Understanding science teachers' use and integration of ICT in a developing country context

by

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Abstract

Information and communication technology (ICT) has infiltrated society to the point of becoming essential to much of its everyday functioning. People rely on ICT to communicate, access information, and stay connected in an increasing globalised community. In many developed countries, ICT is now strongly featured in education for teaching and learning. In South Africa, as in other developing or partly developed countries, ICT use in education remains limited. This research was conducted to explore and understand how those South African science teachers who have access to ICT use it when they teach science. It was done to explain some of the reasons those teachers use ICT in the ways that they do, and to gain a better insight into the value that using ICT adds to both teaching and learning science. The research was designed as a mixed methods study, using both quantitative data collected from 267 Grade 8 science teachers in South Africa through the SITES 2006 teacher questionnaire, and qualitative data collected from three science teachers, all of whom taught science in a context of limited resources typical of a developing country. The data collected and analysed in this study showed that when science teachers have access to ICT for teaching and learning in classrooms typical of developing country contexts, they are able to use that ICT effectively to add value to teaching and learning. The greatest value is added when the teacher has a high technological pedagogical content knowledge. Secondly, at the level of the teacher, personal entrepreneurship is a key factor in a teacher's ability to use ICT to add value to teaching and learning and to support the educational objectives based on 21st century learning objectives. Thirdly, teachers use the available ICT resources in a variety of ways but it seems that access to a personal computer, either laptop or desktop, in the classroom is a minimum requirement for ICT use in subject teaching. And lastly, the gap between ICT policy intentions as outlined in the South African e-Education White Paper (DoE, 2004b) and ICT practice remains large. There was no evidence from this study to suggest that the ICT policy intentions influenced practice at classroom level.

Key Words: Information and Communication Technology; Pedagogy; Pedagogical Content Knowledge; Technological Pedagogical Content Knowledge; Science; Teaching; Learning

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List of Acronyms

Becta	British Educational and Communications Technology Agency
CAT	Computer Applications Technology
Comped	Computers in Education
DfES	Department for Education and Skills
DBE	Department of Basic Education
DoE	Department of Education
ELRC	Education Labour Relations Council
FET	Further Education and Training
GDE	Gauteng Department of Education
HEFCE	Higher Education Funding Council for England
HG	Higher Grade
HSRC	Human Sciences Research Council
ICT	Information and Communication Technology
ICT-TPCK	ICT-Technological Pedagogical Content Knowledge
IEA	International Association for the Evaluation of Educational Achievement
IWB	Interactive White Board
MBLs	Micro-based Laboratories
NCS	National Curriculum Statement
NEIMS	National Education Infrastructure Management System
NEPAD	New Partnership for Africa's Development
OECD	Organisation for Economic Co-operation and Development
PC	Personal Computer
PCK	Pedagogical Content Knowledge
PDA	Personal Digital Assistant
PIRLS	Progress in International Reading Literacy Study
SAMS	South African Management System
SITES	Second Information Technology in Education Study
SRN	School Register of Needs
STEM	Science, Technology, Engineering and Maths
TIMSS	Trends in Mathematics and science Study
TLI	Teacher Laptop Initiative
TPCK	Technological Pedagogical Content Knowledge
UK	United Kingdom
WCED	Western Cape Education Department
WWW	World Wide Web

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List of Appendices

Owing to the length of the data outputs referred to in this thesis, the following appendices are available on the CD which accompanies this document.

CHAPTER ONE

Rationale and Background to the Study

This study was designed to explore how South African science teachers use ICT when they teach science, to explain some of the reasons those teachers use ICT in the ways that they do, and to gain a better insight into the value that using ICT adds to both teaching and learning science. Information and communication technology (ICT) has infiltrated society to the point of becoming almost essential to much of its everyday functioning. People rely on ICT to communicate, access information, and stay connected in an increasing globalised community. In many developed countries, ICT is now strongly featured in education and most teachers and students will use various ICTs for teaching and learning activities (Law, Pelgrum, & Plomp, 2008). In some countries, such as the Netherlands, this ICT access at school is ubiquitous (Law et al., 2008) but not so in South Africa. Here, as in other developing or partly developed countries, it remains erratic. This is not because the value of using ICT in education is not recognized by policy-makers as South Africa has an e-Education policy which acknowledges its importance. The reasons for limited access and successful use of ICT in South African classrooms are complex. This research will assist in understanding that complexity and in decision-making in respect strategies for ICT integration in South African schools as well as schools in other similar developing country contexts.

Defining ICT policy for education is becoming increasingly difficult because of the many alternatives available. There is growing evidence from large-scale projects that have lasted for many years, as well as from many small-scale initiatives in both the developed and developing countries of some successes (and some failures). There is now sufficient empirical evidence from these initiatives for policy-makers to use in policy formulation or policy review to ensure that the high cost of ICT implementation yields real value to the teaching and learning processes in South

African schools. If one is to determine the ratio of cost of a planned country-wide ICT roll-out, to the benefit of doing so, it is imperative that a real evaluation of the value that ICT adds to teaching and learning is conducted.

1.1 Rationale for the study

Research has been conducted in developing countries as a way to understand and improve the pedagogical use of ICT in education, for instance in Chile (Budge, 2009; Hinostroza, Hepp, & Cox, 2009). However it is difficult to find empirical literature on the implementation of ICT in education in South Africa and where it can be found, it is most often focused on policy intentions rather than classroom realities (Howie, 2009). While the South African e-Education policy intentions are promising (DoE, 2004b), the challenge remains at the level of classroom implementation where it is easier to investigate what does not work and why, than to investigate what does work, and why. A major reason for this is that South Africa has a superfluity of classrooms in which limitations on resources prevents integration of ICT into subject teaching. There is little empirical evidence about the ways in which science teachers use ICT in classrooms with limited resources, i.e. the majority, and this study addresses this gap. While it may be useful for South African policy makers to take the lesson of developing countries such as Chile (Blignaut, Hinostroza, Els, & Brun, 2010), empirical evidence from South African classrooms should be more valuable in influencing and informing the country's ICT policy since it is context specific.

1.2 Background to the study

This research is positioned within the already large empirical knowledge-base of ICT use in education, and came about because of my personal interest and experience in science education in South Africa. In addition, a large amount of questionnaire data was collected from science teachers in South Africa as part of the Second Information Technology in Education Study (SITES) 2006. The section which follows gives a brief background to the SITES studies and why that particular data was used in this study.

1.2.1 International perspective gained through SITES

SITES was conceptualised in the late 1990s as a follow-on to the two Computers in Education (Comped) Studies in the early 1990s (Pelgrum & Plomp, 1993 in Voogt & Pelgrum, 2003, p. 1025). The purpose of the SITES studies was broadly to conduct an international comparative research programme exploring the use of ICT in education, the central theme of which was to further understanding of how ICT affects teaching and learning in schools (Pelgrum, 2001). The study consisted of three separate modules: SITES Module 1 (SITES–M1); SITES Module 2 (SITES–M2); and SITES 2006, carried out between 1997 and 2008 under the auspices of The International Association for the Evaluation of Educational Achievement (IEA). South Africa participated in all three modules. The three studies are briefly explained in the section which follows as a way of providing a context for the data that was used in this study.

SITES Module 1 (1997-1999)

The first SITES module, SITES–M1, was an international comparative study designed to help countries estimate their use of ICT relative to other countries, and provided a baseline against which development in ICT use could be evaluated in later years (Law et al., 2008; Pelgrum & Anderson, 1999). SITES–M1 was an international cross-section survey of principals and technology coordinators in schools in the participating countries. Its focus was on ICT resources and the extent to which schools had adopted and implemented pedagogical practices that are considered important to education in the information society (Pelgrum & Anderson, 1999). With regard to the ICT infrastructure in schools, the study examined the student-computer ratio across countries, which indicated how many students per computer there were in a school. As expected, significant difference were found between countries ranging from nine students to one computer in Canada, 12:1 in Denmark and Singapore, and 210:1 in Cyprus (Pelgrum, 2001). When data were collected for the first module, less than 10% of schools in South Africa had access to computers (Pelgrum, 2001). SITES–M1 also examined the extent to which schools had access to the Internet for purposes of teaching and learning. Again there were significant differences with

100% of participating secondary schools in Singapore having access to the Internet compared to less than 10% in South Africa.

One purpose of SITES–M1 was to examine the extent to which countries were changing their approach to pedagogy, and to look at the contribution that ICT was making to that change. Principals were asked 11 questions about the type of pedagogical practices being used in their schools. A factor analysis revealed two factors (Pelgrum, 2001): **emerging practices** (with an emphasis on co-operative project-based learning processes, students responsible for their own learning, engaged students in the search for information, allowed students to control the pace of their own learning); and **traditional practices** (with an emphasis on development skills, all students working on the same material and at the same pace with teachers keeping track of their activities and progress). The SITES–M1 study showed that in the late 1990s, schools in many countries already applied elements of the emerging pedagogy for the information society.

SITES Module 2 (1999-2002)

The second SITES Module, SITES–M2, focused on the extent to which classrooms around the world judged to be innovative were engaging in constructivist, knowledge-building practices that integrated ICT into the curriculum and assessment (Kozma, 2003). It was conducted between 2000 and 2002 in 28 countries, and used common selection criteria, modified by national contexts, to identify 174 innovative ICT classrooms. National research teams used a common set of case study methods to collect data on the pedagogical practices of teachers and students, the role that ICT played in these practices, and the contextual factors that supported and influenced them (Kozma, 2003). This research documented the many ways in which the integration of learning technologies in practice enabled deep understanding of content, sophisticated pedagogy, and impressive student outcomes (Kozma, 2003). For module two, South Africa provided case study data for eight schools, showing exemplary innovations in classrooms across the country. Key findings from this study indicated that in many instances including South Africa, technology was supporting significant changes in classroom teaching and learning.

In some of these cases, students were actively engaging in searching for information, designing products, working together with other students or others outside the classroom, and publishing or presenting their work using word processors and presentation software (Kozma, 2003). In short, SITES–M2 provided evidence that pedagogical innovations using ICT in science were possible (Plomp, 2006).

SITES 2006 (2005-2008)

SITES 2006 was an international comparative study of pedagogy and ICT use in schools. The study focused on the role of ICT in teaching and learning specifically in mathematics and science classrooms. Data for this the third SITES module, SITES 2006, was collected in 2006 from a total of 22 participating countries (Law et al., 2008). A research method similar to the first module was used to address research questions through a survey of schools and mathematics and science teachers in the form of questionnaires. Teachers' pedagogical practices and use of ICT in teaching lay at the core of this study. In this survey, teachers were asked questions about their perceptions of important school or system level factors and the current role of ICT in supporting teaching and learning in their schools. The collective international results from this module were published in 2008, and revealed that in 2006, South Africa was not unexpectedly still lagging far behind other countries in terms of ICT used, with less than 20% of schools using ICT in science education (Law et al., 2008).

Over a period of 11 years, a great deal of data about the education use of ICT has been collected from more than 20 countries. This data has assisted countries: in estimating their current position relative to other countries in the educational use of ICT (SITES M-1); in understanding the pedagogical practices of teachers and learners, the role that ICT plays in these practices, and the contextual factors that support and influence them (SITES M-2); and in understanding the role of ICT in teaching and learning in mathematics and science classrooms (SITES 2006). This sort of survey data is valuable as a way of getting the "big picture" perspective on the educational use of ICT but a more local understanding of education in South Africa is needed to fully understand the context of this study. The South African national and classroom perspective are discussed in the following sections as a way of appreciating the context.

1.2.2 National perspective

Since the introduction of computers into education, their potential has been recognized by researchers, policy-makers and practitioners. The potential of ICT to improve education has a direct influence on policy development, as well as on the prioritisation of the South African government's expenditure on ICT resources in schools. This perceived benefit of ICT to improve education can be discussed from several perspectives (Voogt & Knezek, 2008), one such being the generally accepted belief that society is changing from a predominantly industrial society to a knowledge society.

The concept of the "information society" was first used in Japan as early as 1968 (Kohyama, p 5 in Anderson, 2008) and by the late 1980s, was being used to capture the essence of a culture inundated by information and dominated by information technology. The later concept of the "knowledge society" dominated the 1990s, referring to economic systems where ideas or knowledge functioned as commodities (Anderson, 2008). In many instances the concepts of information (intentionally structured data) and knowledge (the cognitive state needed to interpret and process information) and the types of societies to which they give their names are used interchangeably (Anderson, 2008). There are two particular features of the knowledge society that one should acknowledge: technology makes accessing and sharing knowledge easy; and knowledge functions as a commodity. In a knowledge society, schools should prepare students for jobs that might not yet exist, and being able to use ICT is recognised as one of the core competencies for the twenty first century. For the purposes of this discussion, the term "knowledge society" presumes the existence of an "information society" and will be used to refer to the economic system where ideas of knowledge function as commodities (Anderson, 2008).

The focus of the 1990s was on a heightened awareness of globalisation, rapid change and information technologies. Policy decision makers in many countries, including South Africa, began adopting the rhetoric of twenty first century skills. Some educational outcomes consistently emphasized in policy documents are: communication; creativity in knowledge generation; collaboration; critical thinking; ICT literacy; and life skills (Anderson, 2008, p. 10). This has implications for the skills and learning strategies for students as shown in Table 1.1.

Table 1.1: Implications of the demands of the global knowledge economy for youths in terms of required skills and learning strategies (Anderson, 2008, p. 7)

Demands from society	Required skills	Learning strategies
Knowledge as commodity	Knowledge construction	Inquiry, project learning. constructivism
Rapid change, renewal	Adaptability	Learning to relearn, on-demand learning
Information explosion	Finding, organising, retrieving information, ICT usage	Multi-database browsing exercises
Poorly organised information	Information management, ICT utilization	Database design and implementation
Incompletely evaluated information	Critical thinking	Evaluation problem solving
Collectivisation of knowledge	Teamwork	Collaborative learning

This subscription to a knowledge society perspective has to some extent driven South African policy on ICT in education with a pressure to put computers in all schools, regardless of individual teachers' needs, priorities or competencies. By equipping them with ICT, the government aims to develop and produce a pool of ICT-proficient youth from whom the country can draw trainee ICT engineers, programmers and software developers (DoE, 2004b).

1.2.3 South African classroom perspective

Even though education in South Africa is the single largest category of the combined national and provincial government's spending, poverty-related educational challenges persist. In 2005, the Department of Education (DoE) developed the National Education Infrastructure Management System (NEIMS) to update the 1996 and 2000 School Register of Needs (SRN) databases, which were used to quantify the physical infrastructure for education in all schools in South Africa. This was carried out as a planning strategy for spending on education, and based on equity, democracy and justice. The current NEIMS assessment report (DoE, 2007) showed the results of 25,145 public ordinary schools[1] in South Africa.

According to the figures in this report, in Gauteng as many as 72% of the 1,972 schools have classes with 30 to 45 students per teacher, and 5% of the schools have more than 45 per teacher. Nationally, 57% of the 25,145 schools assessed still have 30 to 45 students per teacher and 5% have more than 45 per teacher. The concept of "students per teacher ratio" is highly contested as "class size" may be a more accurate measure of what teachers have to deal with. Calculating "students per teacher" includes staff with a teaching qualification regardless of their assignment within the school. For example, principals, heads of department and other qualified teachers in a school may not be allocated students and this lowers the "students per teacher" figure. The 2003 Trends in International Mathematics and science Study (TIMSS) (Martin, Mullis, Gonzalez, & Chrostowski, 2004) reported an average science class size for instruction for Grade 8 in South Africa of 45 compared to the international average of 31.

The consequence of these large student numbers is a decrease in available teaching and learning facilities and resources, as well as overcrowded classrooms[2] (Onwu, 1998). Many teachers teach in dilapidated classrooms with insufficient furniture, space and equipment (Onwu, 1998). The 2007 NEIMS report shows that in Gauteng Province, 42% of the 1,972 schools have more than 10% of their students without desks and 49% of schools have more than 10% of their students without chairs. The national figures are 56% and 58% for desks and chairs respectively. The TIMSS 2003 study showed that in South Africa, 39% of school reported a low availability of school resources for science instruction, including a lack of science laboratory equipment and materials, calculators, library materials for science instruction, and audio-visual equipment for science instruction (Martin et al., 2004). An assessment of the availability of science laboratories in Gauteng Province in 2007 shows that only 23%

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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.

of schools that offer science as a subject have space allocated for science laboratories or laboratories that are stocked. These figures are lower in provinces such as Limpopo Province, where as few as 4% of schools have functioning science laboratories compared to 11% nationally. Such a situation will be the reality for the foreseeable future, and is a major constraint on effective science teaching in South Africa and other developing countries (Onwu, 1999).

Lack of culture of learning

The legacy of violent resistance to apartheid, together with the problems of inadequate resourcing, have led to what is referred to as a lack of a "culture of learning" which is still evident in many South African schools (Howie, Van Staden, Draper, & Zimmerman, 2010). Absenteeism, both on the part of teachers and students, vandalism, gangsterism, rape, and drug abuse in schools remain a problem. The Progress in International Reading Literacy Study (PIRLS) 2006 (Howie et al., 2007) with a nationally representative sample, found that 64% of students reported feeling unsafe at school, and 13% indicated serious problems with safety. One-in-five schools indicated that drugs were a serious problem and one-in-six considered vandalism to be a serious problem (Howie et al., 2007).

Technological infrastructure

There is an e-Education policy goal to equip every South African student in the General and Further Education and Training bands (GET and FET) to use ICT confidently and creatively. The aim is to help develop the skills and knowledge they need to achieve personal goals and to be full participants in the global community by 2013. However it is essential that this be seen against the backdrop of the reality in schools with many classrooms struggling against technological infrastructure problems, erratic Internet connections, and difficulty affording and maintaining computers and other ICT technologies (DoE, 2007).

This reality is reported in the NEIMS which shows that while Gauteng Province has only 2% of schools without any electricity, other provinces have much higher figures, for example KwaZulu-Natal (KZN) with 28% of schools with no source of electricity on or near the school and the Eastern Cape 21%. While 93% of Gauteng Province schools have access to a land line connection which allows access to the internet, the Eastern Cape has only 24%, with 46% nationally. Gauteng Province, probably the best resourced province in South Africa, has access to computers for learning in 67% of schools, but only 48% of those have fewer than 100 students per computer. Limpopo has student access to computers in 18% of its schools and only 10% of the schools have less than 100 students per computer. A total of 68% of schools nationally have no access to computers for teaching and learning (DoE, 2007).

Understanding the schools selected for this study

In the 2006 survey (at the time the SITES 2006 data was collected), the DoE reported the condition of general infrastructure in 58% of the schools assessed as excellent (DoE, 2007). Teachers in these classrooms were able to provide their students with an education of a high quality and of a similar standard to that in developed countries such as the United Kingdom, the Netherlands and the United States of America. These classrooms are found in independent, special schools, and government funded schools which were well resourced under the previous government and reserved for white students during apartheid. These government funded schools are still loosely referred to as ex-model C schools (or previous model C schools). In Gauteng Province in 2009, for example, 45% of the schools fell into this category, but one would expect it to be slightly lower in some other provinces. These schools have good general infrastructure, such as well-maintained school buildings, good infrastructure for teaching and learning, such as adequately equipped science laboratories and libraries or media centres, and good sporting facilities, such as a swimming pool, tennis courts, and rugby fields. Many of these schools have managed to maintain high levels of infrastructural resources and high level of academic achievement in mathematics and science education over a long period of time.

However, the schools described above are not in the majority. In 2006, 26% of schools nationally were classified by the DoE as poor or very. In Gauteng Province, almost 10% of schools fell into the category of poor or very poor. Many of these schools are in remote locations such as rural areas and farms and many do not have access to basic resources such as electricity or running water. They often have large student numbers in a single class. Nationally, in 2006, nearly 42% of schools had no piped running water and just over 30% of those used borehole water. More than 16% of schools in 2006 had no source of electricity on or near the school (DoE, 2007).

One or all of the following factors could compromise the learning environments in these very poor schools: lack of physical space for movement due to overcrowding; diminished opportunities for all students to participate actively in the learning process; the impersonalising of teaching; teachers resorting to an instructional mode of predominantly lecture and teacher demonstrations; excessive workload, and a long homework assignment turnaround time; and limited opportunities to meet individual student needs for self-activity and inquiry, motivation, discipline, safety and socialisation (Onwu & Stoffels, 2005). Students in these schools are often directly affected by the inadequate supply of physical resources such as desks, chairs and other classroom furniture as well as an inadequate supply of learning materials and equipment for hands-on learning activities. The effect of limited learning resources is often exacerbated by the teachers' inability to manage those they have. This is often the case because many teachers are unqualified or under-qualified[3], the Human Resource Development Review in 2003 putting the figure at 22% in 2000 (Crouch & Perry, 2001). While teacher qualifications are not in themselves a determinant of teacher quality, they may be used as a proxy for a teacher's level of training and pedagogical knowledge (Shindler, 2008).

Other than the two types of schools polarised on either end of the spectrum of teaching and learning resources described in the previous section, there exist a large number of schools which serve the majority of students. In Gauteng Province, for example, this group is represented by nearly 45% of schools, located in urban townships across the country and populated by black students from the surrounding areas. They are distinguished from the poor and very poor schools by their access to

[3] An unqualified or under-qualified teacher is regarded as having less than a senior certificate pass and a three year educator training diploma or degree.

electricity and running water, however, black students are still typically taught by unqualified teachers, in over-crowded classrooms, and with insufficient text books and other learning materials. These schools are targeted by the DoE as suitable schools for the provision of computer laboratories for tuition, an aspect of ICT use which features in this study. While the end of apartheid meant an end of the official policy of segregation and unequal educational provision, the reality is that little has changed in terms of resources at most of township schools in the 16 years since democracy.

Many well-resourced classrooms have successfully integrated ICT into the teaching and learning programmes in ways that improve opportunities for learning (Kozma, 2003). The priority of very poor schools to focus efforts on integrating ICT into teaching and learning is understandably very low or non-existent, given the lack of access to electricity. The same cannot be said for the majority of classrooms which have the limitations on resources described above but do have the will and in some cases the means to work towards the e-Education policy goal. In order to understand how teachers use ICT to teach science in this middle group of schools typical of developing countries, the SITES 2006 data which represented all schooling contexts in South Africa was re-coded to select and distinguish three levels of resourcing: well-resourced, poor or very poor, and the middle group of schools. Schools with access to a swimming pool or tennis court (or both) were coded as well-resourced, while those without running water or electricity, and no computers available for tuition were coded as very poor schools. The group of schools most likely to represent the majority, and characterize a developing country context were those which had running water, electricity, and computers available for tuition, but no swimming pool or a tennis court. The methodology behind this recoding and organisation of the database for analysis is explained in detail in Chapter 4.

It is not pertinent to this study to debate whether meaningful learning takes place in these contexts, but it is important to show that most classrooms in South African and in other developing countries have teaching and learning environments that are significantly different from the learning environments in developed countries[4]. There is little doubt that the learning environment has an impact on the teaching and learning that occurs. Consequently, understanding what is happening in these environments requires in-depth investigation into these classrooms and the ways teachers use ICT in their teaching of science, particularly when many other negative factors impact on them.

Overall school achievement in 2006

As of 2001, candidates can obtain a Senior Certificate graded with either a normal pass (equivalent to an average score of less than 60%), a merit pass (equivalent to an average score of between 60% and 79%) or a distinction pass (equivalent to an average score of 80% and more).

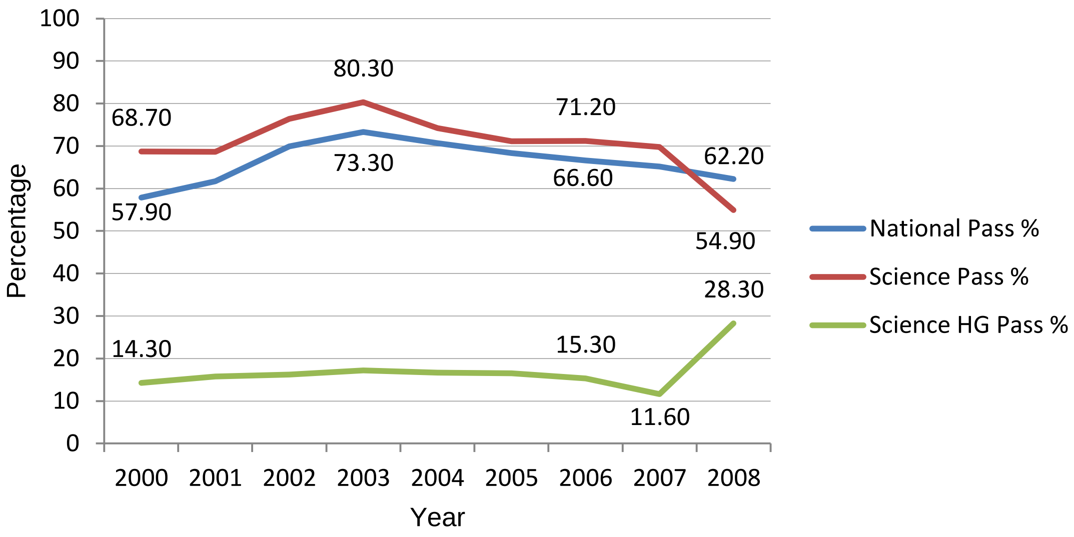

Figure 1.1: South African overall and science pass rates (2000 to 2008)

[4] It should also be noted that within South Africa, there is a well-developed educational sector which is represented by the ex-model C and independent school classrooms.

In 2006[5], the overall national pass rate in the Senior Certificate examination for full-time candidates with six or more subjects was 66.6% (Figure 1.1). In that year, 86%, 11.4% and 2.5% of all candidates passed with a normal pass, a merit pass and a distinction pass, respectively. Just over 7% of the 6 267 schools in South Africa that offered the Senior Certificate examination obtained 100% passes (DoE, 2008).

In 2006, 71.2% passed science but only 15.3% of those students who wrote it passed with a Higher Grade (HG) pass. Without a HG pass in science, students are unable to enrol for further study in science and technology programmes (DoE, 2008). This low pass rate is hardly surprising given a recent national assessment of the availability of science laboratories in South African schools that showed that few schools that offer science as a subject have a qualified science teacher, space allocated for science laboratories, or laboratories that are stocked.

In 2003, the third large-scale international survey of Grade 8 students, TIMSS[6], was conducted. TIMSS is conducted four-yearly by the International Association for the Evaluation of Educational Achievement (IEA) and examines students' proficiency in mathematics and science. It tests the extent to which Years 4 and 8 students have mastered skills in a number of domains, both cognitive and content, common to mathematics and science curricula throughout the world (Martin et al., 2000). Of the 48 countries that participated in the TIMSS 2003 survey at the Year 8 level, South African students were positioned last in both mathematics and science (Martin et al., 2004). This is part of a persistent trend since the first study in 1995 (Howie, 2001). TIMSS 2003 uncovered striking deficiencies in the state of scientific literacy in South African students and given that this result was unchanged from the previous 1999 TIMSS survey (Martin et al., 2000), the results have provided the impetus for discussions on science education and on attempts to improve science teaching and learning.

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[5] Using 2006 is used as the SITES teacher data was collected in 2006

[6] Trends in International Mathematics and Science Study, in which 255 South African schools participated.

ICT infrastructure and access across of South Africa

The Human Sciences Research Council (HSRC) report on the access to ICT in South Africa showed that, in 2007, 13.6% of households in South Africa had access to a personal computer (PC), with the highest access in the Western Cape at 33.8% and the lowest in Limpopo Province, as low as 4.4% (Tlabela, Roodt, Paterson, & Weir-Smith, 2007). While access to the World Wide Web (WWW) is possible via a range of networked devices including 3G mobile telephones, personal digital assistants (PDAs), and desktop and laptop computers, in South Africa Internet access is mainly obtained through PCs. The figures for Internet access in South Africa in 2007 are 9.1%, again with the Western Cape having the highest percentage access at 23.4% and Limpopo Province the lowest at 3% (Tlabela et al., 2007).

Many rural areas lag behind in terms of ICT access, a major factor being the low penetration and quality of fixed line telecommunication services. Although there have been recent developments and cost reductions in wireless communication technologies, there is still a cost barrier which will not be easily overcome. Cellular phone technologies 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 cell phones is still low at 33.1%, and less than 50% even for Gauteng Province (Tlabela et al., 2007).

1.2.4 ICT initiatives across South Africa relevant to this study

A number of important ICT initiatives have been initiated across South Africa, suggesting that work is being done to provide ICT access to schools. Whilst some of these are not directly aligned with the e-Education policy and others have lapsed, their inheritance remains important when exploring ICT use in schools (Blignaut & Howie, 2009). A number of the initiatives are current or new, and many have not yet reached every school or district, but even though educators' and students' access to ICT is still limited, these initiatives form the basis of the bulk of ICT development and practices in the country.

