Pedagogy and ICT use in South African Science Education

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Abstract

The purpose of this paper is to present work in progress as part of the analysis of the South African SITES 2006 data which forms the basis for an ongoing PhD study. The PhD study aims to examine how teachers in classrooms representing the majority of South African schools use ICT when they teach science and to explore factors which may be used as predictors of ICT use by science teachers in similar developing country contexts. The study is relevant and timeous in light of the South African government's preparation to embark on its roll-out of ICT in schools across the country in 2009, despite a strong 'traditionally important' pedagogical orientation of South African teachers in science education and little evidence to suggest South African teachers are ready to integrate ICT into teaching practice.

Keywords: secondary analysis, educational policies, ICT in Education

Introduction

South Africa faces considerable challenges in education as a whole and more especially with the implementation of ICT in science classrooms. Class sizes in South Africa are large and adequately resourcing these classrooms remains a challenge. In 2005, the Department of Education (DoE) developed the National Education Infrastructure Management System (NEIMS) to quantify the physical infrastructure for education in all schools in South Africa. The NEIMS assessment report published recently, reported on 25 145 public ordinary schools[1] (DoE, 2007). According to the figures in this report, 57 percent of the 25 145 schools assessed nationally still have 30 to 45 learners per teacher and five percent have more than 45 learners per teacher. The concept of "learners per teacher" is highly contested in South Africa as it has been suggested that "class size" may be a more accurate measure of what teachers have to deal with. The 2003 Trends in Mathematics and Science Study (TIMSS) reported an average class size for instruction for grade eight in South African science and mathematics classes of 45 compared to the international average of 31 (Martin, Mullis, Gonzalez, & Chrostowski, 2004).

The consequence of these large classes is a decrease in available teaching and learning facilities and resources as well as overcrowded classrooms[2] (Onwu, 1998). Indeed, many teachers in South Africa teach in dilapidated classrooms with insufficient furniture, space and equipment (Onwu, 1998). The 2007 NEIMS report shows that nationally, 56 percent of the 1972 schools have more than 10 percent of their learners without desks and 58 percent of schools have more than 10 percent of their learners without chairs. An assessment of the availability of science laboratories in South Africa in 2007 shows that 11 percent of schools have functioning science laboratories (DoE, 2007). Many schools in South Africa are also struggling with poor and erratic internet connections, and challenges in terms affordability and maintenance of computers and other ICT technologies. The NEIMS report indicates that nearly 30 percent of schools in some areas of the country still have no source of electricity on or near the school (DoE, 2007) and land line connections are only present in 24 percent of schools in some regions. Nationally, only 46 percent of schools have an operational land line connection (DoE, 2007). Sixty eight percent of schools nationally have no access to computers for teaching and learning (DoE, 2007). This situation is the reality in South Africa for the foreseeable future and is a major constraint that limits effective science teaching in South Africa as well as other developing countries.

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[1] Public ordinary schools refer to schools managed by the state (not independent schools) in which grades higher than grade R (reception) are offered to ordinary learners.
[2] Overcrowded is defined as a classroom in which there is less than 1sqm of floor space per pupil.

ICT in education and social development in South Africa

Despite the difficult teaching and learning conditions in South Africa, ICTs and their role in education cannot be ignored in South Africa. The rapid development of ICTs internationally has stimulated debate about the roles that these technologies can play in improving education and accelerating social development in a developing country such as South Africa. Most of this debate in South Africa tends to centre on the extent to which access to and use of ICT can contribute to reducing the massive inequalities in the population. On the one hand, there is the conviction that South Africa (and Africa in general) will benefit from the development of ICT. The Economic Commission for Africa working group on ICTs meeting in Addis Ababa (Kortecamp & Croninger, 1996) supported the view that building South Africa's Information Society would, amongst other things, provide substantial opportunities for creating new jobs in the emerging global information-based economy. It would provide opportunities for improving quality and distribution and for reducing costs of healthcare, would link all educational institutions and provide access to distance education and the world's best libraries, and open up new markets for trade. On the other hand, there is some awareness of the danger that rapid ICT growth may rather serve to embed inequality and widen the technological gap between those who are connected and those who are not.

