felt that there was a lot they learnt from this internet laboratory lesson. They learnt how to use ICT technology in Science lessons, chemistry and practical skills. They felt that now they were encouraged and could see value of using the internet in Science.

In 2014, a school visit and teacher interview confirmed that the school has smart boards, data projectors and internet access in all its classrooms and laboratories. The teachers use these resources effectively in class teaching and on a daily basis. The Science teachers use Yanka Electronics and free Physics Education Technology (pHET) simulation software packages to teach Science in an interactive way. All their learners had computer tablets at school and internet access at home. There was integration of class ICT with home ICT, as they are given homework where they need to use ICT. The school uses a Moodle system to communicate with all teachers and learners, and they have developed an active website with current information on school activities. The teachers have also undergone ICT training courses to implement pedagogical use of ICT in their lessons.

Vusikama High

Vusikama High is a school of average SES in Umlazi district, with relatively good Grade 12 results. In 2009 the traditional chalkboard method was the norm in this school in Science teaching. Grade 10 learners reported that no or little laboratory practical work was done and textbook work was written on the board with little discussion or explanation by the teacher. There was no media visible in classroom (no pictures, charts, overhead projector, etc.). The teacher, Bongani, reported that the Computer Science centre was used only by the principal, administration and Computer Science teachers for their learners. A Computer Science teacher reported that although the school has internet in her computer room and teachers are allowed to use it for their subject lessons, no teacher has yet taken this opportunity.

In a discussion with the principal it seemed that he was more concerned about learners' ICT skills and not his teachers' pedagogical ICT skills. He felt that his Science teachers were just coping with daily work and new curriculum issues and had no time for ICT training. The principal indicated that the school had plans to introduce a media centre with internet connections for access to learners and teachers. The school also has a close cooperation with a school in the USA, and learners in Grade 12 are in email communication with learners in a school in the USA. A researcher from the USA had recently visited and demonstrated the use of CDs, the internet, etc., in Science teaching to Bongani and his learners. The principal was keen to allow researchers to assist, as long as it was mainly for the learners' benefit.

In 2014, there was extended internet access at the school, but only for teachers' use. The classroom has data projection cages, but the projector was missing. The teacher indicated that due to theft they have to borrow the data projector and computer from the school administrator as it is stored in the steel safe. This makes it difficult to use on a daily basis, but he does book it and uses it weekly. He uses it mostly for pre-prepared PowerPoint delivery of Science lessons.

The teacher had a computer but no internet access at home, and hence was limited in the use of ICT at home. However, he uses some time at school to prepare his ICT-integrated lessons.

Beechwood Secondary

In 2009 a visit to Beechwood Secondary confirmed the provision of a computer room plus a newly built media room with internet access. The principal, a former Physical Science teacher, was keen on ICT and encouraged teachers to use ICT. The principal requested more support from researchers in ICT use in subject areas. He was keen to purchase CDs and so on for his school and motivated the governing body for funds in this regard. This school had created space in their timetables to allow compulsory use of two periods per subject per week to have access to the computer LAN.

Ben, the Science teacher, taught the topic of Light in Grade 10, using demonstrations from sites previously planned. Learners, in pairs, discussed reflection, refraction and interference of light waves. Real-time simulation provided a visual learning format for the learners. Ben reported that he had to search several sites the night before at home so that the learners would not waste their time searching the internet. He

planned to develop other lessons using the internet. When asked about laboratory experiments, Ben indicated that he will supplement the lessons with a few standard experiments, but felt the ICT simulations were pedagogically exciting and easy to use.

In 2014, it was found that the school uses data projectors and PowerPoint in most of its classes, including all its laboratories. The Science teacher indicated that he uses these facilities daily in the class and regularly download materials. He explained that with the internet and PowerPoint he can insert colorful pictures, videos and appropriate YouTube visuals in his Science lessons and the students enjoy these lessons.

DISCUSSION

Visits to the low-SES schools in 2009 suggested that daily activities of traditional textbook and chalkboard teaching were the norm. The pressure of external examinations, a new curriculum and implementation issues, meetings, assessment processes, discipline and funding were the main activities and consumed most of their time. Fund-raising to pay for normal school maintenance and administration took most of teachers' and principal's time, and budgets left little for 'luxuries' like ICT.