The majority of ICT initiatives in developing countries focus on ICT resources in schools, and some aim for capacity building of educators and students. The minority are successful in enabling educators to integrate ICTs into the curriculum and to manage this change, South Africa being no exception (Blignaut & Howie, 2009). The funding provision of large-scale initiatives demands quick-wins to establish return on investment but the establishment of new computer laboratories in schools earns more goodwill from donors and is a less demanding target than skilling educators to integrate ICT into their teaching and learning – a process that may take many years. The sustainability of ICT initiatives is therefore of utmost importance if they are to support the long-term goals of the e-Education policy. A full list of these initiatives is in Blignaut and Howie (2009). Some of these initiatives where evident in the classrooms I visited as part of this study, suggesting that they are indeed having an impact. Those initiatives are summarised in the section which follows. The extent of that impact is discussed in the analysis of the data.

Gauteng Online

Gauteng Online was launched in 2000 (GautengOnline, 2003) as a directorate of the Gauteng Department of Education (GDE) with the intention of issuing all schools in the province with a secure computer room equipped with 25 desk-top computers. The computer room was to be equipped with a broad-band Internet connection, e-mail facilities, and computers for use in curriculum delivery, specifically to: build a province-wide school computer network; create a strong local IT industry that has the capacity for IT development and innovation; enhance the efficacy of government for improved service delivery; position Gauteng Province at the cutting edge of change through technological innovation; and bridge the digital divide.

Intel Teach to the Future (Intel® Teach Program)

The Intel® Teach Program is aimed at helping teachers to be more effective educators through professional development focused on how to integrate technology into their lessons, promoting problem solving, critical thinking and collaboration skills among their students. This programme is a Global Intel® Innovation in Education initiative which operates with SchoolNet SA as a local partner, the later having adapted the international version of the curriculum for local interpretations (Intel Education, 2003). It is an official professional development programme of the South African Council for Educators that targets educators in all nine provinces with ICT training funded either by the Provincial Department of Education or by the school. The Intel® Teach Project is an extensive training programme for educators to use ICT in the classroom. It aims to enable educators to use ICT in their teaching, and to engage students to use ICT to conduct research, compile information, and communicate with others (Intel Education, 2003).

The Khanya Project

The Khanya project, like Gauteng Online, is a provincial initiative operating as a directorate of the Western Cape Provincial Education Department (Khanya, 2001), established in April 2001. It services government-funded schools in the Western Cape with its primary objectives being to:

- increase educator capacity and effectiveness by means of technology
- harness the power of technology to deliver the curriculum
- enhance the quality of the learning experience in the classroom, providing an opportunity for students to benefit from a variety of learning styles
- integrate appropriate and available technology into the curriculum delivery process as different technologies mature
- use technology to assist all disabled students to maximise learning
- improve Senior Certificate and FET results, as well as student outcomes in all grades, in terms of number of passes and quality of results
- increase the number of students taking mathematics and science on the higher grade and those coping successfully
- increase the number of students qualified and competent to enter tertiary education institutions after obtaining their Senior Certificates and FETs
- improve numeracy and literacy in lower grades in order to build a stronger foundation for future matriculants (Grade 12s).

Through the Khanya Project, nearly 1,000 schools in the Western Cape have access to ICT and educators trained to use it. While the PIRLS 2006 study (Howie et al.,

2007) emphasized the importance of educators in laying the foundation for literacy development amongst primary school students, the Western Cape Education Department (WCED) has recognized the problem of educator shortages in many of its schools and set up the Khanya Project on the assumption that technology could help address the increasing shortage of educator capacity in schools. Its primary goal was to empower all educators and students in Western Cape schools to develop the necessary skills to use ICT in support of teaching and learning. The emphasis of the Khanya Project was on providing computer technology as a teaching aid and improving curriculum delivery. Two of the project goals worth noting are: to harness the power of technology to deliver the primary school literacy and numeracy curriculum; to improve literacy and numeracy results in lower grades in order to build a stronger foundation for future matriculants. Every educator is to be empowered to use appropriate and available technology to deliver curriculum to every student in the province by 2012, with a progressive eradication of the digital divide, starting with the poorest of the poor schools; and striving to achieve racial and gender equity (Khanya, 2001).

Teacher Laptop Initiative

In May 2009, the then Minister of Education, Naledi Pandor, announced the Teacher Laptop Initiative (TLI) as part of a government strategy to improve the integration of ICT in teaching and learning (DoE, 2009). The initiative, which started in July 2009, aimed to ensure that every teacher in South Africa owned and used a laptop in their teaching, as well as for administration. Managed by the Education Labour Relations Council (ELRC), the TLI was designed to address a need for a quality education system and forms part of a plan by the Department of Basic Education (DBE) and other stakeholders to improve the overall quality of education. It aimed to accomplish this by making resources available to students and teachers in the public education sector. The ICT packages for teachers consist of a laptop with prescribed minimum specifications, including software for school administration, the national curriculum statement documents, as well as Internet connectivity, insurance and finance, as per the requirements of Government Gazette 32207. Qualifying teachers will receive a monthly allowance of R130.00 (taxable) and are required to fund the difference between this and the monthly repayments of the package. Most of the packages from the provisionally accredited suppliers cost between R250.00 and R390.00 per month and repayments are spread over a period of five years. Despite the enthusiastic announcements from department officials in July 2009, the TLI only started gaining momentum in July 2010[7].

1.3 Main Research Question

Current thinking about ICT in education suggests that while traditionally important pedagogical practices are still dominant in science education, ICT contributes to innovative pedagogical practices (Voogt, 2009). The SITES studies from 1998 until 2006 assessed, inter alia, how and to what extent education is responding to the requirements of the information society, and how ICT is impacting on these changes. Based on the findings from the three previous SITES modules, when science teachers use ICT to teach, and understand how to integrate these technologies into their teaching, value is added to the learning environment and students are afforded the opportunity to improve their learning (Kozma, 2003; Law et al., 2008; Pelgrum, 2001).

Against the above background, the research question is posed as follows:

What is the value that using ICT adds to the teaching and learning of Science when teachers use ICT in a context of limited resources, typical of a developing country?

Value is not an easy concept to assess. In the earlier Kennisnet Four in Balance monitor (Kennisnet, 2007), the term 'yields' was used to explain the increasing importance of ICT in education. The types of yields from using ICT reported were: students learn more, learn quicker, and learn more enjoyably; results are better for both high and low performing students; students are more motivated and have more self-confidence; and support is provided for several pedagogical approaches, such as transfer of knowledge, independent studying, and cooperative learning. In a later version of the Four in Balance Model (Kennisnet, 2009), the term 'benefits' is used as

[7] Time was not allowed to analyse the effect of the launch at the time of writing this document.

a way of assessing the contribution of ICT to efficient, effective, and interesting teaching and learning. The monitor illustrates the benefits or value that is added to education with three examples: ICT is very suited to offering subject matter in multiple ways, for example visually, with audio, and interactively which helps students learn more effectively; ICT can assist weaker students to make progress as the learning material can be directed at the level appropriate for each student; and if ICT is used, students are more motivated to learn.

For the purposes of this study, the concept of value is associated with three aspects of teaching and learning i.e. teaching and learning which is: more effective; more efficient; and more enjoyable. More effective teaching and learning would require a move away from a predominantly teacher-centre and lecture-style pedagogy to a more student-centred and activity-based pedagogy in line with current thinking about how children learn. More efficient teaching and learning would require better curriculum coverage through access to high quality digital learning materials, especially in instances where class sizes are large and teachers' Subject Content Knowledge (SCK) and Pedagogical Content Knowledge (PCK) is inadequate. More enjoyable teaching and learning would require an increase in student participation in science lessons. This is especially difficult for students who come from poor communities with little home or community educational support.

As a way of ascertaining the value that using ICT adds to teaching and learning in South African classrooms, the main research question was operationalized by two sub-questions:

1. *How do science teachers use ICT in a context of limited resources?*
2. *Why do science teachers use ICT in the ways that they do?*

The value added (yields and benefits) by using ICT in South African classrooms was established through an in-depth exploration of how and why teachers use it in the ways that they do.

1.4 Significance of the study

The experiences of science teachers' use of ICT in contexts where resources are limited are valuable to inform the current and developing knowledge base in this area of research. How and why science teachers in contexts typical of developing countries use ICT may assist in filling some of the gaps in knowledge which relate specifically to classrooms with limited resources. In addition to contributing to the knowledge base in this area of research, understanding the value that this use of ICT offers to science teaching and learning will allow us to make a significant contribution to the current policy debate in South Africa prior to a nation-wide roll-out of ICT in schools.

New developments in education show great promise for helping teachers improve teaching and learning when ICT is integrated into the classroom. It is important to understand the links between the complex issues faced by teachers which determine how they are able to use ICT when teaching. This information may be relevant to the South African DOE in terms of future investments in ICT in education, as well as contributing to the knowledge base on the complex process of integrating computers and other communication technology in education in developing world contexts. Furthermore, the results provide some clues for those countries which are in a similar position to South Africa, that is where class sizes are large and resources limited.

1.5 Brief overview of chapters

This thesis is presented in eight chapters. Chapter One gives a brief overview of the rationale and background, both from an international perspective, giving a summary of the three SITES modules, and from a national perspective, giving the context of education in South African science classrooms. It also serves to present the research question which formed the basis for the thesis and subsequent research design. Chapter Two begins by defining the concept ICT as it is used in this study, and then discusses technologies as used in education, from a perspective both of policy and from the classroom. It also examines some of the current and emerging technologies used in education, reviewing the literature on the role of ICT in science education, in particular the context for ICT not typical of other school subjects. Lastly, the chapter looks at current empirical research into the obstacles teachers face in the use of ICT.

Chapter Three places this research in a theoretical context, explaining important concepts such as PCK and Technological Pedagogical Content Knowledge (TPCK). It also serves to examine the interpretation of technology-integrated pedagogy used in the SITES studies such as pedagogical orientations (SITES 2006) and patterns of ICT use (SITES-M2). The chapter concludes with a discussion about the Four in Balance Model which was used as a way of structuring the research design and analysis in this study.

Chapter Four presents and justifies the mixed methods research design and specific research methods chosen, detailing how the cases were chosen to gather the qualitative data, and how the SITES 2006 teacher data was organized and used. Chapter Five uses some of the data generated from the SITES 2006 Teacher questionnaire to paint the landscape of pedagogical orientations of South African science teacher and where relevant, compares these to science teachers internationally. This is done as a way of understanding how the pedagogical orientation of teachers influences their pedagogical use of ICT and provides the context for the further data analysis. Chapters Six provides an analysis of the qualitative and quantitative data collected from South African science teachers in classrooms with limited resources to show how these teachers use ICT when they teach science. Chapter Seven provides a similar analysis of the data to explain why teachers use ICT in these classrooms in the ways that they do. The final chapter, Chapter Eight, summarises the research findings and provides a reflection on the conceptual framework which focused the research and the particular research design chosen. This data is then synthesized to ascertain the value that the use of ICT adds to teaching and learning in the South African context for teaching and learning science. Finally, the conclusions and recommendations are presented.

CHAPTER TWO

Review of Literature

This chapter reviews the literature relevant for this thesis. It begins by discussing what is probably the most important concept in this study, namely ICT, and explains the different ways in which it is used in the literature, and pertaining to this thesis (section 2.1). It examines the background literature on what types of technologies are currently used in education (section 2.3), particularly from the perspective of ICT policy (section 2.2), and its use of ICT in education from a classroom perspective (section 2.4). The argument is then extended to the role and rationale of ICT in science education in particular (section 2.5), as science education offers possibilities for ICT use that are unique to that subject.

2.1 The concept ICT

The concept Information and Communication Technology (ICT) is central to this study and as such, it is necessary to explain how it is understood and used in this study. On the issue of ICT in the curriculum, three separate aspects can be identified (Webb, 2002): learning ICT (as a subject); learning through ICT; and using ICT as a tool for learning. In South Africa, Information Technology (IT) is learnt as a subject in both the primary and lower secondary school years (grades R-9) and in the upper secondary school years (grades 10-12). The curricula are presented in the Revised National Curriculum Statements (RNCS) as "Technology" (DoE, 2002b) for grades R to 9 and as "Computer Applications Technology (CAT)" (DoE, 2003) for grades 10 to 12, and are examinable subjects. Learning "through" ICT describes situations where the ICT facility becomes the whole learning environment, providing learning materials and acting as the tutor and the assessor. This is typical of distance education using ICT where little or no contact with a teacher is provided. The third aspect, using ICT such as computers and networked communication to support teaching and learning, includes a wide range of applications of ICT as a tool for learning e.g. using a word processor, and running simulation tests in science (Webb, 2002), and is the kind of integration of ICT into classroom-based learning envisaged by the government's e-Education policy (DoE, 2004b). This study looks at the role of ICT from the third perspective i.e. exploring the role of ICT as a tool for learning as currently used in classrooms. It will not enter into the on-going debate about whether ICT should be taught as a separate subject, or the extent to which it should be integrated into other subject areas.

The terminology used in this field of study is often confusing, partly owing to the rapid technological changes and developments (Voogt & Knezek, 2008). The term computer technology has been replaced by 'ICT' or 'information technology' (IT) or simply 'technology'. The term IT is often used interchangeably with ICT. ICT refers to all technologies used for processing information and for communicating, and some include in the definition those products that have been made to store, access, and use information and which support the information and communication activities of e-learning (Andrews & Haythornwaithe, 2007). The South African White Paper on e-Education (DoE, 2004b) uses the term ICT to represent the convergence of information technology (the items of hardware and software that allow the user to access, retrieve, store, organise, manipulate and present information by electronic means) and communication technology (telecommunications equipment through which information can be sought, sent and accessed). ICTs are the combination of networks, hardware and software as well as the means of communication, collaboration and engagement that enable the processing, management and exchange of data, information and knowledge (DoE, 2004b).

More recently, new terms came about to indicate computer use in education, inter alia e-learning (electronic learning), m-learning (mobile learning), web-based education or learning, multimedia learning, and computer-based learning (CBL). The term e-learning is used for learning that is facilitated or delivered through the use of computer or communications technologies, Internet, CD-ROM, and television (Voogt & Knezek, 2008). A more expanded definition from the Higher Education Funding Council for England (HEFCE) defines e-learning as the use of technologies in learning opportunities, encompassing flexible learning as well as distance learning;

and the use of ICT as a communications and delivery tool, between individuals and groups, to support students and improve the management of learning (Andrews & Haythornwaithe, 2007). The South African e-Education White Paper uses the term e-learning to refer to flexible learning using ICT resources, tools and applications which focus on accessing information, interaction among teachers, students and the online environment, collaborative learning and the production of materials, resources and learning experiences (DoE, 2004b).

Similar to e-leaning, the term m-learning emphasizes the facilitation of learning through the use of mobile computer technology, such as mobile phones, personal digital assistants (PDAs) and laptop computers. If the WWW is used to deliver education and/or instruction, the terms Web-based education or Web-based instruction are also used. The term 'multimedia learning' is often used when a mix of audio and video technologies are integrated in the learning environment. The most recent term emerging for computer use in education is 'ubiquitous learning' (Voogt & Knezek, 2008), which alludes to the ever-presence of computer technology in the environment and the potential of computer technology to make learning possible at any time and in any place.

2.2 Policy perspective on ICT in education

The main arguments for a sustained use of ICT in education in both developed and developing countries at the level of policy can be summarized as:

- Like literacy and numeracy, IT is an essential "life skill"
- IT provides an opportunity for economic development and is a requirement for employability
- IT is a tool for educational management
- IT is a tool that can improve teaching and learning (OECD, 2001).

National ICT policies for education can serve important functions and "provide a rationale, a set of goals, and a vision for how education systems might be with the introduction of ICT, and how students, teachers, parents and the general population might benefit from its use in schools" (Kozma, 2008, p. 1084). National ICT policies allow the co-ordination of a country's educational goals. While classroom innovation may occur without a national policy, they are less likely to be sustained without the guidance of one (Kozma, 2008). Kozma (2008) has identified four rationales which are used to justify the investment in advancing the use of ICT in education, namely: to support economic growth; to promote social development; to advance educational reform; and ICT to support educational management.

These policy rationales are not mutually exclusive and some countries such as South Africa use two or more rationales to reinforce each other. For example, in promoting the use of ICT in education to advance educational reform:

> Learning through the use of ICTs is arguably one of the most powerful means of supporting students to achieve the nationally-stated curriculum goals. It must however be very thoughtfully selected and integrated into educational planning and management. In particular, the use of ICTs for learning encourages: learner-centred learning; active, exploratory, inquiry-based learning; collaborative work among students and teachers; and creativity, analytical skills, critical thinking and informed decision-making (DoE, 2004b, p. 19).

It also focuses on the potential social impact of ICT and justifies its expenditure by a policy which promotes ICT use to share knowledge, foster cultural creativity, increase democratic participation, and enhance social cohesion. In articulating the ways in which educational ICT can support these broad social goals, the policy states:

> The lack of developed infrastructure for information and communication technologies is widening the gap between Africa and the developed world. In response to this under-development, Africa has adopted a renewal framework, the New Partnership for Africa's Development (NEPAD), which identifies ICTs as central in the struggle to reduce poverty on the continent. ICTs provide hope for overcoming barriers of social and geographical isolation, increase access to information and education, and enable the poor to participate in the making of decisions that have an impact on their lives (DoE, 2004b, p. 9).

Although this level of strategic articulation may provide a vision of a future in which policy goals are achieved, and justifies the financial expenditure on ICT infrastructure, the operational plans of these policies need five specific operational components (Kozma, 2008): **infrastructural development** (including the budget allocation for technical resources); **teacher training** (including teacher professional development programmes specifying skills that teachers need to acquire); **technical support** (including what hardware and software technical assistance teachers should get); **pedagogical and curricula change** (including the articulation of ICT-related changes in curriculum, pedagogical practices, and assessment); **content development** (may include the specifics about the development of digital content where needed).

In order to craft effective educational ICT policies, Kozma (2008) makes specific recommendations that can assist policy-makers in national, provincial and local ICT in education policy construction. Firstly, national ICT policies will be the most effective if they are aligned with other strategic and operational policies (Kozma, 2008). For example, the goals and rationales of specific ICT programmes and projects (such as Gauteng Online and the Khanya Project[8]), should be directly tied to the national goals and rationales for ICT in education. Secondly, they are more likely to be effective if there is horizontal alignment. In other words, ICT in education policy should be aligned with other policies within the education system. For example, the e-learning policy in South Africa should be aligned with the specific goals and rationales of the NCS. Lastly, national policies should be aligned with provincial policies. For example, the national e-Education policy should provide the direction and policy goals for the provincial Gauteng Online policy.

There are gaps between policies and the changes in classroom practice the policies intended to effect. In many instances, policies are articulated but teachers are not aware of their specifics or goals. A study by Cohen and Hill (in Kozma, 2008) indicated that policies were more likely to be implemented in the classroom where the teachers had the opportunity to become knowledgeable with policy-related materials. Teachers should participate directly in content-specific professional development programmes aligned to the policy.

[8] These programmes are specifically mentioned here as it is discussed as part of the understanding of teacher use of ICT in Chapter Six)

Kozma (2008) further suggests that public-private partnerships are an important resource in effective policy implementation in countries, a point recognised in the South African e-Education policy:

> Sources of funding will include the following: private sector donations and support from international development assistance agencies; appropriate public-private partnerships to ensure the sustainability of the e-Education policy implementation (DoE, 2004b, p. 36).

Howie (2009) in her work on ICT policies and practices suggests that most of the discussion on ICT policies in education has been conducted from the context of developed, and hence well resourced, educational contexts. The challenges presented by ICT in education in developing countries such as South Africa and Chile need serious consideration. Some of the conditions making teaching and learning difficult in developing countries were discussed in section 1.2.2. Given the large investment in ICT in education, especially in developing countries where huge demands are made on limited financial resources, policies should offer specific goals for how the investment in technology can advance economic, social, and educational development (Kozma, 2008). Beyond the programmes, a policy should clearly describe how the resources will impact on the education system with measurable outcomes. The investments should be carefully monitored and programmes evaluated to provide policy-makers with reliable information to assist them in revising and refining the policies where necessary. Monitoring and evaluation programmes are essential to increase the likelihood that ICT policies will benefit students, schools, communities, and the economy in general.

2.3 Technologies and their use in education

There are a variety of technologies which have different characteristics and educational applications. A comprehensive, but not exhaustive, summary is given in Table 2.1.

Table 2.1: Classification of different IT applications (OECD, 2001, pp. 38-39)

Type of Application	Examples	Educational use
General Tools	Word-processing, presentation spreadsheet, multimedia authoring, including Web publishing	Becoming more and more important; require innovative and creative thinking from the teacher; quality is in the application, not the tool itself, since such tools are not dependent on particular content
Teacher Tools	On-line lesson outlines; computer-projector systems; interactive whiteboards	Lesson preparation; whole class teaching with shared view of screen; interaction managed by teacher
Communications	e-mail, e-learning; video-conferencing, Internet browsers	Require a view of education as reaching beyond school, for which they offer huge potential; familiar in the out-of-school context
Resources	Especially Web-based, whether general of specifically educational	Used according to availability, in whatever way wished; for resource-based, skills oriented learning
Computer-Assisted Instruction (CAI)	Drill-and-practice, related to a certain kind of content and relatively unsophisticated	Offers individual learning opportunities without expensive development; appears to fit well with transmission models of teaching and learning
Integrated Learning Systems (ILS)	Individualized task assignment, assessment and progression, including CAI, with recording and reporting if achievement	They appear to sit outside teacher-led instruction and learning, but are only truly effective as an integrated part of the learning process, which may have to be re-thought
Computer-based assessment Tools	Examination boards are developing computer-based examinations, which attempt to mimic paper-based tests	Components give advantage to the computer literate; teachers will need to incorporate some elements of similar tasks in their teaching, to prepare students adequately
Management Tools	Classroom procedures	Students' progress, deficiency analysis, etc
	School administration	Financial, personnel and educational resources
	Publication of results	Parents, governors, inspectorate, general public
	Communication	e.g. school to home and vice versa

New and emerging technologies are constantly explored to improve or create new teaching and learning opportunities. Hinostroza et al. (2008) suggest that emerging technologies can be grouped, based on its intention, into one of three groups:

1. Expanding learning opportunities (learn anywhere and anytime) based largely on mobile technologies (cell phones being one example)
2. Creating new learning scenarios in traditional contexts (tools for students focused on improving learning in schools)
3. Improving teaching and learning processes (tools for teachers focused on improving teachers' classroom teaching)

There is a recent focus on the use of digital technologies, such as the interactive white board (IWB), as a way of improving learning (Hinostroza et al., 2008). IWBs are a pedagogic tool for promoting interactive whole class teaching. IWBs are not new but their increased use in schools can expand and make better use of resources available to teachers. Emerging literature on the main benefits for teaching and learning of an IWB are that it:

- provides versatility with applications for all ages (no keyboard necessary making it user-friendly for younger children)
- allows more opportunity for interaction and discussions in the classroom
- increases lesson enjoyment and motivation
- encourages spontaneity and lesson flexibility
- enables teachers to save and print what is on the board and to share and re-use materials
- is easy to use so inspires teachers to use more ICT
- allows more opportunities for participation and collaboration
- allows different learning styles to be accommodated in a single class.

Students on the whole are enthusiastic about particular aspects of IWBs, such as their versatility in the classroom, multimedia capabilities and the fun and enjoyment they bring to learning (Hall & Higgins, 2005). It has also been suggested that while increased student motivation is certainly worth investigation, it may be somewhat overstated (Torff & Tirotta, 2010). Some studies show positive gains in literacy, mathematics and science achievement in primary school children, especially in average or above average achievers (Lewin, Somekh, & Steadman, 2008) but other studies are sceptical about the ability to accurately measure an increase in attainment (Smith, Hardman, & Higgins, 2006). When the impact of IWBs on students was investigated in South African classrooms, the ICT literacy of the teacher using the interactive technology seemed to be a key factor in its success, or lack of success (Slay, Siebörger, & Hodgkinson-Williams, 2008a, 2008b). Teachers in South African studies reported technical difficulties which prevented the optimal use of the interactive technology such as difficulties with: calibration and infrastructural issues; hardware and software; training and support; timetabling; and portability (Slay et al., 2008a). As with many other technologies, when investigating the value of IWBs the findings suggest that such technology by itself will not bring about fundamental change in the traditional patterns of whole class teaching (Smith et al., 2006).

2.4 Technology in the classroom

Perhaps the most important purpose of formal schooling is to assist students to achieve their fullest learning potential. The type of learning that focuses this study is the learning that takes place in classrooms with technology. As such, this section will provide a summary of current research on learning, learning with technology, accessing teaching and learning resources using one particular technology, the Internet, and using technology to assess the learning of students when they also use technology.

Current thinking about formal school learning

How students learn at school has been the focus of a great deal of research over the past few decades with much that is known about learning brought together in the seminal work of Bransford et al. (2000) with the National Research Council. More than just learning, it is learning with understanding that is the ultimate goal of formal education. The early work of Piaget (1978) and Vygotsky (1978) has led to an acknowledgment of pre-existing knowledge (prior knowledge, skills, and beliefs) of students, as well as the need to address their incomplete understandings, false beliefs and naive formulations of concepts as part of the process of teaching.

This current understanding of learning has implications for education (Bransford et al., 2000). Firstly, teachers should understand that students come to their classroom with preconceptions about how the world works. If the teacher is unable to engage the students' initial understanding of concepts, students may maintain their incorrect understanding of them and may even be able to learn the 'correct' answer for the purposes of assessment whilst maintaining their prior understanding when they leave the classroom. Secondly, if students are to develop competence in an area of inquiry, they must have a good foundation of the factual knowledge, understand the evidence and ideas in the context of a conceptual framework, and be able to organize their knowledge in ways that allow them to retrieve that knowledge and apply it in different situations. Thirdly, if a teacher adopts a "meta-cognitive" approach to teaching, students are more likely to be able to take control of their own learning by defining learning goals and monitoring their own progress in learning.

These principles of learning have profound implications for teachers and teaching (Bransford et al., 2000). More than understanding the pre-existing ideas of students, teachers should know how to address and work with these pre-existing understandings. This requires that they themselves should have a depth in subject content knowledge as well as pedagogical content knowledge. In order to achieve this sort of teaching and learning, firstly classrooms should be student-centred and teachers should pay close attention to the knowledge, attitudes and skills that students bring into the classroom. Secondly, teachers should give careful attention to what is taught (subject content knowledge), why it is taught (understanding), and what mastery or competence looks like. Thirdly, teachers should know how to assess that mastery through formative and on-going assessment strategies. Good formative assessment allows both students and teachers monitor progress and learning. Lastly, teachers should understand that learning is influenced by the context in which it takes place. This is particularly important in the developing country context as many students (including those in this study) live in poor and very poor communities which are often unable to support the learning that occurs in the school.

2.4.1 Learning with technology

Attempts to use computers and other technologies to improve student learning at school began many years ago (Bransford et al., 2000). Since the early days, the presence of computers in schools has increased dramatically, mostly in classrooms in developed countries. It is now widely accepted that computers and other ICTs play a significant role in providing interconnectivity in a globalised world (Pelgrum & Plomp, 1993). There is a growing appreciation for the role that ICT can play in changing the way people learn, not only in preparing school leavers for an information society, but also in the teaching and learning processes (Kozma, 2003). Therefore, we should move beyond teaching *about* computers and how to use them (computer literacy), to teaching and learning *with* computers.

A number of features associated with new technologies hold promise for change in education. The data emerging from the SITES-M2 case studies indicate key aspects for change (Kozma, 2003):

- technology has the potential to bring exciting curricula, based on real-world problems, into the classroom
- the interactive nature of technology is a key feature that gives students immediate feedback on their performance and allows them to reflect on their ideas and revise their understanding
- networked technologies allows teachers and students to build local and international communities that connect them with interesting people and extend their opportunities for learning.

Other research suggests that technology can allow increased access to authentic data through the Internet (Osborne & Hennessy, 2003). Technology in itself does not improve student achievement, but research is helping educators to understand how technology creates circumstances and opportunities for improving learning (Gibson, 2001).

In 2005, as part of the focus on ICT and educational change, the Department for Education and Skills (DfES) in the United Kingdom (UK) launched its e-strategy setting out six priorities for the implementation of ICT in education, one of which focused on transforming teaching and learning through the development of a collaborative approach to personalised learning activities. Some key elements of this priority are to embed technology across the curriculum and extend the curriculum with a special focus on "information age" skills and new forms of pedagogy which focus on flexibility and personalisation (Twining et al., 2006). The British Educational and Communications Technology Agency (Becta) reviewed the extent to which educational change had indeed been successful in the DfES report "Educational Change and ICT" (Twining et al., 2006). Their research found, among other things, that: the key to successful implementation of any e-learning strategy or policy involves the effective management of educational change, which is primarily about people rather than about technology; for technological change to be incorporated into education, there should be a buy-in at all levels in the system; leadership is vital for effective educational transformation; support in the forms of technical infrastructure, technical support to teachers when they need it, and continuing professional development for teachers using technology is essential; and there should be a shared vision informing use of technology in education. Indeed, in terms of the workload of teachers, there has been no evidence to suggest that it will diminish the role of the teacher if a serious attempt to exploit technology is made (Noss & Pachler, 1999). The research of Noss and Pachler (1999) has suggested that teachers need to spend a great deal of time monitoring, directing and assisting in the learning process when using technology. Teachers will continue to play a key role in learning with technology.