The South African e-Education policy

After democratisation in 1994, the first South African educational White Paper (DoE, 1995) established a clear policy commitment to education. The general philosophy, goals, values, and principles for the new education and training system outlined the need to form the basis of a plan to explore the use of technology in education. The e-Education White Paper (DoE, 2004) was the first and is currently the only policy document informing decision-making on the use of ICT in education. The government, through the e-Education White Paper, has expressed a strong commitment to the use of ICTs in education (DoE, 2004). The White Paper sets out the government's response to a new information and communication environment in education internationally with a focus on developing students' twenty-first century skills. It provides a framework for the collaboration of Government and the private sector in the provision of ICTs in education in order to turn schools into centres of quality learning and teaching for the twenty-first century (DoE, 2004). The implementation of these comprehensive strategic policy goals requires a multi-year implementation strategy with three phases, the third and last being that ICTs should be integrated at all levels of the education system (2010 – 2013). The policy on e-education acknowledges the massive financial investment required to attain its strategic goals. Despite this, there is no national budget for e-Education implementation.

The South African e-Education policy in context - ICT access in South Africa

Policy goals do not occur in a vacuum. A recent South African Human Sciences Research Council (HSRC) report on mapping ICT access in South Africa has allowed for first time understanding of the distribution of and access to ICT in South Africa (Tlabela, Roodt, Paterson, & Weir-Smith, 2007). The combined indicator on private ICT access was developed from the following variables: access to landline telephones (number of households with access to main telephone lines); number of households with access to mobile telephones; access to computers (number of households with access to Personal Computers); and access to the Internet (number of households with Internet access). In 2007, 13.6 percent of households in South Africa had access to a Personal Computer (PC) with the highest access in the Western Cape at 33.8 percent and the lowest being Limpopo Province with 4.4 percent (Tlabela et al., 2007). While access to the World Wide Web is possible via a range of networked devices[3], in South Africa internet access is mainly obtained through PCs connected to land lines. Internet access in South Africa in 2007 was 9.1 percent (Tlabela et al., 2007). Many rural areas within South Africa lag behind in terms of ICT access. One of the major factors that have prevented many rural areas from benefiting from the potential of ICT has been the low penetration and quality of fixed line telecommunication services. Although there have been recent developments and cost reductions in wireless communication technologies, it is still too expensive for many rural communities (Tlabela et al., 2007). Cellular phone

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[3] 3G mobile telephones, personal digital assistants (PDAs), desktop and laptop computers

technologies in South Africa now make it possible to service rural communities at a lower cost than installing a land line. However, the national average percentage of households with access to these phones is still low at 33.1 percent (Tlabela et al., 2007).

ICT in South African school (SITES M1 and SITES M2 case studies)

South Africa was one of the 26 countries that participated in the Second Information and Technology in Education Study (SITES M1) (Howie, Muller, & Paterson, 2005; Pelgrum & Anderson, 2001). The previous SITES studies have shown that based on the context described above, it is not surprising that the vast majority of schools in South Africa have a long way to go to compare favourably with countries such as Europe, Canada and Singapore. This is specifically apparent when comparing developments in access to ICT in terms of infrastructure for ICT, curriculum and pedagogy, staff development in ICT at schools, policies and usage of ICT in schools, and successful practices with ICT in schools. Between South African schools, there are substantial differences in the quality and functioning of ICT equipment. The implementation of ICT to enhance learning is hampered in many cases by financial constraints (insufficient numbers of computers), lack of computer literacy amongst teachers, lack of training regarding the integration of ICT into different learning areas, absence of a properly developed curriculum for teaching computer skills, and insufficient time for lesson preparation.

In South Africa, SITES-M2 focused on the extent to which classrooms in South Africa judged to be innovative were engaging in constructivist, knowledge building practices that integrated ICT into the curriculum and assessment (Kozma, 2003). South Africa provided case study data for eight schools showing exemplary innovations in classrooms across the country. Despite post-apartheid policies of racial desegregation of government schools and substantial increases in funding to 'previously disadvantaged[4]' schools, the resource inequalities of the apartheid years persist and many township schools remain poorly resourced with very limited infrastructure. The eight South African case studies reported ICT innovative pedagogical practices in schools with a majority white learner population serving largely middle class communities. These case studies cannot effectively inform policy decisions about ICT in education for most schools in South Africa. The SITES 2006 data will allow us assessment of how ICT in education has developed in South Africa in the last 6 years and allows identification of the areas of greatest concern moving forward. Preliminary analysis of the South African data confirms that ICT use remains very low, even in those schools in South Africa that have access to ICT for teachers and learners. When South African science teachers were asked whether they used ICT with their target class, only 16 percent answered that they did. This should raise concerns for policy makers initiating a roll-out of ICT in all South African schools in 2008.