High SES like Seedoone and Beechwood were better resourced, had a well organized curriculum, sponsors from business and community, and high school fees and budgets to accommodate ICT needs. These schools have active and resourceful media centers with computers and internet for learners and teachers, more administrative staff, extra governing body-paid teachers and smaller numbers of learners (20-25) in class. These provisions and structures made it possible for the teachers to organize small group of learners to participate in argumentation and discussions where learners engaged in collaborative learning using ICT. It was evident that in these schools traditional teacher-centred lessons had switched to learner–centred classrooms using ICT.

Sam and Ben in the high-SES schools had more time to improve the understanding of scientific concepts of their learners, and integrated their learning with different media such as visual data and real-time simulations. In contrast, disadvantaged, low-SES schools like Vusikama had many social and discipline problems, security issues, funding issues and teaching and learning problems to attend to. The schools' economic status reflected the home economic status of the learners in all four cases. The home environments and socio-technical factors that support or constrain the use of computers and the internet in schools, often heighten the educational inequity present in a developing country like SA.

A comparative study of school technology use in high SES and low SES schools (Warschauer et al. 2004) showed that low SES schools tended to have less stable teaching staff, administrative staff, and information technology support staff, which made planning for technology use more difficult, especially for ICT-subject teaching. Warschauer et al. (2004: 581) reported that the high SES schools also "tended to invest more in professional development, hiring full-time technical support staff and developing lines of communication among teachers, office staff, media specialists, technical staff, and administration that promoted robust digital networks". This, in turn, "encouraged more widespread teacher use of new technologies". In comparison, "the low-SES schools had achieved less success in creating the kinds of support networks that made technology workable".

In the present study, a similar observation was made, and teachers in low-SES schools were less confident and had less technical support, and hence were more reluctant to rely on using ICT in their Science lessons. Vusikama had a Computer Science room, but this was rarely used by Science and other subject teachers. Science teachers in high-SES schools were keen to explore the internet or computer in their teaching when it was available. Teachers in both low- and high-SES schools were generally too busy with the new curriculum changes, and did not have the time to explore or use the internet (even if it was available), as they were busy with assessment and laboratory work. These schools were generally not using videos, television or CDs in class. The overhead projector was also rarely used.

Traditional teaching is still being done at both low- and high-SES schools, as found in these four cases, with little and superficial group work. It seemed that only when teachers were supported by the researchers that ICT with subject integration became a useful pedagogy. Generally, there seems to be a lack of enthusiasm

from management, compounded by infrastructure difficulties in using media, even though there is acknowledgement that ICT skills are essential for teaching and for school leavers. It was easier to teach on the board, give examples and exercises (not real problem solving) than engage in the daily infrastructure hassles of ICT inclusion in Science lessons.

Besides, in the study, the role of the teacher in constructivist learning is observed. In the three high-SES schools the teachers focused on learners using the technology to develop deeper understandings, and accessed more materials than the traditional textbook. Also, learners were actively engaged as participants in selecting the sequence of learning (see Seadoone Secondary). Other studies have found differences not only in constructivist versus rote applications of technology, but in different types of constructivist activity: that occurring in low-SES schools is more typically focused on what Scardamalia and Bereiter (2003) call 'shallow' as opposed to 'deep constructivism'. In these instances, individual or collaborative student-centered work, such as writing newsletters or finding information on Web pages, was often carried out with very limited goals, such as development of the most basic computer skills, rather than the achievement of deeper knowledge, understanding, or analysis through critical inquiry, as more frequently occurred in high-SES schools (Scardamalia and Bereiter 2003).

In 2014, a visit to these four schools and discussion with teachers revealed that due to easier, faster and cheaper internet access, the schools were accessing data and using ICT resources in the school administration and classrooms for teaching and learning, although at different levels. The three schools with resources and adequate funds upgraded their facilities and ICT infrastructure and trained their teachers. This motivated their teachers and managers to implement ICT in the administration of the school and in the classrooms. Learners who had access to ICT facilities at home were also given integrated homework, and so used the internet regularly at home and school. The schools which still had poor funding, safety and resources made the internet available to the teachers only, and while there was use of free ICT software packages by motivated Science teachers, they were limited by the infrastructure and lack of easy access to computers and data projectors.