The enthusiasm surrounding the potential of ICT to have a role in educational change (Baggott La Velle, McFarlane, & Brawn, 2003) comes with a caution, as significant improvement in student attainment is not consistently measured at classroom level (Baggott La Velle et al., 2003; Becta, 2002; McFarlane et al., 2000; Twining et al., 2006). This is despite many years of ICT use in education in many different settings (Jakobsdottir, 2001) but hardly surprising given the lengthy time-scales needed for impacts to become measurable, and the mismatch often found between the methods of assessment being used and the changes made possible by ICT (Becta, 2002). The weak correlation between ICT and student attainment is explained by McFarlane et al. (2000), not in terms of lack of learning, but rather in terms of the need to reconceptualise our notion of attainment to identify learning not measured by large-scale quantitative studies with content-orientated measures.

Fuchs and Woessmann (2004) used data from the Programme for International Student Assessment (PISA) to analyse the relationship between student availability and use of home and school computers and educational achievement. When they controlled for family background and school environment, they actually found a negative correlation between the availability of computers at home and student attainment in mathematics and reading. Their paper suggests that the mere availability of computers at home for student use may actually distract from learning (Fuchs & Woessmann, 2004). While their analysis of the data is descriptive rather than causal, there does seem to be a need to make sense of this sort of contradictory evidence about the use of ICT in education to improve student learning.

2.4.2 Accessing teaching and learning resources with technology

Perhaps one of the greatest values of ICT in education lies in the Internet and how it allows access to information resources on the Web. The Internet is a global system of interconnected computer networks that use communication protocols to serve billions of users worldwide. It is a *network of networks* that consists of millions of private, public, academic, business, and government sites that are linked by electronic and optical networking technologies. Information resources on the Internet include documents on one computer that can be linked to documents on another by means of hyperlinks. The Internet is a data communications system, while the Web is a collection of interconnected documents which can be communicated via the Internet. In terms of educational value, Kuiper et al. (2005) have identified and summarized four characteristics of the WWW which include (1) a huge scope containing up-to-date written sources of information which offer both general and specialized information, (2) easy access by students who are both information consumers and providers of information, (3) a hypertext structure which allows text, opinions and ideas to be linked to one another and, (4) a visual character in the form of videos, music clips and audio recordings.

All of these aspects make access to the potential of the Internet a great affordance in project-based learning (Mistler-Jackson & Songer, 2000). The Internet provides students with authentic data and enables them to collaborate with peers and scientists (Mistler-Jackson & Songer, 2000). With email and video-conferencing, there is no longer a need for teachers and students to coincide in time and location (Noss & Pachler, 1999). Electronic communication enables students to become part of a community of learning (McFarlane & Sakellariou, 2002; Songer, 2003) and provide opportunities for collaboration with peers and professional scientists from outside the classroom and the school (Mistler-Jackson & Songer, 2000; Noss & Pachler, 1999; Songer, 2003).

2.4.3 Assessing with technology

Despite many years of research into the relationship between the use of digital technology and learning, the ways in which the use of digital technology shapes assessment in schools is still not well understood. Some of that research is focused around the use of technology to replace conventional assessment methods, that is, testing the same thing in a different way. Raikes and Harding (2003) argue that using a computer-based assessment will deliver tests at a lower cost, allow greater flexibility regarding administration of the test, allow instant scoring and feedback, reduce the possibility of errors, and allow for better targeted test items through the use of adaptive testing. Despite the obvious advantages of this sort of computer-based testing, not all schools have equal access to technology and not all students had equal prior computer experience, which may impact on the validity of the test scores (Russell, Goldberg, & O'Connor, 2003). To be fair to all students, regardless of the level of technology available, Raikes and Harding (2003) suggest that there should be a period of transition to prevent discrimination and recommend that computer-based tests and conventional pen-and-paper tests run parallel. Notwithstanding the benefits, attention should be paid to ensuring that there is equivalence in the paper-based and computer-based assessments and that the hardware and software are reliable and resilient.

There are three broad categories of technology and assessment that are addressed here (McFarlane, 2003). Firstly, computers can be used to assess the same thing in a different way. Here, the computer assessment simply replaces traditional assessment strategies. In this sort of computer use, the assessment criteria for the assessment remain unchanged, tending towards the automation of objective tests, the most obvious being multiple-choice items.

Secondly, in addition to the use of computer-based assessment which simply assesses the same thing in a different way, computers can be used to assess skills and knowledge which are difficult of even impossible to test using the conventional pen-and-paper method. In these instances the assessment criteria are different from those of traditional pen-and-paper tests. The 21st century skills with new educational goals and supported by an increased use of technology are difficult to assess in traditional ways and it is argued that there now should be assessment criteria different from traditional assessment criteria when computer-based testing is used (McFarlane, 2003; Ridgway & McCusker, 2003). Computers are well suited to the assessment of process skills such as discovering rules and finding relationships by the use of simulations and interactive games. In science, students can work with complex and real datasets which would not be possible without technology (Ridgway & McCusker, 2003). When Writh and Klieme (2003) looked at problem solving, they suggested that at least two aspects of competence be distinguished, the one focusing on analytical aspects where the goal is well defined, and all relevant information is either explicitly given or can be inferred by reasoning, and the other on dynamic aspects if relevant information is not available or directly deducible. The dynamic feedback which the computer-based test can provide to students when assessing the dynamic aspects of problem solving cannot, according to Writh and Klieme (2003), be given by traditional paper-based assessments.

Thirdly, computer-based assessment should also be examined in the context of using it to measure the outcomes of computer-based learning. In other words, assessing *learning with computers* rather than assessing *learning* with computers[9]. Here the distinction is made between learning *about* technology and learning *with* technology. Using the seven clusters of ICT-use and the learning characteristics associated with each suggested in the SITES-2 framework and outlined in section 3.1.1 (Kozma, 2003), the implications for testing to assess the aspects of learning with computers is addressed. These authors contend that 21st century assessments should incorporate the explicit examination of technologies in supporting, extending, and transforming student learning.

2.5 The role of ICT in science education

Research has not been able to provide conclusive evidence of positive impact on student achievement (Balanskat, Blamire, & Kefala, 2006; Harrison et al., 2002). Some promising findings of positive impact come from home language in primary education and science (Balanskat et al., 2006), although there are still conflicting findings on improved attainment in science (Webb, 2008).

The differences of specific roles of ICT in science education from other subject areas were explored in this study. Themes that arose in this exploration included the role of ICT in practical work (simulations, data logging tools), the role of ICT in developing conceptual learning in Science, and the role of ICT in motivating students to continue with science beyond the early school grades. The literature addressing these three themes is presented here and will be referred to later in the analysis.

2.5.1 ICT and science practical work

Research focused around ICT in science education centres predominantly around the use of technology to support practical work (Becta, 2004), in particular, the use of simulations and data-loggers as tools to assist in the practical investigations unique to science.

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[9] The italic is needed to show the correct emphasis.

Simulations

The use of digital simulations as a specific application of ICT has received much attention in science education, the obvious benefits to school science being that they enable students to explore and investigate phenomena not possible in the classroom. For example, investigations of phenomena which are too difficult or too dangerous (using toxic chemicals), too large or small (cosmic or molecular reactions), or too fast or slow for direct observation (McFarlane & Sakellariou, 2002; Webb, 2008).

Some studies on the use of ICT in science simulations have focused on the most difficult aspect of science teaching, developing students' conceptual understanding of difficult science topics. McFarlane and Sakellariou (2002) argue that using ICT either as a tool or as a substitute for the laboratory-based elements of an investigation can aid theoretical conceptual understanding in some topics in the science curriculum (McFarlane & Sakellariou, 2002). Some experimental studies have shown that computer simulations can be as effective as the real activity in teaching science concepts and improving scientific understanding across a variety of topics (Baxter & Preece, 2000; Huppert, Lomask, & Lazarowitz, 2002; Trindade, Fiolhais, & Almeida, 2002; Zacharia, 2005). Students in ICT-supported science classrooms also benefit from the instant feedback from experiments, as well as from the chance for more independent and self-directed learning (Baggott La Velle et al., 2003).

In summary, there is evidence that focusing on specific areas of difficulty in science and addressing those with carefully designed ICT-based simulations can lead to productive learning (Webb, 2005, 2008). However, sacrificing the "hands-on" aspect of learning science is not without criticism. Simulations as a tool for practical work completely remove any mechanical manipulation of equipment, thus eliminating experimental error. "Sanitized" data produced by simulations may serve to reinforce misconceptions (Osborne & Hennessy, 2003).

Data loggers

Another application of IT in science practical work is the use of data loggers (Webb, 2008), also called Micro-based laboratories or MBLs, that allow students to collect, record, and store data collected experimentally in the field or classroom for more accurate results. They can provide quicker and more accurate collection of data, saving lesson time and giving more accurate results (Osborne & Hennessy, 2003) while reducing the mechanical aspects of practical work and allowing students to concentrate on interpreting and analyzing data (McFarlane & Sakellariou, 2002).

Research into the value of MBLs in terms of science learning has produced varying results. Linn and Hsi (2000) found that students were much better at interpreting their experimental findings when they were able to use real time data-collecting strategies. Newton's (2000) small-scale qualitative study showed that while there was a considerable potential contribution of data-logging to learning science, its successful implementation depended on a number of factors, including the availability of resources and the skills of the teachers.

2.5.2 ICT and conceptual understanding in science

Linn and Hsi (2000) report on a collaborative project that has investigated pedagogical issues for science education in classrooms that use ICT and produced a list of "pragmatic pedagogical principles" for conceptual understanding in science. The principles were to: encourage students to build on their scientific ideas as they develop increasingly powerful and useful pragmatic scientific principles; encourage students to investigate personally relevant problems that revisit their scientific ideas regularly; scaffold science ideas so that students participate in the inquiry process; model the scientific process of considering alternative explanations and diagnosing mistakes; scaffold students' feedback to explain their ideas; provide multiple visual representations from varied media; encourage students to listen and learn from each other; design social activities to promote productive and respectful interactions; scaffold groups to design criteria and standards; employ multiple social activity structures; encourage students to reflect on their scientific ideas and on their own progress in understanding science; engage students as critics of diverse scientific information; engage students in varied sustained scientific project experiences; and establish an inquiry process which can be generalized and is suitable for diverse scientific projects (Linn & Hsi, 2000). One key idea in these "pragmatic pedagogical principles" is understanding or identifying the thinking processes of students, especially when using new technologies as ways of learning (Cox et al., 2004).

When trying to understand science concepts and processes, understanding can be aided by visual modes of presentation. Trindade et al. (2002) developed a 3-D virtual environment for studying particular aspects of physics as a way of catering for the different learning modes of their students. Their research suggests that using a virtual environment may help students with high spatial aptitude to acquire better conceptual understanding. Osborne and Hennessy (2003) review the impact of ICT use on the science curriculum, pedagogy and learning and show that there are various ways of linking ICT use to existing classroom teaching, either supporting or replacing it (Osborne & Hennessy, 2003). They conclude, however, that evidence of ICT transforming education is only found in isolated pockets as it is not yet entrenched in the teaching practice of many science teachers.

2.5.3 ICT and student motivation in science

Trends across developed and developing countries show a drop in interest and take-up of Science, Technology, Engineering and Mathematics (STEM) subjects (European Union, 2004; National Science Board, 2008). The TIMSS 2003 study reported that 16% of South African Grade 8 general science students answered "disagree" to the statement "I enjoy learning science", as did 33% of Australian students, 49% of Chinese Taipei students, and 62% of Korean students (Martin et al., 2004). Some researchers are hoping that ICT might provide the motivation required to keep young students interested in science beyond the primary school years. One factor attributed to this decline in interest (and achievement) in the STEM subjects is the change in children and the way they think and learn. This change is brought about when children grow up with technology in their everyday lives (Jukes & Dosaj, 2006; Prensky, 2001). Today's students, those growing up with access to technology on a daily basis, are referred to as Digital Natives. In OECD countries, this phenomenon of young people who experience access to digital technologies in this way is almost universal (OECD, 2008). They think and process information fundamentally differently from the past generation of students, known as Digital Immigrants. Teachers who have not grown up with technology typically fall into this group. Students of these teachers are easily bored when work is presented as "lectures, step-by-step logic and 'tell-test' instruction" (Prensky, 2001, p. 3). Using ICT integrated into the teaching of science may be the only way to motivate this generation of Digital Native students.

Most teachers report a motivation effect of ICT when teaching science (Betts, 2003; McFarlane & Friedler, 2003; Mistler-Jackson & Songer, 2000; OECD, 2006, 2008). In the most recent SITES 2006 study (2008), when science teachers were asked about their curriculum goals for using ICT, the response "to increase learning motivation" as a curriculum goal was unanimous across all countries (Law & Chow, 2008). Students may be motivated to learn science because using ICT may give them opportunities to have more control over their own learning by allowing them to study the topics they are interested in and that are relevant to their own lives (Osborne & Collins, 2000). The results from Betts' study (2003) suggested that ICT can motivate students and enhance the quality of learning where its use is tailored to lesson objectives and the specific needs of the students. McFarlane & Friedler's study (2003) of the motivational effect of portable computers showed a positive effect on student motivation. However, they caution that despite teachers' perceptions about the motivational effect of ICT it alone cannot sustain the motivation to use computers. Rather it is the teacher use and integration of ICT into the curriculum that plays a pivotal role in keeping students motivated (McFarlane & Friedler, 2003).

2.6 Obstacles to successful integration of ICT

When trying to understand the role of ICT in school education, attention should focus on factors that prevent successful integration of ICT in education. These obstacles, or barriers, could be related to resources, the skills and levels of training available to teachers who use ICT, personal beliefs of teachers who use ICT in their teaching, institutional and cultural factors, as well as other factors which may influence the use of ICT in education.

The summary of research on this topic by Becta suggests four categories of factors: resource-related; those associated with training, skills, knowledge and computer experience; attitudinal and personality; institutional and cultural (Becta, 2003). According to Pelgrum (2001), the highest rated barrier to the use of ICT in teaching is the lack of resources. In the recent SITES 2006 study (Law et al., 2008), teachers were asked about the barriers to using ICT in teaching and the results were slightly different from Pelgrum's findings of 2001 (Pelgrum, 2001). Teachers were asked to categorise their personal perceptions about the possible obstacles to ICT use. School-related obstacles (including availability of resources both in and out of school, and lack of flexibility) were rated lowest and teacher-related obstacles (including lack of skills, knowledge and time) were rated highest (Law & Chow, 2008). Teachers in South Africa put student-related obstacles (including lack of ICT skills, and lack of access to ICT outside the school) as high as 70% (the highest score rated).

Time, for both formal training and self-directed exploration features in the literature as barriers to ICT use (Becta, 2003). Managing ICT in teaching means that teachers have to find the time to source, test and evaluate software for use in their specific teaching environment. Cuban et al. (2001) gathered evidence from interviews with teachers, students and school staff, surveys, and classroom observations that pointed to the limited time, together with the difficulties in finding suitable training in ICT use as barriers. In the SITES 2006 study, science teachers in South Africa reported an attendance at ICT-related professional and technical development activities as low as 8% (scoring lowest of the 22 countries in the study). It is suggested that the low attendance is as a result of lack of availability, rather than an unwillingness to attend, as South African teachers also rated among the highest in "desire to attend" in the same survey (Law & Chow, 2007).

A significant determinant in a teachers' willingness to use ICT is their level of confidence in using ICT (Pelgrum, 2001). This may be an actual barrier if the teacher has insufficient training or experience or a perceived barrier as some teachers may carry the perception that computers are complicated and difficult to use (Drenoyianni & Selwood, 1998; Jakobsdottir, 2001; Molefe, Lemmer, & Smit, 2005) and hence lack the self-confidence to use ICT. In the data from the SITES 2006 study, South African science teachers rated their own ICT competencies and were positioned lowest for general ICT competence and second lowest for pedagogical competence of the 22 countries in the study (Law & Chow, 2008). Science teachers' confidence in using ICT in science education should be seen against the backdrop of the low levels of subject content knowledge and certification. Jita and Ndlalane (2005) investigated the subject matter knowledge of teachers and teacher leaders participating in a professional development programme and concluded that the subject content knowledge of science teachers was inadequate for mastery of these some science curriculum topics.

2.7 Concluding remarks

A number of technologies have made their way into education. Apart from the popular word-processing, presentation and spreadsheet tools, a number of tools specifically designed for teaching, such as the interactive white board, are making their way into classrooms. In addition, on-line web-based resources are also becoming increasingly popular for accessing information useful in the classroom setting. The range of tools and their application for education were presented in section 2.3. It is argued that a sustained use of technology in education is sufficiently important to warrant attention in education policy. It is through effective policy development that ICT can be effectively and efficiently integrated into education in ways that improves teaching and learning. It is also argued that there is great potential for teaching and learning when technology is effectively integrated into the classroom, both as teaching and learning tools and as assessment tools. Many of the features associated with new technologies hold promise for change in education in line with the demands of the 21st century. Technology in science education has a unique role to play in helping to meet the demands of practical work and the development of conceptual understanding in a conceptually difficult subject. In summary, the literature supports the integration of technology in education in general and science education in particular from a variety of different perspectives.

CHAPTER THREE

The Conceptual Framework

The knowledge base of teaching with technology is often criticised for a lack of theory and conceptual frameworks to inform and guide research in the field (Angeli, 2005; Angeli & Valanides, 2005; Mishra & Koehler, 2006; Zhao & Frank, 2003). More recently, attempts have been made to develop frameworks to assist in this regard. The pedagogical use of ICT in education has been examined in a number of studies through a variety of conceptual frameworks. Two of these ways of examining the pedagogical use of ICT, namely the patterns of ICT use (SITES-M2) and pedagogical orientations (SITES 2006), are discussed in the first part of this chapter (section 3.1). The second part of this chapter then discusses the conceptual framework which was used in this study, namely the Four in Balance Model, formulated to investigate the value of the pedagogical use of ICT (section 3.2). It provides the lens for this research which was designed to address the research question: *What is the value that using ICT adds to the teaching and learning of Science when teachers use ICT in a context of limited resources, typical of a developing country?* The last part of the chapter unpacks one aspect of the Four in Balance Model, teacher expertise, by showing the development of a more explicit conceptual understanding of teacher expertise when teaching with technology, the concept of Technological Pedagogical Content Knowledge (TPCK). The discussion shows how the concept of TPCK (Angeli & Valanides, 2009) was developed over a number of years, building on previous concepts such as Content Knowledge (CK), Pedagogical Knowledge (PK), and finally Pedagogical Content Knowledge (PCK) (Shulman, 1986). The development of these has led to a better understanding of how to understand teachers' use of ICT in their teaching practice.

3.1 Examining pedagogical use of ICT in science

Pedagogical use of ICT has been investigated in a number of studies using different conceptualizations of pedagogy and of use. The SITES-M2 study has articulated a framework for patterns of ICT use, and the SITES 2006 study has a particularly useful conceptualization of pedagogical orientations, both of which were useful for this study.

3.1.1 Patterns of ICT use (SITES-M2)

As part of understanding the relationship between the use of ICT and classroom practices, the SITES-M2 study sought to differentiate between various uses of ICT and their associated patterns of teacher and student practices in the 174 cases from 28 participating countries, including South Africa (Kozma, 2003). The SITES-M2 study focused on innovative pedagogical practices and the analysis focused on codes generated from the analysis related to teacher practice, student activities, ICT practices, and the technologies used. These four focus areas were derived from the activities listed in Table 3.1 (adapted from Kozma, 2003, p. 49).

Table 3.1: ICT activities within four focus areas (from SITES-M2)

TEACHER PRACTICE	STUDENT PRACTICE	ICT PRACTICES	ICT USED
Lecture	Conduct research	Tutor	Laptop
Advise	Search for information	Communicate	LAN
Create Structure	Solve problems	Search for information	e-mail
Design materials	Analyze data	Create products	Web resources
Monitor	Publish results	Collaborate	Productivity tool
Collaborate with students	Create products	Simulate/research	Web design tools
Collaborate with colleagues	Collaborate with others	Monitor	Collaborative environment
Collaborate with outside	Collaborate with outside	Plan	Multimedia
Drill and practice	Assess themselves		Simulations
	Pick own tasks		Tutorials
			Course management

Through a combination of qualitative and quantitative methods, the SITES-M2 study examined the similarities across cases and across countries to identify patterns of innovative pedagogical practices. Seven different patterns of practices emerged as a result of cluster analysis, each of which is summarized in Table 3.2 (adapted from Ainley, Banks, & Fleming, 2002, p. 77; Quellmalz & Kozma, 2003).

Table 3.2: Patterns of Innovative uses of ICT (SITES-M2)

Pattern	Summary of Characteristics of the Cluster	Teacher Practices	Student Practices	ICT Use	Combined Outcomes
Tool use	A strong emphasis on the extensive use of technology tools, such as e-mail and productivity tools, to communicate, to search for information and to create products. These tools include word processing.		Students often collaborated with each other to search for information and create products	Students and teachers in this group were most likely to use e-mail and other productivity tools. They used multimedia tools and web resources. They used technology to create products, search for information, and communicate.	
Student Collaborative research	These cases were characterized by students working collaboratively in pairs or groups to conduct research, less frequently to collect and analyse data. Information and communication technologies were used to conduct research or create a presentation on the group's ideas or their solution to a problem.	Teachers in this cluster were most likely to give lectures and provide structure for students. They provided advice and monitored student activities. They often designed materials.	Students in this cluster were most likely to collaborate with other students to conduct research and analyse data. They also search for information and solved problems	Students and teachers in this group were most likely to use Web design tools, multimedia, e-mail, laptops, and LANs. They were most likely to use technology to simulate research and collaborate. They also used Web resources and productivity tools. They used technology to communicate, search for information, and create products	Students in this cluster were most likely to acquire new ICT, problem-solving, and collaboration skills. Teachers acquired new pedagogical skills. The curriculum and class day was more likely to be reorganised.
Information Management	The primary use of information and communication technologies in this cluster was for the purposes of searching for – organizing, managing and using – information for teaching and learning purposes. Some use of productivity tools was apparent, particularly for the purposes of presenting information gleaned from information searches.	Teachers in this group most often designed materials and created structure for students. They often provided students with advice and monitored their progress. They often collaborated with colleagues.	Students in this cluster were most likely to search for information, solve problems, publish results, and access their own work and that of others. They also collaborated with other students to conduct research and create products.	Teachers in this group were most likely to use course management tools and to use technology to plan instruction and monitor student progress. Teachers and students were most likely to use Web resources to search for information and productivity tools to create products. They also used multimedia, LANs, and email to communicate.	Students were more likely to acquire ICT skills, communication and collaboration skills, and information handling and problem solving skills. Teachers acquired new pedagogical skills. The curriculum was more likely to be reorganised.

Pattern	Summary of Characteristics of the Cluster	Teacher Practices	Student Practices	ICT Use	Combined Outcomes
Teacher Collaboration	Emphasis on teacher collaboration with both students and other teachers often for the purposes of designing instructional materials or activities.	Teachers in this cluster were most likely to collaborate with colleagues, students, and outside actors. They also designed materials, created structure for students, provided them with advice, and monitored their progress.	Students in this group were most likely to pick their own tasks. They also collaborate with each other and others outside the class to search for information, created products, and publish results.	Teachers and students in this group were most likely to use technology o create products and to use simulations. They also used productivity tools, multimedia, and email. They used the Internet to search for information and communicate with others.	Teachers acquired new collaborative skills.
Outside Communication	Characterized be the tendency for student to make use of communication technologies such as e-mail, the Internet, conferencing software or listservs to work with other students outside of the classroom environment	Teachers often created structure, advised students, and monitored their progress. They also collaborated with colleagues.	Students in this cluster were most likely to collaborate with others outside the class. They also collaborated with other students to conduct research, search for information, create products, and publish results.	Students and teachers in this group were most likely to use collaborative environments and were amongst the most frequent email users. They most often used technology to communicate. They used Web resources to search for information, and they used productivity tools.	
Product creation	The primary use of information technology in this cluster was to facilitate the design and creation of digital products using software packages	All teachers in this cluster created structure and advised students.	Students in this cluster were most likely to create products. They also collaborated with each other to search for information and publish results.	Students and teachers in this group were among those who most often used technology to create products. They also used Web resources to search for information and used productivity and multimedia tools.	
Tutorial Projects	Characterized by the use of tutorial or drill-and-practice software to allow students to work independently, to receive feedback on their performance and to refine their skills.	Teachers often designed materials, frequently in collaboration with colleagues.	Students in this group were most likely to engage in drill and practice.	All the students in this group used tutorial packages.	

Each of the seven patterns illustrates a different way in which ICT was used to facilitate learning or instruction in the classroom and was used to focus the analysis of teacher use of ICT in the three case studies in this research.

3.1.2 Pedagogical orientations (SITES 2006)

Through the three SITES studies, the concept of pedagogical practice paradigms has evolved to a point of being a useful and valuable way in which to frame other studies in ICT in education.

Traditional and emerging pedagogical practices paradigms

As a result of the SITES-M1 study, the International Association for the Evaluation of Educational Achievement (IEA) developed a conceptualization called the "Emerging Pedagogical Practices Paradigm" (EPPP) (Kozma, 2003; Law et al., 2008; Pelgrum & Anderson, 1999). This concept of *emerging pedagogical practice orientation* was developed to capture the changes occurring in classrooms internationally that align with what is believed to be learning outcomes for the knowledge society. For the first SITES module, the traditionally important pedagogical paradigm was established to encompass the *traditionally important pedagogical practice orientation* established in the industrial society (Law et al., 2008; Pelgrum & Anderson, 1999). The SITES-M1 study investigated, inter alia, the balance between the two different pedagogical practice orientations in classrooms internationally. The implications for pedagogy in the information society different from the industrial society are summarised in Table 3.3:

Table 3.3: Pedagogy in the Information Society and in the Industrial Society

Aspect	Less or lower (pedagogy in an industrial society)	More (pedagogy in the information society)
Active	Activities prescribed by the teacher Whole-class instruction Variation in terms of activities Programme-determined pace	Activities determined by students Small groups Variety of activities Learner-determined pace
Collaborative	Individual Homogeneous groups Likelihood of everyone for him/herself	Working in teams Heterogeneous groups Supporting one another
Creative	Reproductive learning Application of known solutions to problems	Productive learning Finding new solutions to problems
Integrative	Linkage between theory and practice Separate subjects Discipline based Individual teachers	Integration of theory and practice Relationships/connections between subjects Thematic Teams of teachers
Evaluative	Teacher-directed Summative	Student-directed Diagnostic

(Voogt, 2003 in Voogt, 2009, p. 326)

Voogt and Pelgrum (2003, p. 83, in Plomp, 2006) summarized these 'emerging' pedagogical practices for the information society as:

- The new goals that reflect the demands of the information society imply the need for students to become competent in information management, communications and collaboration, and meta-cognition.
- Less structured sources of information will become important as learning materials.
- The traditional boundaries between subjects need to be bridged. Content should not be divided into isolated facts and topics but offered in an integrated way. In addition, students need to be able to understand relations between concepts instead of being able simply to reproduce facts.
- The current gap between discipline-related content taught in schools and the application of knowledge in real life also should be bridged. The curriculum should be centred on authentic problems parallel to those in real world settings.

- The boundaries between the school and the outside world should fade. It is expected that students will spend less time in the classroom and the school. Moreover, instruction in the classroom should move from an approach focused on teaching 30 children to one focused on meeting the needs of individual students.

The SITES innovative pedagogical orientation

The SITES-M2 case studies, through their reporting of innovative classroom practice, focused on innovative pedagogical practices, with evidence that some of these practices provided students with opportunities to take responsibility for their own learning, to identify their own learning needs and strategies, and to develop collaboration, inquiry and communication skills (Kozma, 2003; Law et al., 2008). From the SITES-M2 study, an important dimension of connectedness with peers and experts beyond the classroom was identified. There was evidence of students collaborating with outside peers and experts in their field to create products and publish results (Law et al., 2008).

When the third module, SITES 2006, was designed, the indicator for the emerging pedagogical practice orientation was replaced with the more refined indicators of the *connectedness orientation* and the *lifelong learning orientation* (Law et al., 2008). Table 3.4 summarises the development of terminology in the three studies (Voogt, 2009).