Conceptual Framework

The conceptual framework for investigating and understanding the use of computers and other ICTs in education has been developed over a number of years and is strongly influenced by the international SITES studies. I will develop and use a conceptual framework building on the frameworks already developed in these studies. In particular this study draws on the SITES conceptual frameworks in trying to understand teacher level, school level and system level predictors of ICT use in science education. The study has a strong focus on teachers and their ICT pedagogical practices.

Methodology

Over two decades of research has provided extensive evidence of how science teachers use ICT in teaching, both as a tutor to facilitate them with the routine tasks of repetitive drills and as a tool for conceptual learning, allowing new teaching styles and more learner-centred learning. Much of the evidence gathered on the role of ICT in science education, however, is gathered in learning environments which are rich in teaching and learning resources. Asking similar questions about the complexity of teaching and learning science using ICT in learning

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[4] There is a widely accepted point of view that the term 'previously' is somewhat misrepresentative as these schools remain disadvantaged 14 years after democracy.

environments in which resources are a constraining factor may reveal different insights. The purpose of my research is to understand how teachers use ICT to teach science in contexts with large poorly resourced science classrooms as well as to explore factors which may be used as predictors of ICT use by science teachers in developing country contexts.

Researching a complex phenomenon in a classroom with multiple influences means that a simple cause and effect analysis is inappropriate for addressing the research question. As such, a pragmatic mixed method approach has been selected as the most suitable research design in answering the following research questions:

1. What are science teachers' pedagogical practices when they use ICT to teach science?
   This question will be addressed using descriptive statistics of South Africa science teacher pedagogical practices and ICT-use from the SITES 2006 data. How teachers use ICT to teach science will be further explored in in-depth interviews with teachers selected for their self-reported 'satisfying experience' with ICT[5].

2. What factors may be used as predictors of ICT use in South African science classrooms?
   This will involve correlating selected teacher variables with ICT-use[6] and a regression analysis of the ICT-using lifelong learning oriented practices of a teacher and the contextual factors at the teacher's school.

3. In what ways does the use of ICT in large, poorly resourced science classrooms provide opportunities for learners to learn science that would not be possible without ICT?
   Opportunities to learn science will be investigated in in-depth interviews with the teachers selected for their self-reported 'satisfying experience' with ICT[7].

For the purposes of this paper, question 1 is partly addressed by an analysis of the SITES 2006 data for South Africa. Descriptive analyses and some of the preparatory analyses that are needed are presented.

Preliminary findings Discussion

The focus of the study is the South African science teachers' pedagogical practices and orientations and the use of ICT in them. This is driven by the hypothesis/assumption that ICT is important for bringing changes to classroom teaching and learning to foster the development of students' 21st century skills. The SITES 2006 teacher questionnaire included three sets of core indicators for pedagogical orientations. Two of these sets of core indicators aimed to find out what teachers and students did in the teaching and learning process. These are referred to as '*teacher practice orientation*' and '*student practice orientation*' indicators respectively. The third set of core indicators was aimed at finding out teachers' curriculum goal orientation as a way of exploring and understanding teachers' pedagogical orientations.

Core indicator: Teachers' curriculum goals

In SITES 2006, teacher were asked, "In your teaching of the target class in this school year, how important is it for you to achieve the following goals?" and 13 curriculum goals were listed. The curriculum goals were measured on a 4-point Likert scale (1=not at all, 2=a little, 3=somewhat, 4=very much). The curriculum goals: to *increase learning motivation*, to *prepare students for further education* and to *improve assessment performance* were ranked as most important by science teachers in all systems including South Africa with a mean score above 3.0 on the Likert scale (Law, Pelgrum, & Plomp, 2008). It was found that the goal *to increase learning motivation* was considered the most important goal by all countries except South Africa. In South Africa it was rated as the second most important goal.The goal that ranked as relatively not important by science teachers, with a mean below 3.0 was to *learn from experts and peers from other schools/countries* in all systems except

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[5] SITES Teacher questionnaire Q38
[6] SITES Teacher questionnaire Q18
[7] SITES Teacher questionnaire Q38

South Africa (Law et al., 2008). South Africa ranked to *prepare learners for competent ICT* behaviour as lowest with a mean score of 2.58. These figures are listed in table 1 below.