CONCLUSION

The study investigated and compared the quantitative and qualitative use of ICT by Science teachers in schools in 2009 and 2014, in a province in SA. In the quantitative aspect of the study (group B), in 2009 135 science teachers' use of ICT multimedia was reported and the results are given in Tables 2, 4 and 6. The quantitative study revealed that the most common use of the internet was a weekly search for educational materials and communicating via email, followed by use of teaching in class by about 13% (19 of 135 teachers). The significant concern is that the majority (over 80%) of these Science teachers did not use the multimedia resources available for integrated ICT pedagogical teaching, as evident in Table 6.

In 2014, 53 Science teachers' use of ICT multimedia was reported and the results are given in Tables 3, 5 and 7. The quantitative study revealed that the most common use of the internet was a daily and weekly search for educational materials and communicating via email, followed by use of PowerPoint in teaching in class. The significant concern is that the majority (over 75%) of these Science teachers still do not use the multimedia resources available for integrated ICT pedagogical teaching, as evident in Table 7.

The quantitative studies show that in 2009 and 2014 the majority of Science teachers are competent in the general use of the computer, but still only a minority use it together with the relevant Science software and use the internet on a regular basis in their teaching. While the quantitative study showed lack of access to ICT rooms and lack of training in specific skills, the qualitative study showed that those schools where the Science teachers had regular use of the computer and science software and the internet did integrate ICT skills with Science skills. They also used a constructivists approach and addressed sociocultural needs of their students, facilitating students to dialogue and share knowledge.

The qualitative study of the four cases (group D) of teachers' pedagogical use of ICT in the Science classroom revealed that these teachers reflected a positive attitude and did include use of the internet in Science teaching and learning. They also facilitated collaborative sociocultural constructivist learning in class through discussions and group-work. The learners were

more active in learning. However, the teachers reported that they needed intensive training and classroom guidance in PCK in ICT, preferably supported by subject and ICT discipline specialists. The qualitative study also suggested that teachers were waiting for some impetus such as easier access to ICT rooms or external pressure from management to make effective ICT use in Science classrooms.

With data taken a few years ago, in 2007 (Tables 2, 4 and 6), analysis revealed the status of use of ICT with limited resources, skills and use in the classroom. However, with a more recent dataset in 2014 (Tables 3, 5 and 7), analysis showed some improvement in competency levels as well as use of computers in the classroom, especially updating on new ICT materials and use of data projectors, PowerPoint presentations and software simulations. We attribute these changes to limited government and industrial contributions in provision of some ICT resources, such as computers and data projectors, and a higher degree of motivation by administrators and teachers to keep abreast with provision and use of ICT resources and also learners' advancing knowledge of ICT.

IMPLICATIONS

The qualitative study, although limited by only being four cases, implies that teachers can seek innovative ways of instruction using ICT and generate new skills in their learners, for example analysis of detailed images, movie clips, and use of simulations. As SA Science laboratory resources are limited and performance in external matric examinations are poor, using ICT – especially with learners of different abilities and cultural and resource backgrounds – can further motivate learners to experience Science and Technology in action, and thus improve performance in Science. However, to effect significant changes in multimedia use, Science teachers need to believe that their efforts will be worthwhile and appreciated in improving Science education. ICT technology requires negotiation, collaborative decision-making and curriculum adaptation, and constant updates by all those who use it. Although technology-related access, use and outcomes are difficult to measure, all available evidence suggests they are critically important factors in shaping social-cultural futures.

As the quantitative study was carried out in 2007, there have been some developments, since then, in infrastructure of ICT-computer rooms and teachers' proficiency in using the internet, PowerPoint etc. Later visits to the schools (2009,2014) showed that some Science teachers are using simulations and so on in Science classes, but these are mainly highly motivated individuals in well-resourced schools, and there still remains a large gap in the regular pedagogical use of ICT/Science-relevant programmes in Science classes.

The study implied that an integrated approach towards ICT in Science education requires the development of exemplary ICT-based Science lessons and the training of Science teachers on instructional skills for these lessons. A useful and practical way to short-circuit the ICT time-lag that may arise due to slow bureaucratic interventions is for Science educators (teachers and lecturers) to effectively share information and ICT skills through the formation of Science-ICT subject societies in local school districts, where online materials can shared and discussed.

Further, the advancement and sustenance of regular ICT use in schools on a long-term basis requires funding, personal and professional commitment, technical support and collaboration amongst administrators and all educators. This has implications for the way in which national, regional and local education ICT departments plan and operate with school districts and subject teachers. The study suggested that an ICT management team should be formed in schools which liaise with the DoE, tertiary institutions and private funders for further and sustained educational support.

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