Table 3.4: Development of terminology through the three SITES studies, Adapted from (Voogt, 2009)

	Study characteristics	Terminology used for education associated with the industrial society	Terminology used for education associated with the information society
SITES M-1	Survey for principals and technical co-ordinators	Traditionally important practice paradigm (traditional pedagogy)	Emergent paradigm (emerging pedagogy)
SITES M-2	Case studies	—	Innovative pedagogical practices using technology (innovative pedagogy)
SITES 2006	Survey for principals, technical co-ordinators, and maths and science teachers	Traditionally important practice orientation	Innovative practice orientation (lifelong learning orientation plus connectedness orientation)

Voogt and Pelgrum (2003) argue that for many education systems around the world to adapt to the information society, it is necessary that they substantially change their curricula so that students are able to develop competencies that are not addressed in traditional curricula. This means acquiring such key skills as digital literacy and teamwork, problem-solving, and project management, referred to as lifelong learning competencies. The concept of lifelong learning as an educational strategy emerged about three decades ago through the efforts of Organisation for Economic Co-operation and Development (OECD), the United Nations Educational and Scientific Council (UNESCO) and the Council of Europe (OECD, 2004). It emerged to challenge the idea that while individuals continue to learn throughout their lives, formal educational opportunities were only being offered in the early part of life, typically about 12 years and usually through formal schooling. Lifelong learning refers to all learning throughout an individual's life, not just formal programmes of adult education (OECD, 2004). The concept, as articulated by the OECD has four main features:

- A systemic view – the lifelong learning framework views the demand for, and supply of, learning opportunities, as part of a connected system covering the whole lifecycle and comprising all forms of formal and informal learning.
- Centrality of the learner – learning must meet students' needs.

- Motivation to learn – attention must be given to developing the capacity for 'learning to learn' through self-paced and self-directed learning.
- Multiple objectives of education policy – a student's objectives such as personal development, knowledge development, economic and social objects, may change over a lifetime.

There are a number of important socio-economic forces pushing for lifelong learning, notably the increased pace of globalisation and technological change, the changing nature of work and the labour market, and the aging populations among them (OECD, 2004). There is a need in the new global community to continue to upgrade work and like skills throughout life. Individuals are now more likely to experience frequent changes in jobs over their working life. For the individual, lifelong learning emphasizes creativity, initiative, and responsiveness (OECD, 2004). In 2006, the European Union (EU) outlined eight key competencies for lifelong learning, those which all individuals need for personal fulfilment and development, active citizenship, social inclusion and employment (OECD, 2006). They are:

1. Communication in the mother tongue
2. Communication in foreign languages
3. Mathematical competence and basic competencies in science and technology
4. Digital competence
5. Learning to learn
6. Social and civic competencies
7. Sense of initiative and entrepreneurship
8. Cultural awareness and expression.

Each of these is considered to be equally important because of its contribution to a successful life in a knowledge society. Lifelong learning as an emerging educational paradigm is ambitious and can only realistically be achieved over a long period of time. In South Africa, the concept has been adopted both at a political and policy level. In defining e-Education, the White Paper (DoE, 2004b) articulates the challenges of an education system that equips people with the knowledge, skills, ideas and values needed for lifelong learning. The DoE believes that the development in ICT in education creates access to learning opportunities, redresses inequalities, improves the quality of learning and teaching, and delivers lifelong learning (DoE, 2004b). ICT in education is seen by many countries, including South Africa, as among the most effective ways of increasing and widening participation in lifelong learning, while keeping down costs to an affordable level.

3.2 Conceptual framework for this study

The Dutch have been monitoring ICT use for some time to see where and how computers are used in their primary and secondary schools (Kennisnet, 2009). They are interested in finding out what works as regards ICT in schools, and perhaps more importantly, why it works. The conceptual framework used in this study is informed by the Four in Balance Model, a scientific approach to the introduction of ICT in education (Kennisnet, 2009) that is used in the Dutch schools. The model proposes that the effective long-term use of ICT in teaching requires the balanced deployment of four basic elements: *vision (overall view), expertise, digital learning materials, and ICT infrastructure*. Two types of building blocks: educational software and ICT infrastructure, comprise the technical building blocks, while vision and staff competencies comprise the social building blocks (Plomp, 2006). When these four elements are in balance, ICT adds value to the teaching and learning process. The following is a brief explanation of these four basic elements (Kennisnet, 2009, p. 12):

• **Vision:** the school's view of what constitutes good teaching and how the school aims to achieve it. This involves the school's objectives, the role of the teachers and students, the actual teaching content, and the materials that the school uses. The vision adopted by the school's managers and teaching staff determines both the school's policy and the design and organisation of its teaching.

• **Expertise:** teachers and students need to have sufficient knowledge and skills in order to utilise ICT to achieve educational objectives. This involves not only basic ICT skills such as the ability to operate a computer, but pedagogical ICT skills are also necessary if ICT is to be used to help design and organise learning processes. These additional skills therefore specifically concern the use of ICT to achieve educational objectives.

• **Digital learning materials:** all digital educational content–both formal and informal–constitutes digital learning material. This includes computer programmes.

• **ICT infrastructure:** the availability and quality of computers, networks, and Internet connections constitute infrastructure facilities. In addition to this traditional definition, electronic learning environments and the management and maintenance of the school's ICT facilities are also taken to be part of the ICT infrastructure.

Although teachers play a role in this, individual teachers cannot create this cohesion all by themselves, so **collaboration and support** from the school's managers (Principals and Heads of Department) is necessary. It is up to these managers to provide **leadership** in this process and create conditions for support and collaboration with other professionals. Figure 3.1 shows the basic elements as they relate to one another.

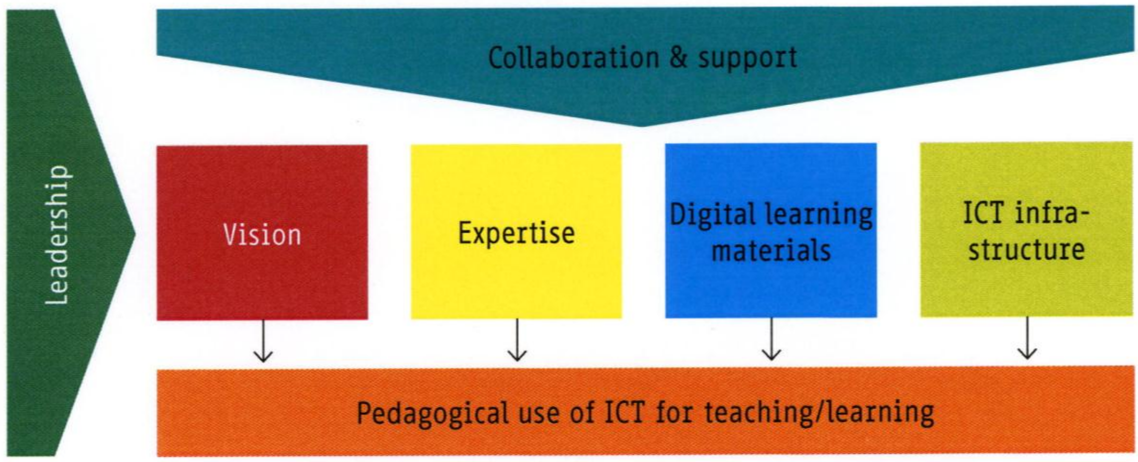

Figure 3.1: Basic Elements of the Four in Balance Model (Kennisnet, 2009, p. 13)

The Four in Balance Model provided a starting point for exploring and understanding ICT use South African teachers, albeit that the context of teaching and learning is significantly different. Amongst other things, the four aspects presented in the model (vision, expertise, digital learning materials, and ICT infrastructure), as well as the other components, were examined by using the data from the South African science teachers collected using the SITES 2006 teacher questionnaire, together with the qualitative data collected from three science teachers in the case studies. The Four in Balance Model was developed and is used to monitor the value of ICT use in the Netherlands, a developed country with a high level of ICT infrastructure in schools. South Africa provides a significantly different context, one in which the majority of teachers teach in classrooms with limited infrastructural and technology resources (discussed in section 1.2.3). There is no equivalent model for examining the value of ICT in a developing country context. For this reason, the Four in Balance Model provided a good starting point for this study. Part of the intellectual contribution of this study is the examination of the robustness of the Four in Balance Model, and the subsequent adjustment of the model to make it of use in a developing country context such as South Africa. This contribution is discussed in the Chapter 8.

3.3 Teacher expertise as Technological Pedagogical Content Knowledge

One aspect of the Four in Balance Model was of particular importance to this study, that of teacher expertise. Teacher expertise in ICT use was a theme that emerged through the in-depth case studies as an important aspect of teacher use of ICT. The model articulates teacher expertise as the knowledge and skills needed for the pedagogical use of ICT. Mishra and Koehlar (2006) argue that the pedagogical use technology requires the development of a complex form of knowledge that they refer to as Technological Pedagogical Content Knowledge (TPCK). TPCK attempts to capture some of the essential qualities and complexity of teacher knowledge required to integrate ICT in teaching and is thus more explicit that the use of **expertise** presented in the Four in Balance Model. The development of their concept TPCK is discussed in the following section.

3.3.1 Pedagogical Content Knowledge

Within the context of teaching policy, teacher education, and educational reform, Shulman has been credited with advancing thinking about teacher knowledge, through his model of Pedagogical Reasoning (Shulman, 1987) which provides a detailed description of educational processes that can also provide a basis for examining the issues and problems associated with teaching and learning ICT (Webb, 2002). Shulman's (1987) model focuses on the processes involved in teaching, including the transformation of knowledge so that it can be taught. Through his research with experienced and novice teachers' teaching practices, Shulman identified the sources, suggested outlines of the teacher knowledge-base, and identified the types of teacher knowledge and skills that would be needed by teachers in order to teach well. Schulman (1987) argues that teaching is often trivialised and the complexities often ignored, and proposes that there exists an elaborate knowledge base for teaching.

This formulation of a teacher's capacity to teach, in its simplest articulation, requires that the teacher understand what is to be learnt and how it is to be taught (Shulman, 1987). Teaching then proceeds through a series of activities in which students are given specific instructions and opportunities to learn. The learning, however, ultimately remains the responsibility of the student. A teachers' knowledge base would at least fall into the following categories: *content knowledge*; *general pedagogical knowledge* (with special reference to those broad principals and strategies of classroom strategies of classroom management and organisation that appear to transcend subject matter); *curriculum knowledge* (with particular grasp of the materials and programmes that serve as 'tools for the trade' for teachers); *pedagogical content knowledge* (that special combination of content and pedagogy that is uniquely the territory of teachers, their own special form of professional understanding); *knowledge of students and of their characteristics; knowledge of educational contexts; knowledge of educational ends, purposes, and values, and their philosophical and historical grounds* (Shulman, 1987, p. 8).

Shulman (Shulman, 1987) considers pedagogical content knowledge of special interest because it identifies the special body of knowledge for teaching and represents the coming together of content and pedagogy into an understanding of how particular topics are organised and presented for effective teaching. Other researchers have adopted the term pedagogical content knowledge and defined it for particular subjects such as science. For example Linn and Hsi (2000) state that:

> Pedagogical content knowledge refers to knowledge about a topic that enables improved teaching of that discipline. In science such knowledge involves an understanding of the ideas students bring to class, the context in which students apply their science knowledge, and the multiple models of the same topic used by students and experts in the various contexts of application (Linn & Hsi, 2000, p. 337).

Shulman (1987) identifies four sources of the teaching knowledge base: scholarship in content disciplines; materials and setting of the institutionalized educational process (such as curricula, textbooks, school organisations); research on schooling, social organisations, human learning, teaching and development, together with the other social and cultural phenomena that affect what teachers can do; and the wisdom of practice. He used his research with student-teachers to understand the complex process of teaching through the processes of pedagogical reasoning and action. He emphasized the process of teaching as comprehension and reasoning, and as transformation and reflection (Shulman, 1987), identifying aspects of pedagogical reasoning when he put forward his Model of Pedagogical Reasoning and Action (Shulman, 1987, p. 15). The model, summarised in brief, includes aspects of pedagogical reasoning such as: Comprehension (the need to understand before being able to teach); Transformation (the transformation of ideas in some way before being taught); Instruction (observable acts of teaching); Evaluation (checking for understanding and misunderstanding); Reflection (reflection on teaching and learning that has occurred); and New Comprehension (comprehension adjusted based on reflections).

3.3.2 Technology integrated pedagogy

Shulman (1986) did not explicitly discuss technology and its relation to content, pedagogy and students, and thus his original concept PCK did not specifically explain how teachers use the affordances of technology to transform content and pedagogy for students (Angeli & Valanides, 2009). Mishra and Koehler (2006) argued that Shulman's construct of PCK needed to be revisited and proposed a conceptual framework for educational technology by building on his formulation of "pedagogical content knowledge" and extending it to the domain of teachers integrating technology into their teaching practice. The basis for the framework developed by

Mishra and Koehler (2006) is the understanding that teaching is a highly complex activity, drawing on many different types of knowledge articulated by Shulman in his framework. There are clearly many knowledge systems that are fundamental to teaching, including knowledge of student thinking and learning, and knowledge of subject matter. Shulman advanced the argument by suggesting that PCK lies at the intersection of content and pedagogy. Successful teachers have to confront both issues (content and pedagogy) simultaneously and PCK is a conception now widely used in the area of science education (Hewson & Hewson, 1988; National Science Teachers Association, 2003) and valued for teacher education programmes. A diagrammatic representation of Shulman's PCK is shown in Figure 3.2.

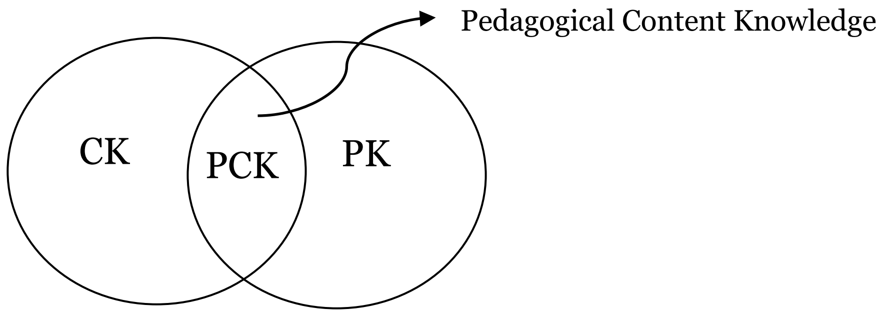

Figure 3.2: Diagrammatic representation of Shulman's conceptualization of PCK

Although Shulman did not discuss technology and its relation to pedagogy, Mishra and Koehler (2006) suggest that it was not that he thought technology to be unimportant, rather the sorts of technologies present when he developed his framework, such as text books, overhead projectors, and typewriters, were commonplace in the classroom so did not receive special attention. The presence of these technologies in classrooms was standardised and fairly stable, and teachers could focus on content and pedagogy in the assurance that the context would not change too dramatically over their teaching career. However, since the 1980s a new range of digital technologies has become available, namely information and communication technologies, which have come to the forefront of educational discourse. The rapid evolution of these technologies means that they cannot be easily overlooked, and teachers will frequently have to learn new techniques and skills as old ones become obsolete. Technology has become an important aspect of teacher knowledge.

In the same way that knowledge of content and knowledge of pedagogy were considered separate aspects of teacher knowledge prior to Shulman's work, knowledge of technology is often considered to be separate from knowledge and pedagogy (Mishra & Koehler, 2006). Technology, according to Mishra and Koehler (2006) is viewed as constituting a separate set of knowledge and skills that has to be learned and the relationship between these skills is commonly considered to be relatively simple to acquire and implement. In their opinion, the relationship between content, pedagogy, and technology should be seen as complex and nuanced.

Mishra and Koehler (2006) have developed a conceptual framework that emphasises the connections, interactions, affordances, and constraints between and among content, pedagogy, and technology. Understanding all three of these aspects of teacher knowledge is important for developing good teaching. Mishra and Koehler's framework of teacher knowledge for technology integration emphasises the complex interplay of these three parts of knowledge. Other scholars have argued that knowledge about technology cannot be treated as content-free, and that good teaching requires and understanding of how it relates to the pedagogy of content. What sets their work apart from others is their specific articulation of the relationships between content, pedagogy and technology (Mishra & Koehler, 2006), a relationship discussed further in the following section.

Technological Pedagogical Content Knowledge

Mishra and Koehler (2006) look at the three components in pairs: pedagogical content knowledge (PCK); technological content knowledge (TCK); and technological pedagogical knowledge (TPK). Finally, all three are taken together in a developing concept TPCK, a comprehensive term that has prevailed in current literature. They suggest three pairs of knowledge intersection and one triad as the elements and relationships of knowledge that they suggest are important in their framework.

Content knowledge (CK) as articulated in Shulman's work (1986) is knowledge about the actual subject matter that is to be learned or taught. Clearly, teachers must know and understand the discipline that they teach, including knowledge of central facts, concepts, theories, and procedures within a given field; knowledge of explanatory frameworks that organize and connect ideas; and knowledge of the rules of evidence and proof. Teachers must also understand the nature of knowledge and inquiry in different fields. Pedagogical knowledge (PK) is deep knowledge about the processes and practices or methods of teaching and learning and how they encompass, among other things, overall educational purposes, values, and aims (Mishra & Koehler, 2006). This is a generic form of knowledge that is involved in all issues of student learning, classroom management, lesson plan development and implementation, and student evaluation. It includes knowledge about techniques or methods to be used in the classroom; the nature of the target audience; and strategies for evaluating student understanding. A teacher with deep pedagogical knowledge understands how students construct knowledge, acquire skills, and develop habits of mind and positive dispositions toward learning. As such, pedagogical knowledge requires an understanding of cognitive, social, and developmental theories of learning and how they apply to students in their classroom (Mishra & Koehler, 2006).

Mishra and Koehler's (2006) idea of pedagogical content knowledge is consistent with, and similar to, Shulman's idea of knowledge of pedagogy that is applicable to the teaching of specific content. This knowledge includes knowing what teaching approaches fit the content and knowing how elements of the content can be arranged for better teaching. PCK is concerned with the representation and formulation of concepts, pedagogical techniques, knowing what makes concepts difficult or easy to learn, knowledge of students' prior knowledge, and theories of epistemology. It also involves knowledge of teaching strategies that incorporate appropriate conceptual representations in order to address students' difficulties and misconceptions and promote meaningful understanding.

Technology knowledge (TK) is knowledge about standard technologies, such as books, chalk and blackboard, and more advanced technologies, such as the Internet and digital video (Mishra & Koehler, 2006). This involves the skills required to operate particular technologies. In the case of digital technologies, it includes knowledge of operating systems and computer hardware, and the ability to use standard sets of software tools such as word processors, spreadsheets, browsers, and e-mail. TK includes, amongst others, knowledge of how to install and remove peripheral devices and software programs, and create and archive documents. Since technology is continually changing, the nature of TK should also shift with time. The ability to learn and adapt to new technologies irrespective of what the specific technologies are is important.

Technological content knowledge (TCK) is knowledge about the way in which technology and content are equally related (Mishra & Koehler, 2006). Although technology constrains the kinds of representations possible, newer technologies often afford newer and more varied representations and greater flexibility in navigating these representations. Teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology.

Technological pedagogical knowledge (TPK) is knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and on the other hand, knowing how teaching might change as the result of using particular technologies (Mishra & Koehler, 2006). This might include an understanding that a range of tools exists for a particular task, the ability to choose a tool based on its fitness, strategies for using the tool's affordances, and knowledge of pedagogical strategies and the ability to apply those strategies for use of technologies.

TPCK is a developing form of knowledge that goes beyond all three components, content, pedagogy, and technology (Mishra & Koehler, 2006). This knowledge is different from knowledge of a disciplinary or technology expert and also from the general pedagogical knowledge shared by teachers across disciplines. Using Mishra and Koehler's (2006) model, TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. TPCK is represented graphically in Figure 3.3 (Mishra & Koehler, 2006, p. 1025).

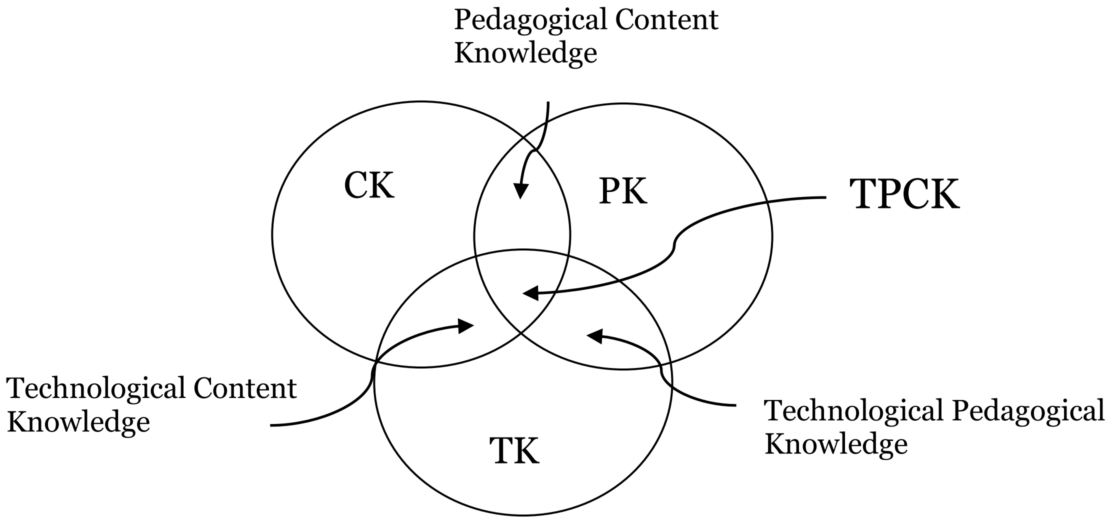

Figure 3.3: Diagrammatic representation of TPCK (Mishra & Koehler, 2006, p. 1025)

The central argument of the TPCK framework presented by Mishra and Koehler (2006) is that there is no single technological solution that applies for every teacher. Teachers should rather draw on a particular technology solution for their specific context and then adjust it to develop their own nuanced understanding of complex relationships between technology, content, and pedagogy. They should then develop their own strategies appropriate to their classroom context.

3.4 Concluding remarks

The field of ICT in education is anchored in theories of pedagogy (PCK) and the more recent technology integrated pedagogy (TPCK). This chapter provided a review of the some of those theories, showing how the concepts have developed over time. It also gives a summary of the Four in Balance Model used in this study to understand and ascertain the value that the pedagogical use of ICT in South African schools adds. Chapter Four discusses the mixed methods research design for the study as well as the particular methods of collecting both the quantitative and qualitative data for this study to answer the main research question (section 1.3).

CHAPTER FOUR

Research Design and Methods

This research was designed to answer the main research question: *What is the value that using ICT adds to the teaching and learning of Science when teachers use ICT in a context of limited resources, typical of a developing country?* This chapter provides an argument for my pragmatic approach to the particular research design (section 4.2), for my choice of a mixed methods approach to collecting data to answer my research question (section 4.3), for how the SITES 2006 survey data was used to understand the landscape of ICT use in South Africa science classrooms (section 4.4), and for the selection of three cases to gain a more in-depth understanding of how and why teachers are using ICT (section 4.5). This chapter also outlines the specific research methods including the specific instruments chosen for the different phases of the research, the sort of data that each instrument allowed me to gather, and how that data was managed and analysed. Where appropriate, the limitations inherent in this particular research design and choice of data collection strategies, as well as factors which enhance the study's credibility and trustworthiness are discussed.

4.1 Research assumptions

Personal philosophical assumptions influence a researchers stance towards the nature of reality, how a researcher knows what s/he knows, the role of values in the research, the language of the research, and the methods chosen in the research process (Creswell, 2007). I came to this study with a set of beliefs, assumptions, and perspectives about the nature of teaching and learning, particularly of science, and the use in it of ICT, all of which influenced what I chose to study, the research design, and data collection methods. The perspectives on teaching and learning and science education developed through many years of teaching school science, working as a teacher educator, and developing materials for use by science teachers in their classrooms. These perspectives were sharpened by following debates in the literature on learning (Bransford et al., 2000; Driver, 1990, 1994; Driver, Asoko, Leach, Mortimer, & Scott, 1994) and through participation in academic conferences. My perspectives developed more recently through my work with the data on science teachers' pedagogical orientations in the SITES 2006 study as part of my recent employment, and my attendance at the IEA International Conference (Taiwan, 2008), and the e-learning in Africa Conference (Senegal, 2009). Some of my personal perspectives informed by current research literature on the topic and relevant to this study are:

- Teachers' pedagogies and pedagogical reasoning influence their pedagogical use of ICT. This is a perspective in line with the SITES 2006 study and had an influence on my choice of research focus. This study is grounded on a view that without a good understanding of how learning occurs, it would be difficult for a teacher to use technology effectively to support the learning process. This assumption was explored in depth in this study and one of the research conclusions presented in the final chapter supports it.
- ICT in itself does not support learning but only when it is integrated into a learning environment is the full potential realized. This is also a perspective in line with the SITES 2006 study.

4.2 Pragmatism as a research paradigm

The research design process in social science research begins with philosophical assumptions, and is further shaped by the researcher's inquiry paradigm (Denzin & Lincoln, 2003; Mertens, 1998) or worldview (Creswell, 2007). As such, researchers bring their own worldviews or sets of beliefs to the particular project (Guba, 1990). Two original paradigms defined by Lincoln and Guba (2003), positivism and naturalistic inquiry (later known as constructivism) were expanded in their later work to five paradigms, which also included critical theory, post-positivism, and participatory research (Denzin & Lincoln, 2003). Creswell (2009) adopted the term "worldview" rather than "paradigm" to define the basic set of beliefs that guide the research. It defines the general orientation of the world and the nature of the research that the author of the research hold (Creswell, 2009, p. 6). Creswell suggests four possible worldviews: positivism, constructivism, advocacy and participatory, and pragmatism (Creswell, 2007, 2009).

The legitimacy of mixing worldviews in the same study, namely the more positivist view of being able to objectively measure student ability (quantitative), and the more constructivist worldview of a more subjective assessment of reality through the lens of the researcher (qualitative), formed the basis of research debates through to the early 1990s. The objective reality seemed to be incompatible with the subjective reality. Since then, pragmatism has arisen as a worldview different from worldviews held by positivists or constructivists. Pragmatists, such as myself, believe philosophically in selecting the research method that works for a particular research problem (Tashakkori & Teddlie, 2003, 2009). Pragmatism, the worldview which shaped the research design for this study, allowed me to focus on the actions, situations, and consequences of the inquiry (Creswell, 2007). Pragmatism allows freedom of choice when choosing methods, techniques and procedures of research to best answer the research question (Cherryholmes, 1992), and to look to a mixed methods approach when collecting and analysing data, rather than focusing on one single approach, ether quantitative or qualitative. This view is gaining support (Maxcy, 2003; Tashakkori & Teddlie, 2003) with an argument for a pragmatic approach as a popular guiding paradigm in social science research methods. It was particularly appropriate to use of variety of research methods to understand broadly how teachers use ICT, why they use it in the ways they do, and what value this use adds to teaching and learning.

4.3 Mixed methods as the research design

As a pragmatic researcher, I focused on 'what' I wanted to know, and 'how' I was going to find out (Cherryholmes, 1992). The design was influenced by the main research question: *What is the value that using ICT adds to the teaching and learning of Science when teachers use ICT in a context of limited resources, typical of a developing country*? In this section I argue for a mixed methods approach, allowing for an appreciation of the broad trends that the quantitative data can provide (numbers) as well as the individual experiences of teachers (words) that emerge from the qualitative data (Mason, 2006).

The initial interest in mixing forms of quantitative data collection can be traced back to the late 1950s, but it was only since the 1970s that there emerged a real interest in collecting both quantitative and qualitative data for the same research question (Creswell, 2002). Since the 1980s there has been a growing acceptance of combining worldviews and methods and the interest in mixed methods procedures is rapidly growing to address complex questions. However, it is only since the early 1990s that there has been widespread support for a distinct mixed methods design (Creswell, 2002), a design suitable to answer the research question for this study, and argued in this chapter.

The statistical SITES 2006 survey was an efficient way of collecting a large amount of data on ICT use from a large sample of South African Grade 8 science teachers. The data from the SITES 2006 survey was used to contribute to a landscape view of teachers' use of ICT in science classrooms in South Africa. The data collected from the SITES 2006 survey is valuable but the reliability of the data, as in all surveys, depends on the teachers' motivation and ability to respond accurately to the questions asked in the Teacher Questionnaire. Some teachers may not have been motivated to give entirely accurate answers, and may more likely have been motivated to give answers that present themselves in a favourable light. My initial interaction with teachers who had completed the SITES 2006 Teacher Questionnaire suggested to me that this might be the case. Credibility was added to the SITES 2006 findings by a more in-depth exploration of teachers' use of ICT in their classroom or computer room through the case studies. It was by visiting the classrooms, speaking to the teachers and hearing their stories about practice that I better understood what it meant to be teaching science to students using ICT in South African classrooms. This justified my decision to integrate quantitative data from a survey with qualitative data from three case studies.