[Take in Table 1 about here]

Core indicator: Teachers' practices

In SITES 2006, teachers were also asked, "In your teaching of the target class in this school year, how often do you conduct the following?" and 12 teacher practices were measured on a 4-point Likert scale (1=never, 2=sometimes, 3=often and 4=nearly always). The three roles most frequently played by science teachers across systems were *classroom management* (means ranging from 2.73 to 3.75 for science teachers), *presenting information or demonstrations or giving class instruction (*means ranging from 2.63 to 3.58 for science teachers), and *assess students' learning (*means ranging from 2.07 to 3.49 for science teachers) (Law et al., 2008). These were the three highest for South African science teachers as well with means of 3.58, 3.33, and 3.29 respectively as seen in Table 2. These are all teacher roles traditionally prevalent in classrooms since the early 20th century, if not earlier. Such findings are compatible with the finding that *traditionally important* goals were considered to be the most important by science teachers in nearly all of the participating systems. In contrast, the teacher practices with the lowest frequencies of occurrence were *to organize or mediate communication with experts/external mentors* (international mean of 1.31 to 2.56 for science teachers), and *to liaise with collaborators* both for science teachers internationally (international mean from 1.45 to 2.38 for science teachers) and in South Africa (mean of 2.56 and 2.38 respectively). Both practices are roles related to connectedness. The very low ICT use reflected in Table 2 is of concern but hardly surprising given that only 38 percent of the schools sampled for the South African survey reported having computers for student use (Law et al., 2008). All other systems reported more than 95 percent of schools with computers for student use. This is similar for the student-practice presented in table 3.

[Take in Table 2 about here]

Core indicator: Students' practices

In SITES 2006, teachers were asked to respond to the question, "In your teaching of the target class in this school year, how often do your students engage in the following activities?" The respondents had to indicate their rating on a on a 4-point Likert scale (1=never, 2=sometimes, 3=often and 4=nearly always) for each of the 12 student activities. The three most frequently practiced student activities as reported by science teachers across all participating systems, were *completing worksheets/exercises* (mean international score of between 2.39 and 3.39), *working at the same pace/sequence* (mean international score between 2.28 and 3.40) and *answering tests* (mean international score between 2.08 and 3.38). For South African science teachers, the mean score was between 2.73 and 3.18 as shown in table 3. These were activities that students engaged in traditionally and were compatible with the earlier findings that teachers valued the *traditionally important* curriculum goals most highly and played *traditionally important* roles most frequently. The three least popular student activities as reported by science teachers across all participating systems, including South Africa, were *collaborating with peers from other schools* (mean score between 1.04 and 1.80), *contributing to the community through their own activities* (mean score between 1.21 and 2.18) and *communicating with outside experts* (mean score between 1.21 and 1.92) all of which belong to the *connectedness* orientation (Law et al., 2008). These low figures indicate that students rarely engage in collaboration or communication with outside parties, if at all.

[Take in Table 3 about here]

South African teachers are similar in their low 'connectedness' pedagogical orientation to science teachers in other education systems. Surprisingly, South African science teachers report the second highest (second to Thailand) 'connectedness' pedagogical orientation as reflected in their espoused curriculum goals and student practice, and the highest 'connectedness' pedagogical orientation as reflected in science teacher practice among

the 22 systems. This is despite having the lowest level of actual connectivity among the 22 participating countries and reporting only 38 percent of schools with actual computer access to their students. Also surprisingly, South African science teachers report the third highest (third to Chile and Thailand) mean level of priority for ICT use with their target class in the following two years despite reporting the lowest percentage of science teachers' self- reported ICT use with their target class. These issues, amongst others, will be addressed in interviews with South African science teachers as part of the larger study.

Conclusion and Implications

This study is still at a very early stage. I hope, through careful analysis and in-depth investigation, to better understand how teachers in the context of large and poorly resourced science classrooms use ICT to teach science. We know from the SITES study that the level of ICT access in South Africa is very low. We also know that even those teachers who have access to at least 25 computers for student use report limited integration of ICT into teaching and learning. Issues around integration inevitably focus on lack of resources and lack of teacher capacity but we need to focus our attention beyond improving access. Rather we need to better understand how teachers use ICT and what sorts of variables can be used as predictors of ICT use in order to focus limited resources more effectively.