An inquiry of this nature should guard against presenting a one-sided view of a particular phenomenon. This was done by ensuring triangulation in data collection. Triangulation, a term originally drawn from naval military science, is now applied to research and allows researchers to improve their inquiries by collecting and integrating different kinds of data bearing on the same phenomenon (Creswell, 2002; Denzin & Lincoln, 2003). Collecting survey interview, observation, field notes, and document data allowed me to combine the strengths of one kind of data collection method to counterbalance the weaknesses of another. A survey, for example, can provide generalizable results while a case study can reveal the teachers' point of view not captured through a questionnaire. Triangulation thus provides a strong case for a mixed methods design.

Data collection and analysis for this study

There are many different conceptions about mixed methods as a choice of research and the data collection procedures and analysis for such a design. My personal conception is influenced by the argument suggesting that we should think in terms of 'meshing' or 'linking' methods (Mason, 2006). Mason makes a convincing argument for thinking in terms of multi-dimensional research strategies that transcend the so-called qualitative-quantitative divide, arguing that mixing methods allows the researcher to think laterally. Mixing methods in this study helped to supersede the micro-macro dichotomy and integrate different forms of data and knowledge.

The SITES 2006 data was collected 2006, a year before this research study was conceptualised. The broad focus area of SITES 2006 "pedagogy and ICT use" provided a conceptual starting point for this study and helped to focus the main research question (Law et al., 2008). Although the SITES 2006 study was designed for a different purpose, the data available was suitable to be used in answering the research question pertaining to this study. The mixed methods design, or two-phase model of this study, consisted of a sequential collection of quantitative and qualitative data, but a concurrent analysis of the two types of data. The concurrent analysis of the two forms of data meant that themes which emerged from the analysis of the case studies influenced the selection of the relevant SITES 2006 questionnaire data, and vice versa. I was able to integrate the qualitative and quantitative data and capture the best of both sources of information (Creswell, 2002), using an in-depth qualitative exploration together with descriptive statistics and a secondary analysis.

This two-phase model is typically labour-intensive and time-consuming. It was made possible in the limited time period of this study because the secondary statistical analysis of the South African data presented in the study was performed using the quantitative data already collected in the international SITES 2006 study. One key aspect supporting the choice of this particular design was that while there is sophisticated secondary analysis using the survey data collected in the SITES 2006 study, as well as some reporting of individual cases of ICT use in South African schools, there has yet to be a linking of a qualitative understanding with the quantitative data of teachers using ICT in science education in South Africa in a mixed methods study.

The sections which follow describe and discuss the collection and analysis strategies for the quantitative survey data, followed by that for the qualitative case study data.

4.4 SITES 2006

The SITES 2006 database formed the basis for the quantitative data used in my study. The IEA is vastly experienced at large international survey studies with student achievement surveys such as the Progress in International Reading Literacy Study (PIRLS) (Howie et al., 2007) and TIMSS (Reddy, 2006), both of which included South Africa. Using the SITES 2006 data generated from the SITES 2006 teacher questionnaire allowed me to access high-quality data about ICT-use in South African science classrooms on a scale that I could not hope to replicate first-hand. The technical expertise of the IEA DPC in developing good surveys and datasets means that the data presented in this study is of a high quality and available at no cost. While my research questions and conceptual framework are different from those in the SITES 2006 study, the overall purpose of the SITES 2006 study is similar, making my use of the data valid and reliable.

Principal, teacher, and technical coordinator questionnaires were taken to a sample of 500 schools in South Africa (section 4.4.1), and just over 600 science teacher questionnaires were returned. In all cases, missing data was excluded before analysis. In all of the education systems in the study except South Africa, the percentage of schools with computers for Grade 8 students was between 95% and

100% (Law et al., 2008). South Africa reported the lowest percentage access of 38%. An underlying assumption of the SITES 2006 study was that teachers' decisions on what ICT to use in their teaching and how to make use of it depends on the nature of the subject, in this case science, and on the characteristics of the students in their class (Law, 2009). Hence, in designing the questionnaire, it was considered important that when teachers answer the questions they think specifically about a single Grade 8 science class in which they used ICT to teach science, the target class. The low ICT access in South African science classes made selecting the target class and completing the questionnaire inappropriate in many instances, and should be considered a limitation in the data presented in Chapters 5-7.

4.4.1 Sampling for SITES 2006

The school population for the SITES 2006 study was defined as *all schools where students are enrolled in the grade that represents the eighth year of learning*. In the case of South Africa, this was Grade 8. If a school did not have a Grade 8 science class, it was excluded from the study sample. The science teacher target population for the SITES 2006 study was defined as all teachers teaching science (or natural science in the case of South African teachers) to Grade 8 students.

While all participating education systems were encouraged to provide complete national coverage in their target population, the research team at the Data Processing Centre (DPC) recognised that political, organisation, and/or operational reasons could make it extremely difficult for some systems like South Africa to meet this objective. For this reason participating systems were permitted to remove a geographical region, an educational sub-system, or even a language group. In the case of South Africa, it was well known that access to ICT in schools was limited and not uniform across the country and the NRC requested that while all nine provinces are included in the South African data base, the sample be weighted more heavily in the two provinces Gauteng Province and the Western Cape. These two provinces were more likely to have a greater percentage of computer use in school than other provinces as each of these had well established ICT in education programmes, Gauteng Online in Gauteng Province (GautengOnline, 2003), and the Khanya Project in the Western Cape (Khanya, 2001). South Africa also requested that the very small farm schools be excluded from the sample as they were geographically inaccessible, typically extremely small in size, and unlikely to have access to electricity, thus making ICT use almost impossible in this group of schools.

For international surveys, first a sample of schools is selected from a complete list of schools containing the population of interest i.e. Grade 8 science teachers. In South Africa, this list of about 8000 schools was compiled from the Education Management Information System (EMIS) database (DoE, 2004a) and the National database on schools as at the time of the survey, the DoE did not have a single reliable database with all ICT using schools. Typically a simple random sample of students, classes or teachers is drawn from the selected schools in a two-stage sampling process. Broadly speaking, schools can be selected with equal or unequal probabilities. For the SITES 2006 study, selecting schools with equal probability would have given every school the same chance to be included in the survey. However, because SITES 2006 selected a small number of teachers within sampled schools, selecting those with equal probability would have generated a large variability in the selection probability of the teachers. Within a sampled school, the probability of selection of a teacher at a school with 20 science teachers would be five times smaller than the probability of selection of a teacher in a school with four science teachers. This sort of variability in the probabilities results in less accurate estimates of statistics for the intended target population i.e. the teachers.

As a solution to the limited accuracy of the simple two-step sampling process, the SITES 2006 study made use of a *probability proportional to size* (PPS) design (Carstens & Pelgrum, 2009), which made a school with 20 science teachers five times more likely to be selected than one with four science teachers. But within a sampled school, the probability of a teacher being selected is inversely proportional to the number of teachers. Therefore, selecting schools with probabilities proportional to their size and selecting a fixed number of teachers with equal probabilities within sampled schools minimizes the variability of the total selection probability of the teachers.

A PPS design would be appropriate for SITES 2006 if the project focused on the teacher population alone. However, because SITES 2006 collected and reported data at two levels, school and teacher, a PPS sample design would have generated a large variability of the school selection probability and, consequently, a large and undesirable, variability of the school weights.

To meet the conflicting requirements of a school survey and a teacher survey, the SITES 2006 research team implemented a sample design that involved the following:

- Stratifying the school sample frame according to the school size (very large, large, medium, small, very small)
- Selecting, within an explicit school-size stratum, schools with an equal probability of selection
- Selecting, within sample schools, teachers with an equal probability of selection.

A more detailed explanation of the sampling design can be found in the SITES 2006 Technical Report (Appendix D) (Carstens & Pelgrum, 2009).

4.4.2 The SITES 2006 teacher questionnaire

The target population for the SITES 2006 study was the school populations (through a principal questionnaire and a technical coordinator questionnaire), and the teacher populations (through a teacher questionnaire) (Carstens & Pelgrum, 2009). Of the three instruments developed for the SITES 2006 study, only the data generated through the Teacher Questionnaire was used for this study. The SITES 2006 teacher questionnaire (Appendix A) was divided into eight parts, each focusing on different aspects of ICT use:

Part I: Information about the Target Class (questions 1-7)
Part II: Curriculum Goals (question 8)
Part III: Teacher Practice (questions 9-15)
Part IV: Student Practice (question 16)
Part V: Learning Resources and Tools (question 17)
Part VI: Impact of ICT Use (questions 18-20)
Part VII: Information about You and Your School (questions 21-36)
Part VIII: Specific Pedagogical Practice that Uses ICT (questions 37-41).

Information generated through this questionnaire was used to support the data gathered in the case studied where relevant and applicable (section 4.5). Not all questions were included as data. In total, the SITES 2006 South African sample contained 500 schools. The number of South African science teachers who participated in SITES 2006 was 622.

4.4.3 Analysis strategies for SITES 2006

To support and promote secondary analyses, the IEA made the SITES 2006 international database and accompanying Analyser User Guide (Appendix C) available to researchers, analysts, and public users (Brese & Carstens, 2009). The IEA IDB Analyser was developed by the IEA Data Processing and Research Center (IEA DPC). It is a stand-alone software package that operates in conjunction with the Statistical Package for the Social Sciences (SPSS, 2008). The IEA IDB Analyzer enables users to combine SPSS data files from IEA's SITES 2006 study and to conduct analyses using SPSS without actually writing syntax code. The IEA IDB Analyzer generates SPSS syntax that takes into account information from the sampling design in the computation of statistics and their standard errors.

The IEA IDB Analyzer consists of two modules, the merge module and the analysis module, which are executed as independent applications. The merge module is used to create analysis datasets by combining data files of different types and from different education systems, and selecting subsets of variables for analysis. The merge module was not used for any analysis in this study as only the South African dataset was accessed. It was not necessary to merge this data with that collected from any other countries. The analysis module provides procedures for computing various statistics and their standard errors for variables of interest. These procedures were applied for the South African education system and for specific subgroups within it[10].

[10] For a more detailed explanation of how to use the and the sorts of analyses possible using the IDB Analyser, refer to the IDB Analyser User Guide (Brese & Carstens, 2009) in Appendix C.

4.4.4 The SITES 2006 sub-sample used for this study

Of the 500 South African schools sampled in the SITES 2006 study, 267 schools were selected as those which best represented the developing country context (discussed in detail in chapter 1), and make up the majority of schools in South Africa. These were selected by sorting the data to remove those schools which would be considered well resourced and serving the middle to upper income population in the country and those which would be considered very poor and lacking adequate infrastructural resources to successfully integrate ICT in teaching and learning. In summary, the well resourced schools were those which had good infrastructural resources such as a swimming pool and/or tennis court. The very poor schools were those which had no access to running water and/or electricity, and in addition had no computers available for instruction.

The group of teachers in the 267 schools sample, discussed above, consisted of 367 science teachers. The majority were in the age group 30-39 (42%) with few below 25 or above 60. The gender split was almost equal with 51% of the teachers' being male. About half of the teachers had a teaching diploma, less than 5% had only a high school certificate, and just over 13% had a Master's degree or higher. Less than 19% had a bachelor's degree in science and nearly 90% had a teaching certificate. The greatest portion of teachers (41%) had between 10 and 19 years of teaching experience. Just over 53% responded that they had access to a computer at home. More than 57% of those who did have a computer at home reported that they used it for teaching related activities and just over 26% reported that the computer at home had access to the Internet.

According to the data gathered from the 367 South African science teachers selected for this study, the average class size was just over 65[11], and nearly 90% of those classes were made up of a mix of boys and girls. More than 95% of those classes were

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[11] The figure is probably inflated as 29 of the teachers reported class sizes of 100 or more. While in the South African context this may be possible, it may also be a result of teachers misinterpreting the question and giving the number of learners in the Grade 8 group rather than in the individual target class.

academic as opposed to vocational. Nearly 74% of the schools reported that absenteeism was low at less than 5% per day, while just over 2% reported that more than 20% of the students were absent each day. Nearly 30% of the classes had more than 90% of students in the class speaking the language of instruction, i.e. English, and more than 56% of the classes had less than 50% English First Language speakers. The majority of classes (just over 46%) spent between 2 and 4 hours on science instruction per week, a small percentage (just over 8%) spent more than 8 hours a week, and a smaller percentage (just over 2%) spent less than 2 hours on science instruction per week.

4.4.5 Analysing the qualitative data

In most questions on the SITES 2006 teacher questionnaire, teachers were asked to rank their responses on a 4-point Likert scale. Examples of these scales are: 1=not at all, 2=a little, 3=somewhat, 4=very much; or 1=never, 2=sometimes, 3=often, 4=nearly always; or 1=not at all, 2=a little, 3=somewhat, 4= a lot. In each of these cases, the mean of the responses using the sampling weights added to the database (Carstens & Pelgrum, 2009) was used to describe teacher responses. Descriptive statistics were generated including percentages, frequencies, means, and standard errors (Appendices E and F). In some instances, mean scores on a 4-point Likert scale were recalculated to a score out of 100[12] to allow mean scores to be compared to percentage scores. Exploratory analyses were first conducted in SPSS and this was followed by using the IDB analyser to generate more precise results.

Together with the mean teacher scores reported, the standard error is indicated in brackets after the mean (Appendix F). Precise percentages to two decimal places with standard errors were calculated for all categories of responses but such detail was deemed unnecessary for the purposes of reporting the data. For ease of interpretation a decision was made to combine the first two responses (for example "not at all" and "a little") and the last two responses (for example "somewhat" and "a

[12] One on the Likert scale was re-coded to zero, two was re-coded to 33.33, three was re-coded to 66.66 and four was re-coded to 100. For the 2-point Likert scale, one as recoded to zero and 2 was re-coded to 100.

lot") and report them in two columns instead of four. When this was done, the two percentage responses were conflated and rounded off. New standard errors were not calculated. The detailed percentage responses with standard errors (Appendix E), and mean responses with standard errors (Appendix F) are available as Appendices.

4.5 The case studies

This phase of the research adopted an interpretive case study strategy, drawing in particular on the work of Creswell (2007), Stake (1995), and Yin (2003). The case study as a research method "is the study of particularity and complexity of a single case, coming to understand its activity within important circumstances" (Stake, 1995, p. xi). Although Stake (1995) does not use the term "methodology" when referring to case study research, it is widely accepted as a methodology by other authors (Creswell, 2007; Denzin & Lincoln, 2005; Yin, 2003). In this study, I explored the bounded system of teacher practice in three individual teacher cases with one single issue, teacher use of ICT. Each of these three cases were selected provided an insight into significantly different use of ICT in science teaching and consequently each case highlighted different perspectives on the same issue (Creswell, 2007). The outcome is a rich and detailed description of events blended with an analysis from each case which has contributed to the knowledge base of teacher use of ICT. These three cases were suitable for this study both for their commonality (Cohen, Manion, & Morrison, 2003; Stake, 1995) and specific incidents that were unique to each case. A more detailed explanation of case selection can be found in section 4.5.1.

One of the most significant contributions of the three individual cases selected for this study is that they allow a nuanced understanding of both how and why teachers use ICT in teaching science in the ways that they do (Cohen et al., 2003). This was achieved by observing the use of ICT in the real classroom context, unique to and dynamic in each individual case. It was also achieved by designing this part of the study as interpretive case studies, allowing me to develop conceptual categories inductively to examine my initial assumptions (Merriam, 1988), without evaluating or judging. This is noteworthy in answering the 'why' questions that arise in this particular study.

4.5.1 Selecting the cases

The principle criterion in school selection was not so much about representing the totality of schools in South Africa with limited resources, but rather about selecting a variety of schools which would best provide an understanding of how teachers are able to use ICT in teaching science, the difficulties facing them in schools with limitations on teaching and learning resources, and the value that such ICT use may add to the teaching and learning experience of the teachers and students in these schools. Having the SITES 2006 national data as a starting point for this study, I was guided by the individual responses to the teacher questionnaire in selecting suitable cases for a more in-depth exploration.

The SITES 2006 data for the 489 secondary schools in South Africa was obtained in 'raw' format as an SPSS file, which lists all the schools that were surveyed in the SITES 2006 study. I used this dataset to select schools which might be suitable for my cases. In addition to the questionnaires completed by schools, the National Research Centre (NRC) collected demographic data in the form of an Infrastructural Checklist (Appendix B) on the schools visited during fieldwork. Each fieldworker completed the checklist giving valuable information such as school access to electricity, numbers of classrooms, percentage of black students in the school, access to computers for administration, access to computers for tuition, access to the Internet and e-mails. This data was invaluable in selecting schools that matched my criterion of being poorly resourced. The province of the school in the SITES 2006 database was not recorded on the questionnaire but as I was the only researcher for this study and ease of access a consideration, it was preferable that the schools selected be in the Gauteng Province region. In order to prioritise Gauteng Province schools in the selection, I used the national schools data base to obtain the latitude and longitude of all the schools in the SITES 2006 study. In some instances, the school names were spelled differently from those in the national database, making matching them a difficult and time-consuming task. Using the co-ordinates of the 489 SITES 2006 schools obtained by matching those with the national schools database, I mapped the SITES 2006 schools using GPS software. This gave me a map of the positions of all the SITES 2006 schools in the country.

Using the same GPS software programme and the co-ordinates, I selected only those SITES 2006 schools that were in the Gauteng Province region then used the original data to select only those schools which, according to the survey data, had access to computers for tuition. This gave me a total of 45 schools, from which I eliminated those that had less than 50% black students (data taken from the demographic questionnaire) and schools that were independent. This left 28 possible schools in Gauteng Province that reported having access to computers available for tuition. The schools were considered suitable sites for the case studies if the following criteria were met: The science teacher has access to a computer and the Internet to access teaching resources (either at school or at home); the students had access to a computer and the Internet for purposes of learning science (either in a laboratory or in the classroom); both the teacher and the students were reasonably proficient in computer and Internet use. I accessed the original survey scripts of these 28 schools with the teachers' names and questionnaire answers. Finally, from the questionnaires I selected three schools which best suited my purpose of exploring how teachers use ICT in teaching science in Gauteng Province.

Selecting suitable cases for investigation proved to be far more difficult than I had anticipated. The first school selected from the SITES 2006 data as discussed above was about 60 kilometres south of Pretoria, and catered for approximately 1,500 students in Grades 8 to 12 from the nearby township. The surrounding community comprises black lower income families. According to the principal who has been at the school for more than 20 years, and held the position of principal for more than 10 years, attendance is good with less than 5% of students absent from school on a daily basis. The principal was friendly, made me welcome in the school, and introduced me to the computer technician. The school had electricity, running water, flushing toilets, was well maintained and reasonably clean. There was evidence of a timetable and students moved to classes in an orderly fashion after break. The principal's office showed signs of a well organised school with photographs of all the students (in classes) on the wall of his office.

I visited the computer room which had been set up as part of the Gauteng Online project and contained 25 computers in a well secured computer room. Not all the computers were in working order and there were no chairs. I was told that about 50 students used the computer room at any one time so they shared a computer and brought their own chairs. Each class, I was told, was allocated a period on the timetable in which they visited the computer room. According to the technician, students were accompanied by their teacher (different subjects) and assisted with subject-specific computer work. There were no students in the computer room when I visited. I arranged a follow-up visit to meet specifically with the science teachers who had completed the SITES 2006 teacher questionnaire in the 2006 study. During this visit, the two teachers I met with said that there had been a misunderstanding. They did not actually use the computer room for science lessons, despite the fact that the SITES 2006 questionnaire that the one teacher had completed indicated that he did use the computers to teach science. The computer room was not functional as they were waiting for Gauteng Online to come and repair the faulty computers which had been offline for some time. As my visit was not evaluative, I did not feel comfortable interrogating the teachers on their obviously inaccurate completion of the questionnaire. The first of my three cases selected from the SITES 2006 data proved to be unsuitable.

Selecting the first case

I contacted the second school from the three selected by telephone. The principal indicated that while they did have a computer room fitted with computers by Gauteng Online, they were not functioning and the science teacher had never used them. The principal I telephoned from the third school suggested I visit as the science teacher used a computer when teaching science and the school was willing to assist me in my study. The science teacher at this school had completed the SITES 2006 teacher questionnaire and this provided a point of entry into the school. This teacher became Mr Sogo (a pseudonym) of my three cases.

Mr Sogo

Mr Sogo has been teaching for more than thirty years at the school and is considered to be very experienced as a teacher. He had a post-secondary Teaching Diploma as well as many certificates obtained through short courses. At the time of the study he was enrolled at the local university doing an Advanced Certificate in Education (Information Technology). He started his teaching career as a Biology (now Life Sciences) teacher in Grade 10 with a Teaching Diploma. In 1983 the school needed a Grade 8 Natural Science teacher and as a result, he moved into the Natural Science department at the school. Once in the position of Natural Science teacher, Mr Sogo extended his teacher training and qualified as a Senior Phase Natural Science Teacher by studying part-time at the nearby teacher training college.

Mr Sogo's school

Mr Sogo was teaching at a school which served about 900 students from the local informal settlement and from the nearby township. Most students at this school were considered very poor and came mostly from families with a low socio-economic status. The school was part of the government-funded feeding scheme and approximately 200 students took advantage of the free cooked lunch each day, for many the only meal of the day. The school was one of a few schools in the province that received a donation of school uniforms in 2005. All of the students were given one full uniform which most subsequently left for other students when they left.

Figure 4.1: Local Informal settlement nearby Mr Sogo's school

Figure 4.2: Local township nearby Mr Sogo's school

General infrastructure at Mr Sogo's school

The school was managed by the GDE and functioned as a Section 21 School. The South African Schools' Act 84 of 1996, created two categories of public schools: Section 20 and Section 21 schools ("South African Schools' Act," 1996). Section 20 of the Act lists a range of functions that the governing bodies of all public schools must undertake. Section 21 listed further functions that may be allocated if the school has shown that it has the capacity to perform such functions effectively. The term "Section 21 Schools" is regarded as synonymous with self-managing or self-reliant. There is less top-down control by the DoE and much less bureaucratic involvement. For this school, being a Section 21 School means that they can purchase the textbooks that they want rather than being provided with books and other resources that they do not need.

The school was not well maintained. The grounds were littered and while there was an allocated cleaner, the mess remained throughout the day. The school did have a fence and security gate with a security guard controlling access but there were many places where the fence was broken. Truancy was a problem. According to Mr Sogo, the fence was in place both to keep students in as well as undesirables out.

Figure 4.3: Classroom block at Mr Sogo's school

Vandalism at the school had been a problem for many years and two years prior to my visits the computer room had been "cleaned out" with all 25 computers stolen. According to Mr Sogo, the local Internet cafés had been the market for the stolen IT equipment. At the time of my visits, many of the classrooms were in a state of disrepair, some without desks or chairs. Most of the classroom walls were devoid of posters or other educational materials.

Figure 4.4: Desks and chairs in Mr Sogo's classroom

The school had a section of four classrooms which had walls but no roof. This section of the school had been built more than twenty years prior to my visits to accommodate a growing number of students. Upon completion of the classroom block, there was an electrical fire which resulted in it being burned. The DoE and the Department of Public Works had been unable to agree on responsibility for repairs, and the buildings remained incomplete and unusable.

Figure 4.5: Burnt classroom block at Mr Sogo' school

The school has a science laboratory but it was not used as one, instead having been converted to a classroom to fit groups of 60 students at one time[13]. The laboratory store room has a large amount of science equipment, some still in unopened boxes, and some in a state of disrepair.

Selecting the second case

Owing to the difficulties experienced in selecting the first case from the SITES 2006 database, I sampled the remaining cases purposefully by asking around for contact details of teachers who might be suitable participants in my study, even if they had not been a participant in the SITES 2006 survey. A prominent science education researcher informed me of a science teacher who used computers in her science teaching at a mission school. This school met the criteria discussed in section 1.2.2. Being in a rural area, the school was quite far from the University. I travelled to the school and spent a day with the teacher. Data that was not collected from the teacher on the day of the visit was collected via e-mail over the following few weeks. This teacher became Mrs Putten (a pseudonym) of my three cases.

Mrs Putten

Mrs Putten taught science at a school located on a mission station in a rural area serving the surrounding rural community. She had been teaching science for fifteen years as was considered a very experienced and competent teacher. Mrs Putten had attended the same school as a student, as her family had lived on the mission station. She had been a top achieving student and had starting teaching at the school as soon as she finished her Grade 12 year. She was highly qualified in her subject area science, and all her tertiary education (undergraduate and post-graduate degrees) had been completed through correspondence courses. Mrs Putten's undergraduate degree had been in Biology (now Life Sciences) but an enthusiastic and gifted student

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[13] This conversion of laboratories into classrooms is not uncommon in township schools, making laboratory practical work impossible.

inspired her to teach science. At the time of the case study, she had just completed a post-graduate degree, a piece of action research on her own use of computers in her teaching practice. Mrs Putten taught English and Science for both the senior and FET phases at the school.

Mrs Putten's school

Mrs Putten taught at a mission school which began in 1986. The school was strongly Christian-based and aimed to provide students with a good academic and value-based education. The school catered for the students in the surrounding rural area and could accommodate about 300 students, mostly in the secondary school. Almost all those in the primary school travelled to school but there were boarding facilities that catered for most of the secondary school students. The students come from different socio-economic backgrounds, and while they mostly lived in basic rural accommodation, some families had moved from cities and chosen that lifestyle to assist the mission. Others came from poor families with little or no formal education.

General infrastructure at Mrs Putten's school

The school was funded by a small fee contribution from the students but was also heavily subsidized by funds raised through the mission. The school was well maintained and neat and there was no litter around the premises. In addition to a new administration block, there were thirteen classrooms, a media centre, and a recently constructed science laboratory.

Figure 4.6: Science laboratory at Mrs Putten's school

The school had the resources to make teaching and learning possible, such as regular and consistent electricity (supplied by a generator), running water and well maintained classrooms. The school had no sports fields and extramural activities at this school were limited. Parts of the school were upgraded or improved when money became available, and this accounted for the relatively new computer room and science laboratory.

Selecting the third case

The third case was also selected on the basis of a referral from a colleague in the field of ICT in education. She was recommended as an enthusiastic user of ICT. This teacher became Mrs Marley (a pseudonym) of my three cases.

Mrs Marley

Mrs Marley had 8 years of teaching experience but that had been spread out over a longer period of time. She was a passionate teacher and spoke frequently of her love for teaching and for the subject she taught. She had qualified as a teacher with a Teaching Diploma but had spent some of her working life in industry and had returned to teaching two years prior to the study. She had not participated in any additional courses since qualifying with her diploma.

Mrs Marley's school

Mrs Marley taught at a school in a township reasonably close to the University of Pretoria campus, thus meeting the criteria outlined in section 1.2.2.

Figure 4.7: Local township near Mrs Marley's school

Her school had 43 teachers (including three temporary teachers), two deputy principals, and one principal. The school was relatively new (opened in 2007), the need for an additional secondary school in the area having been identified in the early 2000s. The school was part-government funded and part-private funded as a part of a public-private partnership initiative co-ordinated by the GDE. A local IT company sponsored the school computer laboratory including the technology infrastructure in the school. Despite this additional source of funding, Mrs Marley described the school as "normal" and it did appear to be a "typical" township school. The school catered for approximately 1,300 students in 24 classrooms from the surrounding township. According to Mrs Marley, the school would like to have a student to teacher ratio of forty to one. However, pressure from the GDE meant that in some classes there were as many as 65 students in a class. In 2009, the first cohort of Grade 12 students completed their National Senior Certificate at the school.

Demand for a place at the school is high, as the community is well aware that the school is well run and managed. Some families have reportedly moved from other provinces such as Limpopo Province to send their children to this school. Because of the high demand for a place, the school is able to institute selection criteria for Grade 8 students, based on their Grade 7 school reports. According to Mrs Marley, the school selection board looked very carefully at the applicants' reports from previous schools to ensure that those selected were reported as being well behaved. They wanted to select children who were disciplined and committed to working hard. The school is managed by the GDE and parents pay approximately R150 per year for their children to attend[14].

General infrastructure at Mrs Marley's school

The additional funding from the public-private partnership arrangement at the school meant that additional infrastructure, not typically available to township schools, was available. This additional infrastructure included a wall around the school, covered parking for teachers' cars and a football field.

The wall surrounding the school limits access and a large gate is supervised by a security guard throughout the day as the only means of access. The school gardens are well kept, the corridors are clean, and the toilets and other facilities well maintained. The management of the school was very proud of their achievements and posters of academic success were displayed in the foyer at the main entrance to the school.

The teachers at this school were supported in terms of access to textbooks, student workbooks, photocopy equipment and other resources to assist them as teachers. In some instances parent were expected to buy additional text books for the students in

[14] At the time of writing, the cost of a loaf of bread was about R8.

some subject areas and according to the teacher interviewed, the parents are generally willing and able to assist in this way. The school had a media centre but which Mrs Marley said was not used as one as it had been converted into a classroom. The shelves in the room did not contain many books and had been pushed to one side. The room was filled with desks and chairs as the GDE had, according to Mrs Marley, decreed that the school fit in more students by converting the media space into an additional classroom. This was not a situation unique to this school.

Figure 4.8: Media centre at Mrs Marley's school

The school had a science laboratory which was also used as an additional classroom[15]. I asked Mrs Marley what she meant by “we don’t have a lab” to which she replied that the laboratory was used as a Grade 12 classroom, not as a science laboratory. They did not have any chemicals or other science equipment in the laboratory and the store room was used as a teacher’s office and was not available for

[15] This was the same situation as Mr. Sogo’s school, and as mentioned earlier, not uncommon in township schools.

me to see during my visits to the school. The students at the school had textbooks for all their subjects and the school had a policy of lending the books to the students for the year, after which they were expected to return them.

Mrs Marley's classroom had adequate desks and chairs but very few other resources. The walls were bare except for a few posters which Mrs Marley had made herself and a copy of the periodic table issued by the GDE.

Figure 4.9: Posters on wall of Mrs Marley's classroom

Organisation of technology instruction at the three schools

All three of the schools selected offered Computer Applications Technology (CAT) to their students. While all three schools had a dedicated computer room, only those of Mrs Putten and Mrs Marley were functional. In these two cases, the computer rooms were used for CAT lessons. CAT lessons are on the school timetable where students learn how to use computers. In South African schools, technology is learnt as a subject in both the primary and lower secondary school years (Grades R-9) and in the upper secondary school years (Grades 10-12). The curricula are presented in the Revised National Curriculum Statements (RNCS) as "Technology" (DoE, 2002b) for

Grades R to 9 and as "Computer Applications Technology" (DoE, 2003) for Grades 10 to 12, and are examinable subjects.

CAT is a new relatively subject in the South African curriculum, drawing from subjects such as Compu-typing and Computer Studies. According to the curriculum statement (DoE, 2003), CAT equips students with knowledge, skills, values and attitudes to create, design and communicate information in different formats. It also makes it possible for students to collect, analyse and edit data and to manipulate, process, present and communicate information to different sectors of society. CAT involves learning about and working with ICT and using it in an end-user environment to solve problems relating to the processing, presentation and communication of information. The subject has three Learning Outcomes: Operational Knowledge of Information and Communication Technologies; Integrated End-user Computer Applications Skills and Knowledge in Problem Solving; and Information Management, none of which are subject-specific. The computers in computer rooms at schools are provided primarily for the students of CAT and while subject teachers may access to the computer room for subject teaching, CAT lessons and all CAT activities take priority.

Summary of the three cases

From the variety of contexts representing limited resources typical of a developing country, I was able to explore the uniqueness of dissimilar uses of ICT, as well as to formulate an understanding of the similarities between the teachers, without going beyond three cases. The contrast of these three teachers allowed me to understand and interpret how these teachers were able to use ICT in teaching science, the difficulties facing them in schools with limitations on teaching and learning resources, and the value that such ICT use may add to the teaching and learning experience of these teachers and students in these and possibly other schools with similar contexts and issues.

4.5.2 Data collection - Strategies and procedures

The qualitative data were collected using interviews, observations, photographs, field notes, and documents. As a case researcher, my role of researcher was that of interpreter (Stake, 1995). In the three cases investigated, I was able to identify a variety of issues, study them, and connect them with information gathered through an extensive knowledge of the current literature on ICT in education. This study involved uncovering new issues, exploring these issues in detail, and using the data gathered to describe teachers' use of ICT based on the different contexts in which they found themselves in each case. In addition, it aimed at finding new connections between the issues already known and understood.

Interviews

Interviews were a very important part of the data collection in the three cases. They are an effective way of obtaining perspectives from teachers on the ways in which they used ICT, as well as why they used ICT in that particular way. Conducting interviews with the teachers allowed me to get information about events that I knew were not going to be observed in the classroom observations, as well as how the individual teachers interpreted their own pedagogical practices (Merriam, 1988). As I was the only researcher in the study, I conducted the interviews with the three individual participants, which meant that I was able to formulate questions with the second and third teachers based on what I had experienced in the interviews with the first teacher. Communication with the second teacher through e-mail was effective and I was able to ask additional questions of her after completing my initial round of data collection with her. Unfortunately, communication with Mr Sogo was not as reliable and I was unable to establish an open line of discussion with this teacher after leaving the school. I was unable to return to Mr Sogo after the initial data collection visits as he was not available to receive me. My attempts to communicate with him through e-mail later in the year failed and there remained some issues I was unable to explore further with him. Additional questions raised with Mrs Marley were not initially addressed with Mr Sogo.

The interview setting

As the interviewer, my role was to put the interviewees at ease by explaining the non-evaluative structure of the research. I did this by first visiting the teachers at their schools to introduce myself and explain the purpose of my research. The physical organisation of the interview setting was an important part of the interview process (Wilkinson & Birmingham, 2003). The more formal approach of sitting at the opposite side of a desk can be intimidating and the interviewer may appear confrontational. A less formal seating arrangement of two chairs facing each other at a slight angle off-centre was used to make the interviewee relaxed and at ease with the situation. The digital audio recorder was placed on a nearby table so that it would record the interview clearly but not appear intrusive. I relied on the recorder to capture what was said so as not to distract the teacher being interviewed or slow down the conversation (Wilkinson & Birmingham, 2003). On my initial meet-and-greet visit with each of the teachers I had explained my research and did not repeat this information at the start of each interview. I also made it clear that their anonymity would be maintained. Each of the teachers knew that I had previously been a science teacher and I used this deliberately to set up the interview style as one teacher talking to another. My experience as a teacher allowed me to identify with the difficulties that these three teachers experienced with teaching on a daily basis and allowed them to trust me, first as a fellow teacher, then as a researcher.

Besides the first meet-and-greet visit in early 2009, I had visited the first teacher, Mr Sogo, on three separate occasions, each visit lasting between one and two hours. I first sat with Mr Sogo in the computer room, having specifically asked to speak to him in this venue as I felt it would provide a suitable environment for our discussion about his use of computers in science teaching. The room was quiet, which allowed a discussion without interruptions. I tried to convey an impression that the interview was important but informal. I saw having a large desk between myself and this teacher as confrontational so chose instead to sit in similar relaxing chairs with no desk in between. The digital audio recorder was placed so as to be as discreet as possible, yet close enough to ensure good quality recording. The interviewee was aware that the interview was to be recorded and had agreed to the use of the recorder. I returned to this school on two other occasions and interviewed Mr Sogo in his classroom. The teacher used his laptop and data projector in the classroom when teaching so it was a suitable place to hold the interviews. On both of these occasions, I spoke to Mr Sogo with no students present, once after school and once in one of his free lessons. On all three occasions, the teacher was relaxed and willing to talk to me about his ICT use.

I visited the second teacher, Mrs Putten, for an entire school day, speaking to her throughout the day and recording three separate formal interviews. This teacher was far from the University of Pretoria and only one visit was possible. For two of the interviews, we sat in her classroom while her students were supervised in the nearby computer room by another teacher. These interviews were semi-structured. The teacher knew that I was visiting for the day and had made arrangements to be free to talk to me. The third interview was unstructured in nature and was conducted in an informal setting over lunch. Questions that were unanswered by the teacher during my visit were asked by e-mail and the responses were captured and analysed in the same way the interview data was analysed.

I visited the third teacher, Mrs Marley, on four separate occasions, each time after school hours as this was the only time the teacher was available to talk to me. Each lasted between 30 minutes and one hour and we sat in the small office at the back of the computer room. The CAT teacher walked in and out during the interviews but did not disturb us in any way as the interviewee was relaxed. Each of the interviews took place after school hours but on all four occasions, there were a few students in the computer room working on their assignments or other class work. The CAT teacher was always available for these students to assist them if they needed help. I sat opposite the teacher and conducted the semi-structured interview with her in a relaxed environment.

The interview protocol - semi-structured interviews

On the continuum from highly structured interviews with predetermined questions and question ordering, to unstructured interviews with a more conversation format with open-ended questions, my interviews were semi-structured (Appendix I). Using a highly structured interview for this study, rigidly adhering to a predetermined set of questions would not allow me to access the teachers' perspectives and understandings of how and why they use ICT (Merriam, 1988). Using a semi-structured format for the interviews meant that while I had a list of questions, the exact wording and question order was not predetermined and I could probe with additional questions when unanticipated issues emerged during the interview.

The interview protocol was arranged into four focus areas: general information about the school and the access to learning and infrastructural resources; information about the technology resources available to teachers and students; use of ICT in teaching and learning in general; and use of ICT specific to science (Appendix G). While this sort of interview protocol provided less flexibility than unstructured interviews, it allowed me to direct the conversation more closely and ensure that the questions I wanted answered were discussed (Merriam, 1988; Watkins & Mortimore, 1999). I wanted the interviewee to feel at ease yet it was important that the issues important to my research questions were not overlooked in the interview. In the cases of Mr Sogo and Mrs Marley I knew that I would have the opportunity to return and ask questions that had not be fully answered, but I wished to avoid this situation arising more than necessary as I was aware that the teachers were busy and it was difficult for them to give up their time.

I was afforded the opportunity to conduct an unstructured interview with Mrs Putten as I was spending a greater length of time with her. This flexible approach (Wilkinson & Birmingham, 2003) allowed the interviewee to guide the discussion and as the teacher was a well-qualified teacher involved in post-graduate research herself, she was familiar with the issues of teachers' use of ICT from her own research. This meant that the teacher was well-informed and knowledgeable on the topic and could raise interesting issues on the topic in an informal setting.

I was aware that I might not get through all the questions on the first visit and knew that I would get an opportunity to return (in the case of Mr Sogo and Mrs Marley) and adjusted the interview protocol on each visit to reflect the questions that I did not ask in the first visit. A revised interview protocol was developed for each subsequent visit. In line with the semi-structured format, I deviated from the protocol on many occasions, following a line of discussion raised either by the teacher or by me when the opportunity arose. This is an interview technique in line with semi-structured interviews as part of qualitative data collection strategies (Creswell, 2003; Yin, 2003).

All interviews were recorded using a digital voice recorder, ensuring that everything said was preserved for transcription and later analysis. During the interviews I took notes but tried to maintain a balance between listening and note-taking so as to remain focused on the conversation. The transcribed interviews meant that every word was preserved. In addition, brief notes taken during the interview ensured that additional visual components of the interview, such as the body language and emotions of the interviewee, were recorded during the interview, as well as my thoughts on additional questions to ask that were not on my original interview protocol.

Observations

Observations were chosen as a research method in an attempt to understand how these three teachers interpreted and understood their role in the classroom when using ICT to teach science (Wilkinson & Birmingham, 2003). It allowed me to move beyond data based on perceptions, i.e. the sort of information gathered in interviews, to access the personal knowledge of the teachers (Cohen et al., 2003). In addition, it allowed me to better understand the complex reality of the classroom, or computer room in two of the cases, which I could not have achieved by simply interviewing the teachers or asking them to complete a questionnaire. For example, I knew that one teacher in particular felt very frustrated by the frequent interruptions to the Internet which affected her lesson planning but it was only when I saw the expression on her face with yet another Internet failure that I began to appreciate the disappointment she felt. The teacher had tried so hard to "showcase" some of the features about which she spoke enthusiastically and could not hide her disappointment at being interrupted.

Another reason for choosing observations as a research method was to corroborate some of the information the teacher had provided in the interviews. One teacher in particular spoke passionately about her students and their enthusiasm for lessons using the computer, and part of my observation focused on what the students were doing while the teacher was talking, their attitude to the computer lesson, how enthusiastic they appeared and whether they did indeed know which keys to use on the computer to access the information the teacher wanted them to access.

On the continuum of observations, from highly structured, knowing exactly what to look for, to unstructured, being responsive to what is observed, my observations fell somewhere in the middle and were semi-structured (Cohen et al., 2003). This semi-structured format (Appendix G) meant that I had some level of preconceived categories for my observations, but left room to generate hypotheses rather than test them (Cohen et al., 2003). Similarly, on the continuum between complete participant in the observations, a strategy where the observer becomes completely involved in the activities and becomes both a participant and an observer, to complete observer, a strategy where the observer is fully detached and remains as unobtrusive and detached as possible, my role fell somewhere in the middle (Bogdan & Biklen, 1992; Cohen et al., 2003; Merriam, 1988). As observer-as-participant, I was able to balance my involvement in the activities in the classroom and still remain detached, making no attempt to influence proceedings in any way. All three of the teachers were interviewed before being observed as talking to the teachers first allowed me to build a suitable rapport with each, facilitating my choice of role as observer-as-participant. It also helped my selection of semi-structured observation strategy and allowed me to focus observations on particular aspects that had been raised in the interviews.

For all of the observations, I requested the teachers to invite me to what they considered to be a "typical" lesson using the computer. I was fully aware that a teacher may use a computer differently on different occasions but in each of these instances the teachers were satisfied that they were showing me what use they made of the computer when teaching science. All other possible uses of the computer not evident in the observed lessons were discussed in detail with the teachers during the interviews.

On my three separate visits to Mr Sogo, I made one informal observation while walking around the school grounds. During this time I had an informal conversation with the teacher about the school in general and also made two formal classroom observations of science lessons. Both of these observations took place in the teacher's classroom while the teacher used the computer as a teaching tool. The students did not have access to a computer during the lessons. On the single visit to Mrs Putten I observed one of her lessons, again one the teacher described as a "typical" lesson using the computer. The lesson was held in the computer room and the students were sitting, each with individual access to a computer. The programme they were using was loaded onto each of the computers and the students worked at their own pace. On the four visits to Mrs Marley, I observed two of the lessons, one during school hours and one after school hours. For the second of these observations, the teacher had asked the students to remain after school for an extra lesson so that I could watch. The students seemed amenable to this request and the teacher convinced me that this was not an unusual request in the context of the school ethos. Both of these lessons were about forty minutes long.

Photographs

Photography is closely aligned with qualitative research and can be used in many different ways. Photographs used in qualitative research can be separated into two categories, those that others have taken and those that the researcher has taken (Bogdan & Biklen, 1992). Perhaps the most common use of photography in social science research is in conjunction with participant observation, most often used as a means of remembering and studying detail that might be overlooked if the photographs were not available for reflection. There is some controversy over the use of photographs in the early stages of research as the use of the camera may emphasize the researcher's role as an outsider (Bogdan & Biklen, 1992). This may be a particularly pertinent issue in the context of classroom research in South Africa as a history of classroom "inspection" may leave the teacher with the sense that the researcher may actually be an evaluator, judging the teacher's performance. Conversely, it has been suggested that the camera can provide the researcher with a legitimate purpose in the setting, in the case of education research, the classroom or school (Bogdan & Biklen, 1992).

Photographs were taken at each of the three schools. They were taken of the school buildings, showing the general conditions of teaching and learning, the room or laboratory which served at the computer room, as well as any other aspects of the school which was deemed worth recording. Ethical issues were considered, and no photographs were taken of the teachers or students which showed faces which may have allowed them to be identified. The camera was used as a tool in this study as a means of capturing the school and classroom context in which the computer is used, for reflection to assist in the process of analysis. In all cases, the teachers were asked if they were comfortable with my taking photographs and in each case assured that the faces of neither the teacher nor the students would not be used in such as way that they could be identified by anyone reading a written report of the study. In all cases, teachers were comfortable with the camera as a tool. Between twenty and fifty photographs were taken at each of the three schools, some of which have been used in the data sections of this thesis.

Field notes

Field notes, written both *in situ* as well as away from the school or classroom, form a vital data collection strategy for qualitative research (Cohen et al., 2003). Field notes were used extensively during the observations as a way of keeping a record of activities during the class time, as well as a way of formulating my personal ideas and hypotheses regarding them. I used the field notes to clarify some issues I had thought about as well as to remind me of questions to add to future interviews with the teacher. In making field notes I was recording what I observed as well as processing and analysing the data at the same time (Silverman & Marvasti, 2008).

Field notes played an important part of the data collected at the schools. I made notes while walking around each of the schools on my first visit to each one. I also made notes during the classroom observations so as to record what was happening during the lesson, my interpretations of those events, as well as notes to myself which needed to be followed up on with the teacher. Some of those follow-up notes became part of future interview questions and some I simply asked the teacher about informally. The field notes, supplemented by the photographs, formed the basis of much of my analysis of the data collected. The field notes also served as an important component of the triangulation of data.

Documents

Of the three major types of documents, public records, personal documents, and physical materials (Merriam, 1988), only physical materials were collected from the teachers. I attempted to collect a copy of each teacher's school policy on ICT. I managed to collect from Mr Sogo and Mrs Marley but Mrs Putten was not able to provide me with the school policy on ICT.

4.5.3 Analysis of qualitative data

The conceptual framework was used to focus the analysis of the data around the aspects suggested by the Kennisnet model (section 3.2) which contribute to understanding the value that the use of ICT added to teaching and learning in the three different schools: vision; expertise; digital learning materials; and ICT infrastructure. These aspects of the use of ICT were analysed in relation to the role of leadership in providing both technical and pedagogical support to teachers, and creating a culture of collaboration within the schools.

The first stage of my data analysis was data reduction (Miles & Huberman, 1994). Reduction, which forms part of the analysis, refers to the process of selecting, focusing, simplifying, abstracting, and transforming the data appearing in notes written in the field and the verbatim transcriptions of interviews with teachers (Miles & Huberman, 1994). This started during field work and continued up until the time of report writing. For this data, my primary methodological dilemma was deciding how to summarise and synthesize this diverse and disparate information into a consistent, yet still information-rich format. The challenge was overcome by using the qualitative data analysis software Atlas.ti. The use of this particular computer software assists in the process of exploring the data with the easy retrieval of data files and the inspection of memos on the screen replaces the time consuming cutting, pasting, photocopying, and colour coding of manual analysis. Atlas.ti allows for the analysis of textual, graphical and audio data (Willig, 2001), although for this study it was only used for the textural data. Beyond simple coding and retrieval of codes typical of cutting and pasting using paper-based analysis, Atlas.ti has several additional features of analysis such as the display of hierarchical relationships between codes and the construction of diagrams and networks (Willig, 2001). In addition, Atlas.ti allows for the use of direct quotations to enrich the presentation of the data, a task which is difficult when dealing with large amounts of unstructured text material, as in the case of this study.

Qualitative data is typically coded using inductive or deductive coding, or a combination of both. Deductive coding implies that the codes would be pre-determined by prior knowledge on the subject then allocated to particular parts of the transcribed text. The extensive literature review allowed me to derive some general themes before analysis and others were added as the study progressed. Inductive coding on the other hand means that codes are developed as the information is presented. Data obtained from the field in the form of words based on observations, interviews, and documents required processing before sense could be made of it.

The recorded interviews were transcribed verbatim by me and one other person employed to transcribe. The transcriptions were all checked for precision of transcription. In a few places the speech was inaudible to the transcribers, and is clearly indicated in square brackets in the transcript. Each interview transcript, field note and observation sheet was typed up for later incorporation in the data analysis phase. Teachers' names and schools were changed to maintain anonymity.

The interviews for each of the teachers were loaded into Atlas.ti. A number of anticipated codes were generated deductively before analysis began and others were added inductively as the coding process proceeded. These two coding processes resulted in 185 codes being generated in total, 24 of those codes had zero grounding generated from deductive coding, and the code with the highest grounding had 16 quotes attached to it. The codes with zero grounding were deleted and some merged. This process resulted in a final code count of 145 codes (Appendix J).

For the case analysis, a family was made with all the documents per school, resulting in three families called Mr Sogo, Mrs Putten and Mrs Marley. Some of the codes were unique to a single case as the teachers each used ICT in different ways and the software and hardware that was available to one teacher was not necessarily available to the others. Mr Sogo had 85 of the codes with quotes attached, Mrs Putten 106, and Mrs Marley 50 (Appendix J).

The second stage of data analysis involved the display of the data (Miles & Huberman, 1994), a condensed presentation of data that allowed me to use it to draw conclusions. The codes were sorted into two main families, the first comprising those codes which would identify data to assist in answering the first operational research question. All the codes which would identify data which would assist in answering the second operational research question were grouped into a second family of codes. The data was displayed in the form of matrices and networks, both designed to make the information easily accessible so that it could be used to understand what was happening and draw conclusions.

The third stage of the analysis was drawing conclusions and verification of conclusions drawn (Miles & Huberman, 1994). This verification was done by sending all the selected quotes and corresponding codes from one of the teachers, together with my analysis of the data for this teacher, to a education specialist colleague who acted as a "critical friend", looking at the data with an unbiased eye to determine whether his conclusions from the data were the same or similar to mine. My interpretation of the data matched his. I continued with my analysis, I noting regularities, patterns in the data, and made assertions based on the available data. While some conclusions emerged during the data collection part of the study, final conclusions could not be made until data collection was over. The audit trail maintained throughout the data collection assisted in verifying findings. While a summary of this analysis has been presented as three distinct stages, all three were continuous throughout the study and should not be seen as linear in sequence.

4.6 Concluding remarks

This study sought to understand the value of using ICT in South African science classrooms. The research question was operationalized by two sub-questions:

1. *How do science teachers use ICT in a context of limited resources?*
2. *Why do science teachers use ICT in the ways that they do?*

The quantitative data collected from South African science teachers in the SITES 2006 study, together with qualitative data from three science teachers, provided the basis for the analysis to answer these two sub-questions. The data collected in answering these two questions allowed for an interpretation of qualitative and quantitative data to address the main research question: *What is the value that using ICT adds to the teaching and learning of Science when teachers use ICT in a context of limited resources, typical of a developing country?* This chapter provided the details of each method chosen to collect both the quantitative and qualitative data as well as the details of each specific strategy selected. It explained each limitation where relevant and how the limitation was overcome through the study.

CHAPTER FIVE

Pedagogical orientations of South African science teachers

The SITES 2006 study examined how science teachers and students used ICT, and whether it contributed to learning activities geared towards the development of 21st century skills. The findings from the study showed that across 22 countries, mostly developed, science teachers' use of ICT in their teaching practice was influenced to some degree by their general pedagogical orientation. The impact of ICT use on students was highly dependent on the teaching approaches adopted when ICT was used and that students were more likely to adopt skills in line with 21st century goals when their teachers provided a more student-centred approach to teaching (Law et al., 2008). In order to establish the pattern of ICT use in a science education in a developing country such as South Africa, a similar analysis was conducted using the data from the South African sample as discussed in section 4.4.4. Questions 8, 9, 14, and 16 on the SITES 2006 Teacher Questionnaire (Appendix A) provided data to understand the sampled South African science teachers' general and ICT-using pedagogical orientations. The data are presented as descriptive statistics in this chapter to establish the landscape of ICT-use in science classrooms in South Africa which may in turn assist in understanding the context of ICT-use in similar developing countries[16]. Secondary analysis of the data, similar to that done in the main SITES 2006 study, showed a strong traditional pedagogical orientation in South African science teachers with very low adoption of 21st century skills. It is the 21st century pedagogical orientation which the South African Department of Education hopes to promote through the e-Education policy (DoE, 2004b). This

[16] A full print-out of the percentage and mean scores for the selected South African science teachers is available in Appendices E and F. All data presented in tables and graphs in this chapter (and the following two chapters) were obtained from those Appendices.

finding is likely to be similar for other developing countries in which access to technology resources is low.

5.1 Pedagogical orientations of South African science teachers

The SITES 2006 science teacher questionnaire data was used to explore South African teachers' pedagogical orientation when they teach science in a context of limited resources. The teachers were asked about their personal curriculum goals (question 8), their own teaching practice (question 14), and the learning practices of their students (question 16). As discussed in Chapter 2, pedagogical orientations are conceived and conceptualised in the SITES studies and categorized broadly into *traditionally important*, referring to teaching practices characteristic of classrooms in the industrial society, and *21st century*, referring to those conducive to developing learning outcomes important for the knowledge society. Twenty-first century pedagogical orientations are further divided into *lifelong learning* orientation and a *connectedness* orientation[17].

The SITES-M2 findings indicated that the curriculum goals of teachers and the roles played by teachers and students in the learning process were the three aspects most indicative of the pedagogical approach or orientation of the teacher (Law et al., 2008). From this, three sets of core indicators of pedagogical orientation, namely the curriculum goal orientation, the teacher's role orientation, and the student's role orientation, were developed (Law et al., 2008). These indicators were constructed on the basis of teachers' responses to questions on the relative importance of a range of curriculum goals and the relative frequency of occurrence of a range of teacher activities and student activities. These indicators are presented in Table 5.2, Table 5.4, and Table 5.6.

[17] Chapter Two gives a more detailed explanation of the concepts.

South African teachers' curriculum goals

As a way of understanding the extent to which the sampled South African science teachers' pedagogical practice is predominantly *traditional*, orientated towards *lifelong learning* or towards a *connectedness* orientation, teachers were asked to rate the importance of achieving particular curriculum goals with their Grade 8 science students. The responses are presented in Table 5.1 (Appendices E and F).

Table 5.1: Science teachers' espoused curriculum goals when they teach science

	In your teaching of the target class in this school year, how important is it for you to achieve the following goals?	Somewhat OR Very Much (%)	Mean Score (SE)
A	To prepare students for the world of work	88	3.59 (0.05)
B	To prepare students for upper secondary education and beyond	97	3.78 (0.02)
C	To provide opportunities for students to learn from experts and peers from other schools/countries	83	3.40 (0.05)
D	To provide activities which incorporate real-world examples/settings/applications for student learning	90	3.58 (0.04)
E	To improve students' performance in assessments/examinations	98	3.86 (0.02)
F	To increase learning motivation and make learning more interesting	98	3.82 (0.03)
G	To individualize student learning experiences in order to address different learning needs	87	3.47 (0.05)
H	To foster students' ability and readiness to set their own learning goals and to plan, monitor and evaluate their own progress	89	3.49 (0.04)
I	To foster students' collaborative and organizational skills for working in teams	94	3.64 (0.04)
J	To foster students' communication skills in face to-face and/or online situations	89	3.51 (0.05)
K	To satisfy parents' and the community's expectations	90	3.55 (0.04)
L	To prepare students for competent ICT use	61	2.58 (0.08)
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.)	49	2.44 (0.08)

There were very high responses to *increasing learning motivation* (98%), *to improve students' performance in assessments/examinations* (98%), and *to prepare students for upper secondary education and beyond* (97%). More than a third of the teachers (39%) did not think that it was important for them to use ICT as part of their normal curriculum goals to prepare their students for competent ICT use, and more than half (51%) did not think that it was important for them to use ICT in their teaching to prepare students for responsible Internet behaviour. This is not surprising as most of the computer use in South African schools is still done as a separate subject, Technology (Grades 8-9) and Computer Applications Technology (CAT) (Grades 10-12), and it is reasonable for teachers to expect the Technology or CAT teacher to deal with those particular issues. The teacher-reported **curriculum goals** have been ranked, using the mean scores on a 4-point Likert scale, from highest mean score to lowest, as shown in Figure 5.1. The three highest scores are shown in red and the three lowest in green.

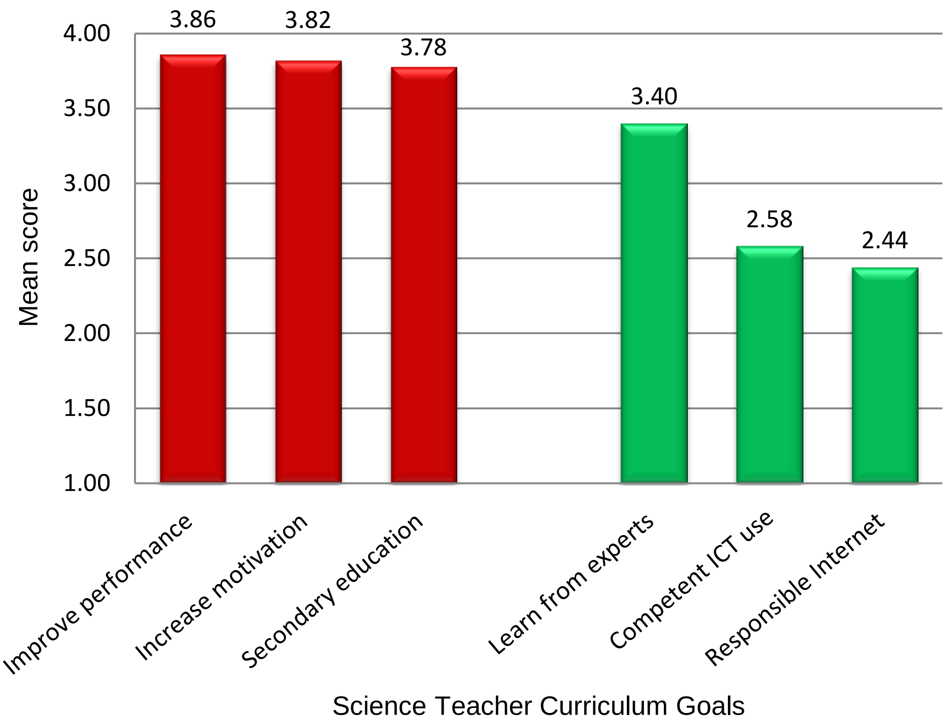

Figure 5.1: Three highest and three lowest South African science teachers' curriculum goals as ranked mean scores

The South African science teachers reported the three curriculum goals: *to improve students' performance in assessments and examinations (3.86); to increase learning motivation (3.82); and to prepare their students for upper secondary education and beyond* (*tertiary education*) (3.78), with the highest mean scores. All were ranked with high mean score close to the maximum of 4.00. The mean scores for assessments and examinations is indicative of the examination driven curriculum experienced by South African teachers in general, with added pressure for student achievement in Science (and Mathematics) over the past few years. Internationally, teachers assigned similar importance to these curriculum goals (Law et al., 2008). It is interesting to note that science teachers ranked the goal *to provide opportunities for students to learn from experts and peers from other schools/countries* as relatively not important, with a mean below 3.00 in all other education systems participating in the study except South Africa (Law et al., 2008). South African teachers ranked that curriculum goal with a mean of 3.40 (Table 5.1).