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Table 1: Teacher Questionnaire Part II: Curriculum Goals (South Africa)

Q8. In your teaching of the target class in this school year, how important is it for you to achieve the following goals?	VERY IMP (%) SA	Std error	Mean score SA
A To prepare students for the world of work	76	1.98	3.65
B To prepare students for upper secondary education and beyond	**84**	1.59	**3.80**
C To provide opportunities for students to learn from experts and peers from other schools/countries	59	2.23	3.37
D To provide activities which incorporate real-world examples/settings/applications for student learning	70	1.98	3.59
E To improve students' performance in assessments/examinations	**89**	1.48	**3.86**
F To increase learning motivation and make learning more interesting	**88**	1.54	**3.86**
G To individualize student learning experiences in order to address different learning needs	59	2.19	3.48
H To foster students' ability and readiness to set their own learning goals and to plan, monitor and evaluate their own progress	62	2.30	3.51
I To foster students' collaborative and organizational skills for working in teams	69	1.94	3.60
J To foster students' communication skills in face to-face and/or online situations	63	2.33	3.50
K To satisfy parents' and the community's expectations	67	2.12	3.58
L To prepare students for competent ICT use	46	2.48	2.89
M To prepare students for responsible Internet behavior (e.g., not to commit mail-bombing, etc.) and/or to cope with cybercrime (e.g., Internet fraud, illegal access to secure information, etc.)	39	2.14	**2.58**

Table 2: Teacher Questionnaire Part III: Teacher Practice (South Africa)

Q14. In your teaching of the target class in this school year, (a) How often do you conduct the following? (b) Do you use ICT for these activities?	NEARLY ALWAYS %	Std error	Mean score SA	ICT used Yes	Std error
A Present information/demonstrations and/or give class instructions	**52**	2.45	**3.33**	**16**	1.85
B Provide remedial or enrichment instruction to individual students and/or small groups of students	25	1.92	2.85	13	1.66
C Help/advise students in exploratory and inquiry activities	32	2.39	3.07	16	1.90
D Organize, observe or monitor student-led whole-class discussions, demonstrations, presentations	34	2.02	3.01	12	1.64
E Assess students' learning through tests/quizzes	**44**	2.15	**3.29**	**16**	1.85
F Provide feedback to individuals and/or small groups of students	42	2.05	3.21	12	1.52
G Use classroom management to ensure an orderly, attentive classroom	**66**	2.10	**3.58**	**12**	1.65
H Organize, monitor and support teambuilding and collaboration among students	40	2.22	3.20	10	1.53
I Organize and/or mediate communication between students and experts/external mentors	22	1.99	2.56	12	1.71

J Liaise with collaborators (within or outside school) for student collaborative activities	**15**	1.73	**2.38**	**12**	1.71
K Provide counseling to individual students	22	2.06	2.72	9	1.46
L Collaborate with parents/guardians/ caretakers in supporting/monitoring students' learning and/or in providing counseling	18	1.69	2.64	11	1.78

Table 3: Teacher Questionnaire Part IV: Student Practice (South Africa)

Q16. In your teaching of the target class in this school year (a) How often do your students engage in the following activities? (b) Do your students use ICT for these activities?	NEARLY ALWAYS	Std error	Mean score SA	ICT used Yes	Std error
A Students working on the same learning materials at the same pace and/or sequence	**23**	1.88	**2.73**	**13**	1.82
B Students learning and/or working during lessons at their own pace	19	1.97	2.71	10	1.55
C Complete worksheets, exercises	**37**	2.17	**3.13**	**14**	1.91
D Give presentations	16	1.71	2.60	14	1.95
E Determine own content goals for learning (e.g., theme/topic for project)	10	1.31	2.19	10	1.32
F Explain and discuss own ideas with teacher and peers	20	1.75	2.70	11	1.44
G Collaborate with peers from other schools within and/or outside the country	7	1.20	1.80	8	1.56
H Answer tests or respond to evaluations	**37**	2.29	**3.18**	**13**	1.72
I Self and/or peer evaluation	14	1.76	2.59	10	1.57
J Reflect on own learning experience review (e.g., writing a learning log) and adjust own learning strategy	10	1.54	2.23	8	1.25
K Communicate with outside parties (e.g., with experts)	7	1.13	1.92	10	1.53
L Contribute to the community through their own learning activities (e.g., by conducting an environmental protection project)	6	1.16	1.89	9	1.44