Responses to Question 8 in the teacher questionnaire (Appendix A) were used to provide indicators for the curriculum goal orientation (Law et al., 2008). Three indicators were computed: *Traditionally important* (questions 8B, 8E and 8K), *Lifelong Learning* (questions 8D, 8G, 8H and 8I) and *Connectedness* (questions 8C, 8J and 8M) shown in Table 5.2. Details of how these scales were developed as well as a discussion about their reliability can be found in the Technical Report (Appendix D) (Carstens & Pelgrum, 2009, p. 96).

Table 5.2: South African curriculum goals contributing to three pedagogical orientation scores

Curriculum goal orientation	**Specific curriculum goals included in the scales***	**Ave Mean***
Traditionally important	(B) To prepare students for upper secondary education and beyond (E) To improve students' performance in assessment/examinations (K) To satisfy parents' and community expectations	3.73
Lifelong learning	(D) To provide activities which incorporate real-world examples/settings/applications for student learning (G) To individualize student learning experiences in order to address different learning needs (H) To foster students' ability and readiness to set their own learning goals and to plan, monitor and evaluate their own progress (I) To foster students' collaborative and organizational skills for working in teams	3.55
Connectedness	(C) To provide opportunities for students to learn from experts and peers from other schools/countries (J) To foster students' communication skills in face-to-face and/or online situations (M) To prepare students for responsible Internet behaviour	3.12

* The Average of mean scores are arithmetic means of the scores for the respective items of the 4-point Likert scale.

When the average arithmetical mean for the sampled South African science teacher scores for each category are calculated and plotted on a graph (Figure 5.2), the traditionally important curriculum goal orientation (3.73) is ranked highest, and the connectedness pedagogical orientation (3.12) lowest. When comparing the South African data to the international data, a similar trend of the traditionally important orientation (ranging from 3.02 to 3.75) being the strongest and the connectedness orientation (ranging from 2.39 to 3.18) being the lowest mean score is evident (Law et al., 2008).

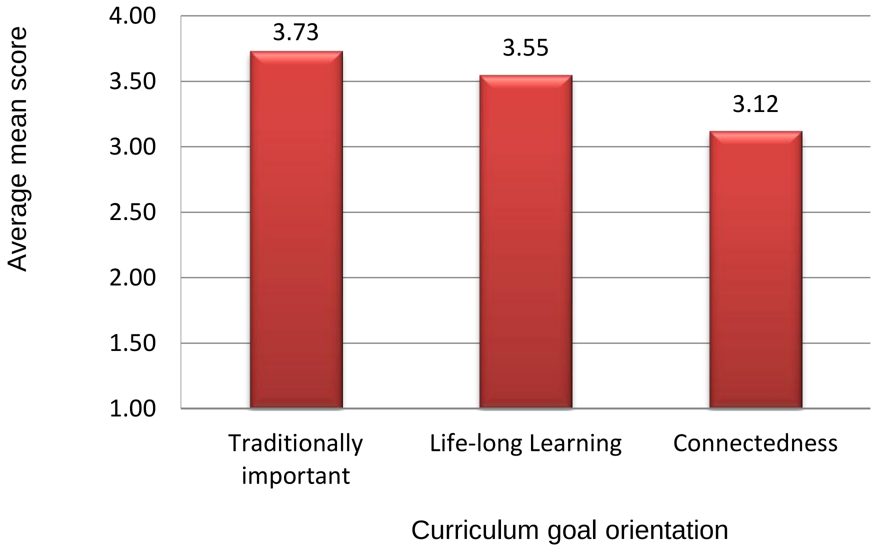

Figure 5.2: Average of the mean scores for South African science teachers curriculum goals contributing to three pedagogical orientations

Internationally, there were a few exceptions to this trend where some systems reported higher mean for the *lifelong learning* goals than for *traditionally important* (Law et al., 2008). This data confirms what might have been anticipated, that is that South African science teachers, like many others internationally, still have teaching goals which are traditional in nature.

South African teacher practice

As a way of understanding the pedagogical practice orientations of science teachers, teachers were asked what sorts of teaching activities were conducted in their science classes during the year. Teaching practices that are traditionally important are well aligned in terms of helping students attain the traditionally important curriculum goals described in the previous section. The teacher responses to questions about their practice are listed in Table 5.3 (Appendices E and F).

Table 5.3: Teacher practice scores

	In your teaching of the target class in this school year, how often do you conduct the following?	Often OR Nearly Always (%)	Mean Score (SE)
A	Present information/demonstrations and/or give class instructions	83	3.27 (0.05)
B	Provide remedial or enrichment instruction to individual students and/or small groups of students	66	2.90 (0.04)
C	Help/advise students in exploratory and inquiry activities	78	3.05 (0.05)
D	Organize, observe or monitor student-led whole-class discussions, demonstrations, presentations	75	3.03 (0.05)
E	Assess students' learning through tests/quizzes	85	3.24 (0.04)
F	Provide feedback to individuals and/or small groups of students	82	3.22 (0.04)
G	Use classroom management to ensure an orderly, attentive classroom	93	3.56 (0.04)
H	Organize, monitor and support teambuilding and collaboration among students	86	3.26 (0.04)
I	Organize and/or mediate communication between students and experts/external mentors	54	2.64 (0.06)
J	Liaise with collaborators (within or outside school) for student collaborative activities	46	2.47 (0.06)
K	Provide counselling to individual students	66	2.71 (0.05)
L	Collaborate with parents/guardians/caretakers in supporting/monitoring students' learning and/or in providing counselling	51	2.62 (0.90)

More than 90% of South African science teachers in the sample reported that they often or nearly always *used classroom management to ensure an orderly, attentive classroom* for science lessons (Table 5.3). This finding is in line with what one might find in the predominantly teacher-centred classrooms in South Africa (Howie et al., 2010). More than 80% of the sampled South African science Teachers often or nearly always *assess students' learning through tests/quizzes* (85%), *present information/demonstrations and/or give class instructions* (83%), and *provide feedback to individuals and/or small groups of students* (82%).

The teacher practice scores have been ranked, using the mean scores on the 4-point Likert scale, from the highest to lowest. The graph (Figure 5.3) shows the three highest (red) and three lowest (green) ranked mean scores.

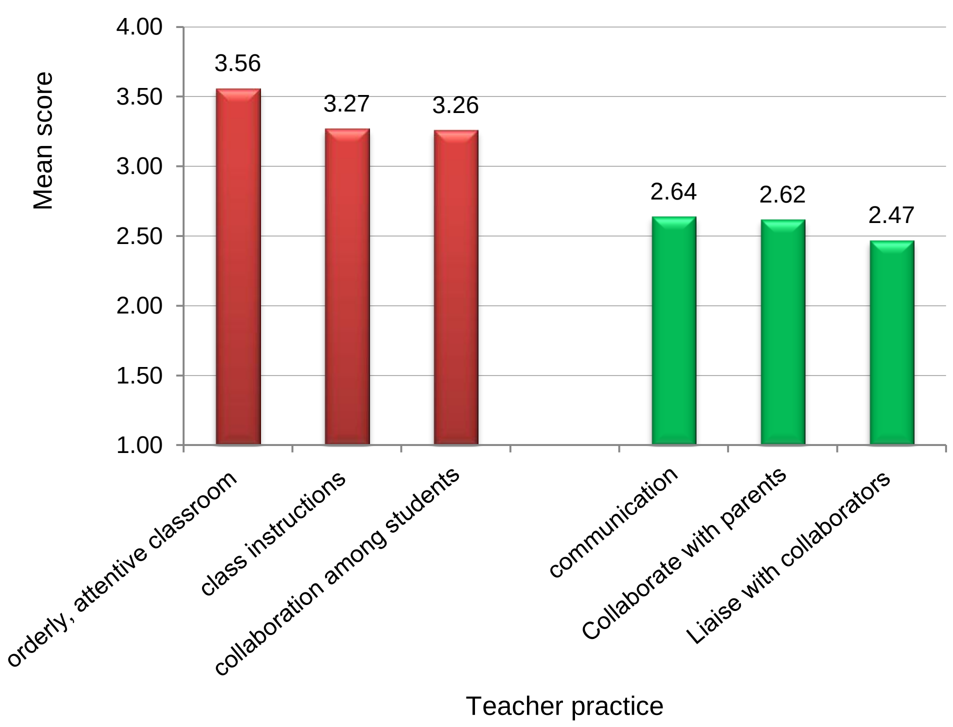

Figure 5.3: Three highest and three lowest teacher practice mean scores for South African science teachers

The highest self-reported practice was to use classroom management to ensure an orderly, attentive classroom (3.56), in line with a teacher role traditionally prevalent in classrooms since the early 20th century, if not earlier, and is the role of the teacher one would typically encounter in South African science classrooms. In contrast, the teacher practice with the lowest importance among the sampled South African science teachers was to liaise with collaborators (mean of 2.47), a teacher practice strongly associated with the connectedness pedagogical orientation and not a practice one would expect to find as commonplace in South African classrooms.

Using Q14 on the teacher questionnaire (Appendix A), three indicators were computed (Law et al., 2008): *Traditionally important* (questions 14A, 14E and 14G), *Lifelong learning* (questions 14B, 14F, 14K, 14C, 14D and 14H) and *Connectedness* (questions 14I, 14J, and 14L). Details of how these scales were developed as well as a discussion about their reliability can be found in the Technical Report (Appendix D) (Carstens & Pelgrum, 2009, p. 97). The specific teacher practices forming these scales are presented in Table 5.4.

Table 5.4: List of teacher practices associated with the three teacher practice orientations

Teacher practice orientation	Teacher practices (roles of the teacher)	Ave Mean*
Traditionally important	(A) Present information/demonstrations and/or give class instructions (E) Assess students' learning through tests/quizzes (G) Use classroom management to ensure an orderly, attentive classroom	3.36
Lifelong learning	(B) Provide remedial or enrichment instruction to individual students and/or small groups of students (F) Provide feedback to individuals and/or small groups of students (K) Provide counseling to individual students (D) Help/advise students in exploratory and inquiry activities (C) Organize, observe or monitor student-led whole-class discussions, demonstrations, presentations (H) Organize, monitor and support team-building and collaboration among students	3.03
Connectedness	(I) Organize and/or mediate communication between students and experts/external mentors (J) Liaise with collaborators (within or outside school) for student collaborative activities (L) Collaborate with parents/guardians/ caretakers in supporting/monitoring students' learning and/or in providing counseling	2.61

* The Average of mean scores are arithmetic means of the scores for the respective items of the 4-point Likert scale.

The first set of teacher roles are well aligned in terms of helping students attain the traditionally important curriculum goals described above. The six roles which fall within the lifelong learning orientation depict more facilitative roles for the teacher that are suited to achieving lifelong learning goals, such as tailoring instruction, providing advice and feedback to suit individual needs, and guiding and monitoring open-ended inquiry, collaboration, and team building. The third set of indicators which fall under connectedness orientation relate to providing opportunities for teachers to work with and learn from peers and experts, both locally and internationally. This group requires teachers to extend their own connectedness, changing from working primarily within the confines of their own classroom to establishing relationships with peers and experts both locally and internationally.

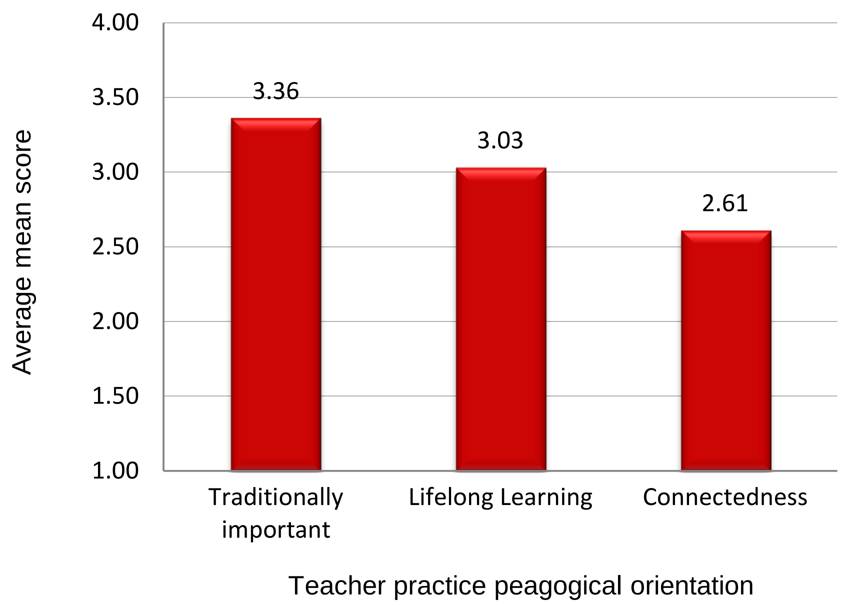

Figure 5.4: Average of mean scores for South African teacher practices contributing to three pedagogical orientation scores

When the average arithmetical mean for the South African science teacher scores for each category are calculated and plotted on a graph (Figure 5.4), the traditionally important curriculum goal orientation (3.36) is ranked highest, and the connectedness pedagogical orientation (2.61) lowest. When comparing the South African data to the international data, a similar trend of the traditionally important orientation being the highest and the connectedness orientation being the lowest mean score is evident (Law et al., 2008).

South African student practice

Contemporary theories of learning from a constructivist perspective attribute considerable importance to students' involvement in the learning process (Driver, 1990, 1994; Driver et al., 1994; Duit, 1994). This is considered essential for deep and meaningful learning. As such, the roles played by students in their learning arguably provide the most important information about the pedagogical orientation of any teaching and learning situation (Law et al., 2008). Teachers were asked about their students' engagement in a number of activities and their responses are shown in Table 5.5 (Appendices E and F).

Table 5.5: Student activities

	In your teaching of the target class in this school year (a) How often do your students engage in the following activities?	Often OR Nearly Always (%)	Mean Score (SE)
A	Students working on the same learning materials at the same pace and/or sequence	55	2.71 (0.06)
B	Students learning and/or working during lessons at their own pace	56	2.67 (0.06)
C	Complete worksheets, exercises	75	3.05 (0.05)
D	Give presentations	53	2.69 (0.06)
E	Determine own content goals for learning (e.g., theme/topic for project)	67	2.27 (0.06)
F	Explain and discuss own ideas with teacher and peers	52	2.75 (0.05)
G	Collaborate with peers from other schools within and/or outside the country	22	1.87 (0.06)
H	Answer tests or respond to evaluations	81	3.19 (0.05)
I	Self and/or peer evaluation	54	2.63 (0.05)
J	Reflect on own learning experience review (e.g., writing a learning log) and adjust own learning strategy	37	2.27 (0.06)
K	Communicate with outside parties (e.g., with experts)	26	2.03 (0.05)
L	Contribute to the community through their own learning activities (e.g., by conducting an environmental protection project)	23	1.95 (0.05)

More than 80% of South African science teachers reported that their students often or almost always *answered tests or responded to evaluations of some sort*. This response is in line with the high reported curriculum goal of improving students' performance in assessments and examinations (section 5.1). These teachers also reported that for only 22% of their time, their students engaged in *collaborating with peers from other schools within or outside the country* often or nearly always. This figure somewhat contradicts the teachers' high response to the curriculum goal *to provide opportunities for students to learn from experts and peers from other schools/countries* (83%) shown in Table 5.1.

The student practice scores have been ranked, using the mean scores on the 4-point Likert scale, from the highest to lowest. The graph (Figure 5.5) shows the three highest (red) and three lowest (green) ranked mean scores.

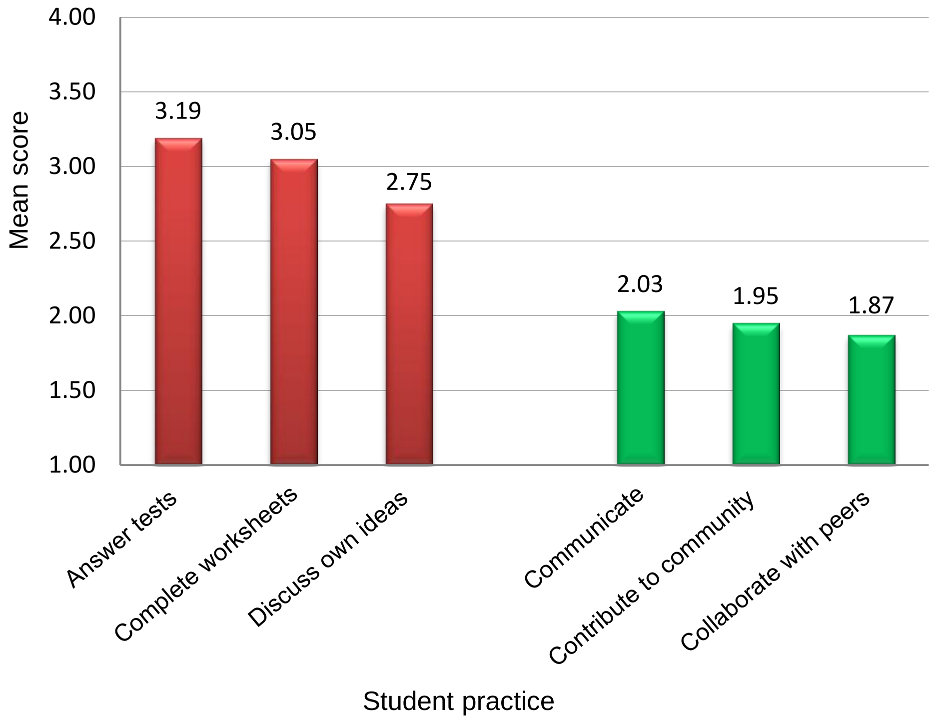

Figure 5.5: Three highest and three lowest South African student practice mean scores

The two most frequently practiced student activities as reported by science teachers in South Africa (Figure 5.5), were *answering tests* (mean score 3.19), and *completing worksheets/exercises* (mean score of 3.05). These are activities that are commonly found in traditional classrooms and the findings are compatible with the earlier ones that teachers valued the *traditionally important* curriculum goals most highly and played *traditionally important* roles most frequently. The two least popular student activities as reported by science teachers in South Africa, were *contributing to the community through their own activities* (mean score 1.95), and *collaborating with peers from other schools* (mean score 1.87), both of which can be associated with the *connectedness* orientation (Law et al., 2008). These low mean scores indicate that students rarely engage in collaboration or communication with outside parties, if at all.

The responses to Question 16 on the teacher questionnaire (Appendix A) were used to compute three indicators for the student-practice orientation (Law et al., 2008):

Traditionally important (questions 16A, 16C and 16H), *Lifelong learning* (questions 16B, 16E, 16F, 16D, 16I and 16J) and *Connectedness* (questions 16G, 16K, and 16L). Details of how these scales were developed as well as a discussion about their reliability can be found in the Technical Report (Appendix D) (Carstens & Pelgrum, 2009, p. 97). These are shown Table 5.6:

Table 5.6: List of student practice items associated with the three student practice orientations

Student practice orientation	**Student practices (activities)**	**Ave Mean***
Traditionally important	(A) Working on the same learning materials at the same pace and/or sequence (C) Complete worksheets, exercises (H) Answer tests or respond to evaluations	2.98
Lifelong learning	(B) Students learning and/or working during lessons at their own pace (E) Determine own content goals for learning (e.g., theme/topic for project) (F) Explain and discuss own ideas with teacher and peers (D) Give presentations (I) Self and/or peer evaluation (J) Reflect on own learning experience	2.55
Connectedness	(G) Collaborate with peers from other schools within and/or outside the country (K) Communicate with outside parties (e.g., with experts) (L) Contribute to the community through their own learning activities (e.g., by conducting an environmental protection project)	1.50

* The average mean of scores are arithmetical means of the scores for the respective items of the 4-point Likert scale.

When the average arithmetical mean for the South African student practice scores for each category are calculated and plotted graphically (Figure 5.6), the traditionally important pedagogical orientation is ranked highest (2.98), and the connectedness pedagogical orientation lowest (1.50).

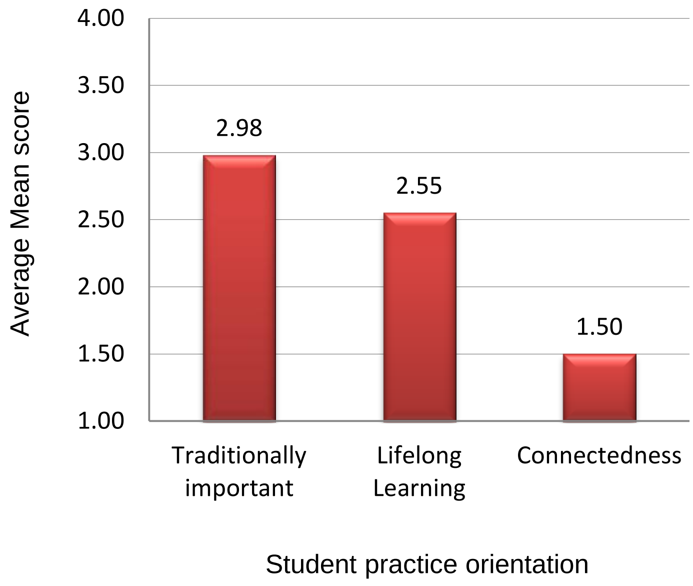

Figure 5.6: Average of mean scores for South African student practice contributing to three pedagogical orientation scores

Activities listed within the lifelong-learning orientation require students to play a much more pro-active and responsible role in their own learning than has traditionally been the case in South African classrooms. These sorts of practices include being able to determine their own content goals for learning (e.g. theme or topic for project), being able to explain and discuss their own ideas with their teacher and peers, and being able to give presentations. Some of these activities require deep cognitive engagement, such as self-evaluations and reflections on one's own learning. Giving students a more responsible role in facilitating their own learning may help them to develop the lifelong-learning skills typically valued for functioning effectively in the knowledge society.

When comparing the South African data to the international data, a similar trend of the traditionally important orientation being the strongest and the connectedness orientation being the lowest mean score is evident (Law et al., 2008). South African science teachers are similar in their low connectedness pedagogical orientation to those in other education systems. Surprisingly, South African science teachers report the second highest connectedness pedagogical orientation (behind Thailand) as reflected in their 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% of schools with actual computer access for their students.

The pattern showing the traditionally important orientation as the highest and the connectedness orientation as the lowest in South Africa and in other participating systems indicates that teaching and learning practices used by the surveyed science teachers are predominantly traditional, with learning goals focused on the mastery of predefined content goals. In this paradigm, teachers play the role of expert instructor and assessor while students follow instructions and complete assigned close-ended tasks (Law, 2009). A closer examination of these findings by Law (2009) shows important differences across the three sets of indicators. For the curriculum goals, the international average mean lifelong learning orientation is only slightly lower than the international average mean traditionally important orientation, indicating that in general, teachers consider the development of students' lifelong learning skills, such as collaborative inquiry and self-directed learning ability to be almost as important as achieving traditionally important goals such as doing well in assessments. On the other hand, average mean connectedness goals were considered to be much less important, indicating that teachers in general did not perceive the provision of opportunities for students to learn with and from peers and experts outside of the school, or the development of communication skills to be high priority curriculum goals (Law, 2009).

Comparing teacher-practice and student-practice pedagogical orientations

When teacher-practice mean scores are compared to student-practice mean scores, for all three pedagogical orientations, the latter are lower than the former (Figure 5.7). This trend was similar to the scores in the other education systems internationally (Law et al., 2008) and it may be interpreted as an indication that teachers are more likely than students to engage in pedagogical activities. The interpretation is in line with a recent study of FET science teachers in schools in

South Africa (Howie et al., 2010). All the science teachers showed a strong teacher-centred approach to science teaching, dominated by "chalk-and-talk" teaching with very little evidence of learner-centred strategies (Howie et al., 2010).

The difference between teacher-practice orientation and learner-practice orientation (Figure 5.7) also increases from the traditionally important orientation (mean difference of 0.38), lifelong learning orientation (mean of difference 0.48), and connectedness orientation (mean difference of 1.11).

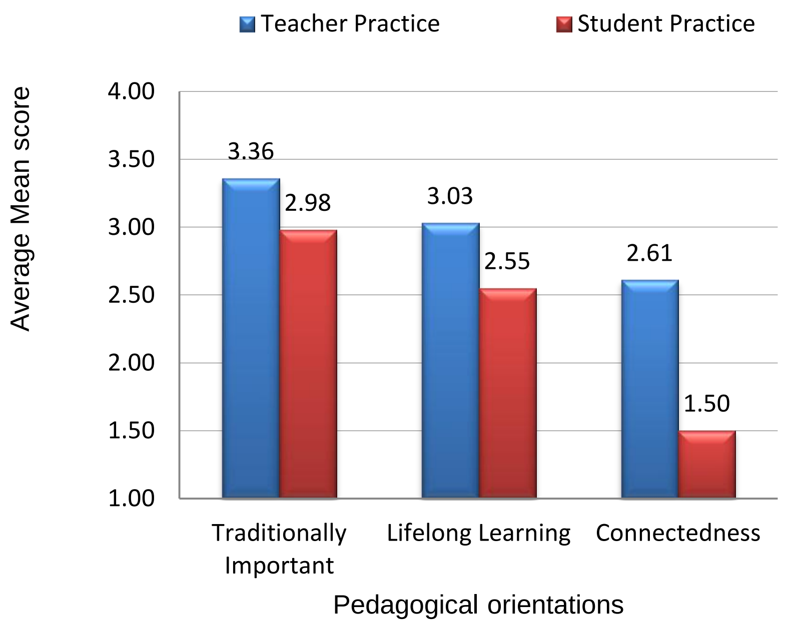

Figure 5.7: Average of mean scores of teacher practice compared to student practice for the three pedagogical orientations

This could point to a developmental trajectory in pedagogical innovation which starts with a change in aspired curriculum goals, followed by a change in teacher practice, and finally a change in student practice.

5.2 Pedagogical orientations when ICT is used in teaching and learning

The previous section showed the data collected to gauge the sampled South African science teachers' pedagogical orientations as reflected by three sets of indicators namely teachers' curriculum goals, teacher practice, and teacher-reported student practice as conceptualised in the SITES 2006 study. The SITES 2006 Teacher Questionnaire explored the impact of ICT-use on pedagogical practice. In other words, do teachers pedagogical orientations in South African science classrooms differ whether ICT is used or not? For this section, the teacher responses to questions about their teaching practice and the learning practices of their students when they used ICT to teach science are reported.

Teacher practice and ICT use

To answer this question, teachers were asked whether they used ICT for the different practices that they had reported on in the previous section. The teacher responses to these questions allow us to examine the pedagogical orientation of South African science teachers' ICT-using practices and compare them to their overall pedagogical orientations. As a way of comparing the teacher practice mean scores on the 4-point Likert scale to the percentage of teachers who responded that they use ICT for the particular practice indicated, the mean scores have be converted to a score on a 100-point scale and are reported in Table 5.7. (Details of this conversion are discussed in section 4.4 and raw data are shown in Appendix I).

Table 5.7: Teacher practice and ICT use

	In your teaching of the target class in this school year, how often do you conduct the following?	Mean %	% using ICT
A	Present information/demonstrations and/or give class instructions	75	14
B	Provide remedial or enrichment instruction to individual students and/or small groups of students	64	13
C	Help/advise students in exploratory and inquiry activities	68	16
D	Organize, observe or monitor student-led whole-class discussions, demonstrations, presentations	68	12
E	Assess students' learning through tests/quizzes	75	14
F	Provide feedback to individuals and/or small groups of students	74	13
G	Use classroom management to ensure an orderly, attentive classroom	85	11
H	Organize, monitor and support teambuilding and collaboration among students	76	10
I	Organize and/or mediate communication between students and experts/external mentors	54	14
J	Liaise with collaborators (within or outside school) for student collaborative activities	49	12
K	Provide counselling to individual students	57	10
L	Collaborate with parents/guardians/ caretakers in supporting/monitoring students' learning and/or in providing counselling	54	12

The sampled South African science teachers reported very low ICT-use for all aspects of Teacher Practice. Lack of access to ICT resources for teaching and learning is an issue that is raised later in this chapter when discussing teacher-reported obstacles to their use of ICT when teaching science (section 7.4). The teacher-reported Teacher-Practice and ICT-use for that Teacher Practice has been ranked in order of decreasing ICT-use, and shown in Figure 5.8.

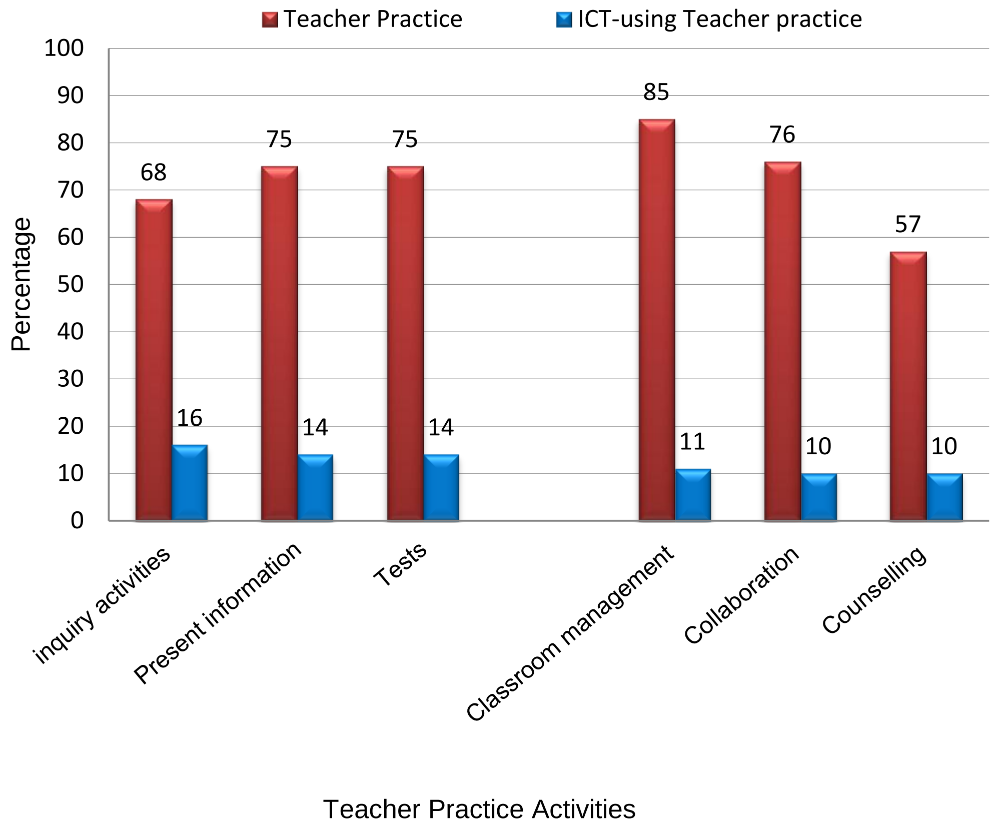

Figure 5.8: South African teacher practice scores compared to ICT-using teacher practice scores on 0-100 scale

The three highest ICT-using teacher practices, *use ICT to help/advise students in exploratory and inquiry activities* (16%), *use ICT to present information/demonstrations and/or give class instruction* (14%), and *use ICT to assess students' learning through tests/quizzes* (14%) (Table 5.7) are associated with the traditionally important orientation for teacher practice. The lowest reported ICT-using teacher practices were *organize, monitor and support teambuilding* and *collaboration among students and provide counselling to individual students* (both 10%).

Table 5.8: Teacher practice orientations when ICT is used

Teacher practice orientation	Teacher practices (roles of the teacher)	Ave of mean* %
Traditionally important	(A) Present information/demonstrations and/or give class instructions (E) Assess students' learning through tests/quizzes (G) Use classroom management to ensure an orderly, attentive classroom	78
Lifelong learning	(B) Provide remedial or enrichment instruction to individual students and/or small groups of students (F) Provide feedback to individuals and/or small groups of students (K) Provide counselling to individual students (D) Help/advise students in exploratory and inquiry activities (C) Organize, observe or monitor student-led whole-class discussions, demonstrations, presentations (H) Organize, monitor and support team-building and collaboration among students	68
Connectedness	(I) Organize and/or mediate communication between students and experts/external mentors (J) Liaise with collaborators (within or outside school) for student collaborative activities (L) Collaborate with parents/guardians/ caretakers in supporting/monitoring students' learning and/or in providing counselling	52

* The scale ratings are arithmetical means of the scores for the respective items of the 4-point Likert scale.

When an average for the different teacher practice and ICT-using teacher practice scores are plotted (Figure 5.9), one can see that the highest ICT-using teacher practice orientation is still associated with the traditionally important orientation, suggesting that even when teachers use ICT, their pedagogical practice remains traditional.

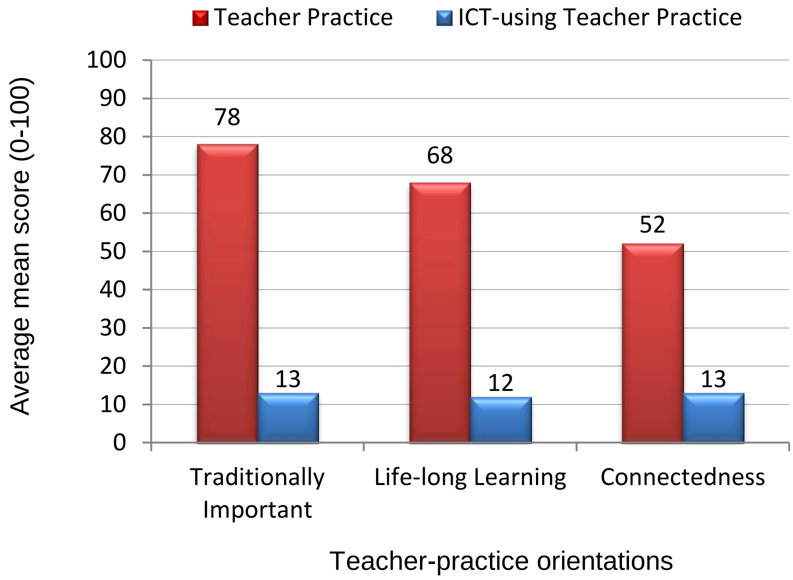

Figure 5.9: South African teacher practice pedagogical orientations compared to ICT-using teacher practice pedagogical orientations

There is a very small spread between the different orientations, most likely as a result of the very low ICT usage by South African science teachers.

Student practice and ICT use

The use of ICT for learner-practice is not surprisingly even lower than that of teacher-use. Schools in South Africa are often supplied with a single computer, mainly for administrative purposes before being provided with computers for student use. Teachers often share a computer to type notes, set tests and examinations and other similar activities rather than using computers for learning activities. As a way of comparing the Student Practice mean scores on the 4-point Likert scale to the percentage of teachers who responded that their students use ICT for the particular practice indicated, the mean scores have been converted to a score on a 100-point scale (details of this conversion are discussed in section 4.4 and raw data are shown in Appendix I)

Table 5.9: Student practice and ICT use

In your teaching of the target class in this school year, how often do your students engage in the following activities?		Mean %	% using ICT
A	Students working on the same learning materials at the same pace and/or sequence	57	12
B	Students learning and/or working during lessons at their own pace	56	10
C	Complete worksheets, exercises	68	13
D	Give presentations	56	11
E	Determine own content goals for learning (e.g., theme/topic for project)	42	9
F	Explain and discuss own ideas with teacher and peers	58	9
G	Collaborate with peers from other schools within and/or outside the country	29	8
H	Answer tests or respond to evaluations	73	11
I	Self and/or peer evaluation	54	9
J	Reflect on own learning experience review (e.g., writing a learning log) and adjust own learning strategy	43	7
K	Communicate with outside parties (e.g., with experts)	34	10
L	Contribute to the community through their own learning activities (e.g., by conducting an environmental protection project)	32	8

When South African science students are able to use ICT to learn Science (Table 5.9), the highest reported use is for *completing worksheets and exercises* (13%) and *working on the same learning materials at the same pace and/or sequence* (12%). The teacher-reported Student Practice and ICT-use for that Student Practice has been ranked in order of decreasing ICT-use, as plotted on Figure 5.10.

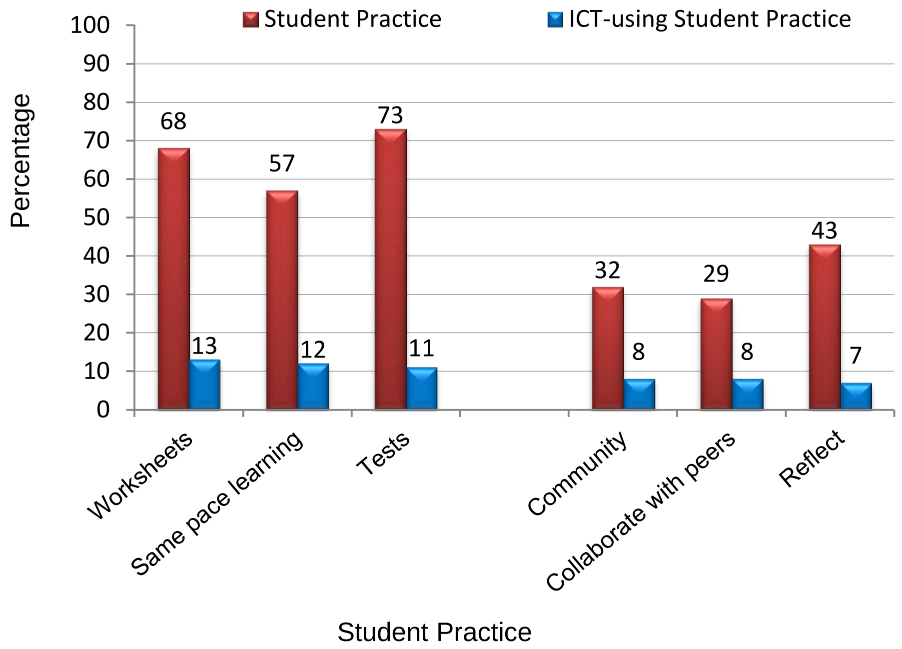

Figure 5.10: South African student practice compared to ICT-using student practice

The top three teacher-reported student practices using ICT are associated with the traditionally important learner-practice orientation (Table 5.10). This confirms the strong traditional orientation in student practice in South African science classrooms and is not surprising, given the strong traditionally orientation of teacher-practice in South African science classrooms.

Table 5.10: South African student practice orientations when ICT is used

Student practice orientation	Student practices (activities)	Ave Mean %*
Traditionally important	(A) Working on the same learning materials at the same pace and/or sequence (C) Complete worksheets, exercises (H) Answer tests or respond to evaluations	66
Lifelong learning	(B) Students learning and/or working during lessons at their own pace (E) Determine own content goals for learning (e.g., theme/topic for project) (F) Explain and discuss own ideas with teacher and peers (D) Give presentations (I) Self and/or peer evaluation (J) Reflect on own learning experience	48
Connectedness	(G) Collaborate with peers from other schools within and/or outside the country (K) Communicate with outside parties (e.g., with experts) (L) Contribute to the community through their own learning activities (e.g., by conducting an environmental protection project)	32

* The average mean are arithmetical average of the mean scores for the respective items of the 100-point scale.

When the average scores for the traditionally important, lifelong learning and connectedness learner-practice orientations are calculated and represented graphically (Figure 5.11), the trend is evident.

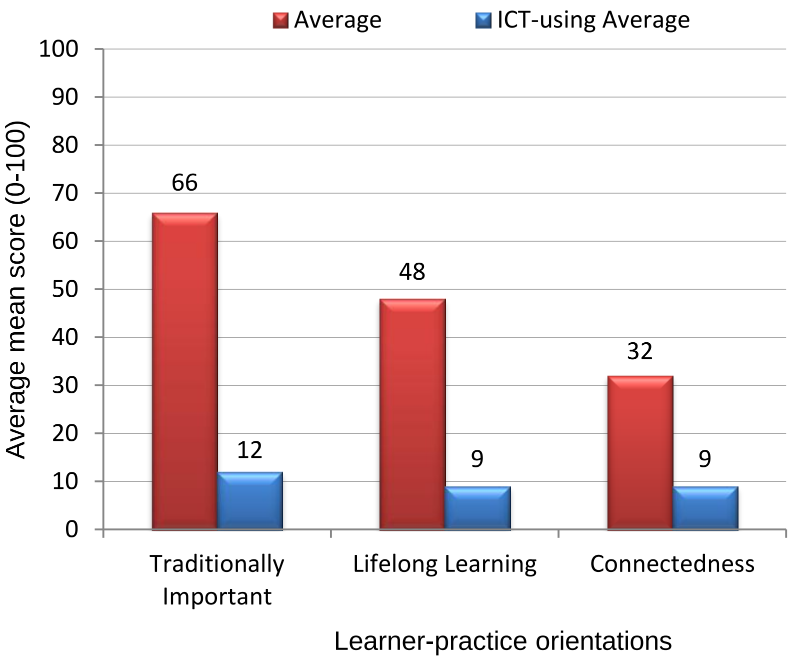

Figure 5.11: South African student practice pedagogical orientations compared to and ICT-using student practice pedagogical orientations

As with the teacher-practice scores, the highest reported Learner Practice scores are for the traditionally important orientation (12%) and the lowest learner-practice scores are for the connectedness orientation (9%).

The overall use of ICT by the sampled South African science teachers is low, with an average ICT use of only 13%. The highest reported activity for which teachers used ICT was to *help/advise students in exploratory and inquiry activities* at 16% and the lowest reported use was for *providing counseling to individual students* at 10% (Table 5.7). ICT use reported for student activities was lower still with an average South African science student use of nearly 11%. The highest reported use was for *students working on the same learning materials at the same pace and/or sequence* at nearly 13% and the lowest reported use for *reflect on own learning experience review (e.g., writing a learning log) and adjust own learning strategy* at 7% (Table 5.9). While the international averages may appear high in comparison to the South African student use of ICT with an average student use of 62% (Law, 2009), the consensus is that given the almost 100% student access to ICT in the other participating systems, this figure is low.

5.3 Concluding remarks

The first part of this chapter focused on teachers' personal curriculum goals (question 8), their own teaching practice (question 14), and the learning practices of their students (question 16) as a way of determining the South African science teacher pedagogical orientation when they teach Science. It showed that the vast majority of South African science teachers adopt a traditional pedagogical orientation when teaching Science. There is little evidence of a connectedness pedagogical orientation. This low connectedness orientation is, amongst other things, the result of limited technology resources (the Internet in particular). This was similar to the pedagogical orientation of most other countries that were part of the SITES 2006 study. The higher teacher lifelong learning and connectedness orientation, when compared to those of the student, suggests that teachers are more likely to make the shift from a traditional pedagogical orientation to a pedagogical orientation in line with 21st century goals before students are ready and able to make that shift.

When asked about their teaching practice and the practices of their students when learning Science, the analysis showed low pedagogical orientations for all three: traditional; lifelong learning; and connectedness. This could be due to the low ICT usage among South Africa science teachers in general. This low ICT use is perhaps one of the important justifications for the mixed methods design, which allowed a more in-depth and hence better understanding of South African science teachers' use of ICT where this ICT use is taking place on a regular basis.

The analysis of the SITES 2006 data for the sampled South African science teachers suggests that when the relationship between ICT use and pedagogical practice is examined, adopting ICT in teaching in science education does not necessarily contribute to pedagogical change and innovation in favour of 21st century pedagogy. While ICT may be considered a lever for change, given the right conditions, it is not the catalyst that will necessarily bring about those changes (Law, 2009). The ICT-using teacher and student practices analysed in the sampled South African science teachers tend to be less strongly oriented towards the traditionally important pedagogical orientation when compared to general teacher and student practices. It has been suggested (Law, 2009) that this indicates a higher probability of success in levering the use of ICT for strengthening 21st century goals if ICT use by teachers and students is encouraged.

CHAPTER SIX

How teachers use ICT when they teach Science

Teachers' use of ICT in teaching Science lies at the core of this study. Both internationally and for the purposes of this study, the key concern driving policy and research interest in the integration of ICT in education is the premise that ICT is important for bringing changes to the classroom teaching and learning to develop students' 21st century skills (Law et al., 2008). These skills include the ability of graduating students to become lifelong students within a context of collaborative inquiry, and the ability to work and learn from experts and peers in a connected global community, referred to as 21st century skills. Understanding how science teachers use ICT will allow an assessment of the extent to which 21st century skills are being realized in classrooms. This use of ICT has been reported for teachers internationally (Law et al., 2008) and this chapter uses the South Africa data SITES 2006 to report how teachers use ICT in South Africa. This distinction is necessary as teachers in South Africa teach in a very different context to most of those in the SITES 2006 study.

This chapter provides a focused discussion of the data collected to address the first sub-question of the study: *How do science teachers use ICT in a context of limited resources?* The question is answered by using a descriptive integrated approach to data presentation that combines the quantitative data collected using the SITES 2006 Teacher Questionnaire and the qualitative data collected from the three individual case studies. This chapter addresses teachers' use of ICT using three themes: the use of learning resources and technology infrastructure (section 6.1); scheduled learning time and use of ICT in that learning time (section 6.2); and use of ICT for assessment of students (section 6.3). A discussion of the findings, summary of the evidence, and research claims are made at the end of the chapter, together with a comparison of the South African science teachers to science teachers internationally using the Patterns of ICT framework developed in the SITES-M2 study.

6.1 Use of learning resources and technology infrastructure

There are a large variety of learning resources and technology tools available for teachers and students. In many developed countries, these tools are widely available to teachers for use on a daily basis. In South Africa, however, this is not the case and learning resources and technology infrastructure is limited. The data gathered through the SITES 2006 teacher questionnaire allows some insight into the level of access available to South African teachers and the first part of this section presents this data giving the landscape of technology use across the country. The second part of this section explore what access to technology the three case teachers had for teaching Science.

Teachers were asked: *How often do you incorporate the following in your teaching of the target class in this school year*? Teachers responded to this question on a 4-point Likert scale (1=never, 2=sometimes, 3=often, 4=nearly always). In the case of South African science teachers, a response of "never" when asked if they incorporated the particular resources into their teacher could either mean, "I have access but never use it", but is more likely to mean "I never use it because I do not have access to it." This section in the SITES 2006 teacher questionnaire received the lowest response from South African science teachers. Responses are shown in Table 6.1 (Appendices E and F).

Table 6.1 Resources and Technology Infrastructure

	How often do you incorporate the following in your teaching of the target class in this school year?	Often OR Nearly Always (%)	Mean Score (SE)
A	Equipment and hands-on materials (e.g., laboratory equipment, musical instruments, art materials, overhead projectors, slide projectors, electronic calculators)	30	2.11 (0.05)
B	Tutorial/exercise software	17	1.54 (0.05)
C	General office suite (e.g., word-processing, database, spreadsheet, presentation software)	5	1.25 (0.03)
D	Multimedia production tools (e.g., media capture and editing equipment, drawing programs, webpage/multimedia production tools)	4	1.26 (0.03)
E	Data-logging tools	3	1.17 (0.03)
F	Simulations/modeling software/digital learning games	4	1.21 (0.03)
G	Communication software (e.g., e-mail, chat, discussion forum)	5	1.21 (0.03)
H	Digital resources (e.g., portal, dictionaries, encyclopedia)	13	1.59 (0.04)
I	Mobile devices (e.g., Personal Digital Assistant (PDA), cell phone)	8	1.39 (0.04)
J	Smart board/interactive whiteboard	9	1.32 (0.03)
K	Learning management system (e.g., web-based learning environments)	3	1.22 (0.03)

The highest teacher response to using the particular resource or technology infrastructure was for *experiment and hands-on equipment* with a response of 30%. Only 3% of teachers responded that they often or nearly always used learning management systems such as web-based learning environments (Table 6.1). When the mean scores on the 4-point Likert scale for the use of the various resources or technology infrastructure are ranked and plotted (Figure 6.1), the very low scores across all technologies are clear. The three highest scores are shown in red and the three lowest in green.

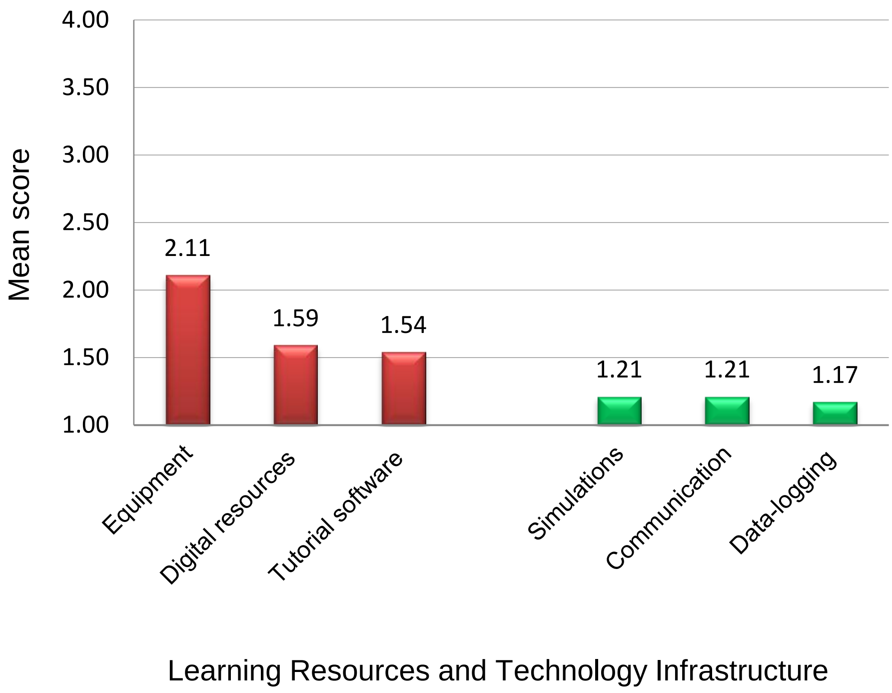

Figure 6.1: Three highest and three lowest South African learning resources used by teachers

South African science teachers were not able to incorporate the suggested learning resources and technology infrastructure into their teaching in the majority of cases. Access to these learning resources and technology infrastructure was explored with the three teachers. Mr Sogo was at a school which had a newly installed computer room, secured with a large steel vault door. The computer room was part of the Gauteng Online Project and contained 25 new computers, all still with plastic packaging on the keyboards (Figure 6.2).

Figure 6.2: Gauteng Online computer room at Mr Sogo's school

None of the computers were connected and the teacher's desk did not have the computer installed (Figure 6.3).

Figure 6.3: Teacher desk in Gauteng Online computer room

The room had been connected previously but each computer had been serviced by its own hard drive. The project personnel were in the process of reorganising the laboratories in Gauteng Province by installing a new 'networked' system in all computer rooms. All computers were supposed to operate off one single hard drive.

The computers in the room had been unconnected for a few months and despite Mr Sogo's persistent calls to the GDE, the computer room remained dysfunctional. I phoned Mr Sogo a year after visiting the school and the situation remained unchanged.

The school had retained the computer hard drives that the department had removed from the revamped Gauteng Online computer room. The school was able to source monitors for the 25 hard drives and these were set up as a second computer room.

Figure 6.4: Second computer room at Mr Sogo's school

None of these computers were connected. Mr Sogo was quite enthusiastic about having the second computer room but was waiting for these computers to be connected. Once connected, use would still be hampered by all the computers requiring programmes to be loaded individually. The issues around moving between the computers with a memory stick, loading each one individually with the work to be done, had not been overlooked by the teacher.

In addition to the school infrastructure, Mr Sogo had a laptop he had received as a prize for his provincial presentation entitled *Learner-centred Learning instead of Teacher-centred Approach* as part of a provincial *e-Learning Showcase (2008)*. He also had a data projector which he used in conjunction with the laptop. His system was fully portable and he kept both devices locked in his car boot when not in use. He had a small digital dictionary which he allowed the students to use. The laptop had standard proprietary word processor, spreadsheet, and presentation software loaded. Mr Sogo did all his marks using the spreadsheet software, his notes were typed using the word processing package, and his lessons were presented using the presentation software.

Mr Sogo used the presentation software extensively for his lessons and his home access to the Internet to gather information, download pictures, or research topics for his lessons. He was also able to use his personal digital camera to take pictures which he used in his lesson presentations. His main motivation for this system of presenting the subject content knowledge was that preparation was easier.

> It's less work because I do my preparation… I prepare and then after preparing, I take everything that I am going to talk about onto the computer. It becomes easier for me just to show them on the data screen. Let's say, maybe a plant cell …. I'm talking about plant and animal cells … it would be difficult for me just to draw a plant and animal cell and explain, rather than downloading it from the Internet, and then taking it on the data projector and explaining. It becomes easier for me (extract from interview with Mr Sogo)

The second teacher, Mrs Putten, was at a school which had a small newly constructed computer room which could accommodate 25 students. The computer room had a teacher's desk with a computer which was networked to all the other computers in the room. When the students worked in the computer room, each had access to their own computer.

Figure 6.5: Computer room at Mrs Putten's school

Mrs Putten had her own tablet laptop, a presenter mouse which could alternate between a mouse and a presenter, using remote access technology, a data-projector, and a cellular phone which allowed her to access the Internet from home, a digital camera and a digital video camera. Mrs Putten had purchased all of the technology resources herself as she considered having unrestricted access to the technology important. She did not like the idea of having to share her resources, and by her own admission, was a "bit of a techie".

Mrs Putten had access to standard proprietary word processor, spreadsheet, and presentation software, in addition to numerous free programmes that she had downloaded from the Internet, including movie-making programmes. Mrs Putten made use of all of her available hardware and software in innovative ways and her extensive knowledge of technology gave me insight into how ICT can be used for teaching Science. Mrs Putten integrated ICT into her teaching in a sophisticated way. Her curriculum for the lower grades was dominated by project-based learning.

One example was a project she developed for her students called "Race in Space" in which her students had to decide which planet was the best planet to host a Space Olympics. They did this through a series of investigations, research, and calculations.

The module required the students to use the Internet to research issues such as gravity on different planets, its impact on their space race, and distances to each planet from the Earth. The information about the different planets was used to make calculations and draw graphs. Over years of developing this sort of research-based project, Mrs Putten found that the students became bogged down with the calculations and graphs and were distracted from the main project focus. In the past, they spent a great deal of time drawing lines and measuring distances. To overcome this, her students used the calculation and graphing functions of the computer programme to generate data and plot the graphs with variables input by the students. Finally, they presented their findings and answered the investigation question: *Which planet is the best planet to have the Space Olympics on*? using presentation software.

Mrs Putten showed a good understanding of strategies for learning with technology and recognized that in some instances, inappropriate uses of technology can hinder learning. This is a finding similar to that of Bransford, Brown, & Cocking (2000). Mrs Putten's view was that if students spent most of their time picking fonts and colours for their presentations, they would waste valuable learning time that could be spent on planning, writing, and revising their ideas. To ensure that her students remained focused on the task and to "*direct them away from silly animations,"* she has developed templates for presentations. In the past, her students were unable to justify their choice of planet sufficiently so she included in her template some guidance: "I force them to list criteria of what a good place would be like, why that is important, and then places that fit the criteria."

In addition to the computer-based project, Mrs Putten had developed a book and CD which accompanied the lessons so that her students could refer to the work on paper. In this way, she made sure that they got the relevant content knowledge in conjunction with the hands-on activities. The CD had hyperlinks which allowed the students to access documents and other information related to the project from a main page. Through project-based learning, Mrs Putten's reported improved student skills such as researching and presenting information. They learnt how to use spreadsheets and presentation software packages, and strategies for linking information through hyperlinks. Mrs Putten also developed “lecture-style” lessons using open-source downloadable software which allowed her to take digital photographs and turn them into a video by adding interesting transitions. She also developed videos of lessons using screen-capture technology.

Mrs Putten found simulation software to be a powerful teaching and learning tool, especially for practical investigations not possible to witness in the school laboratory. One example Mrs Putten showed me was her use of computer simulations when teaching chemical reactions and factors which affect the rates of the reactions. Using the simulation software, her students were able to alter the concentrations of reactants, and see the changes in the rate of the reaction displayed on the monitor. She showed me how she used simulation software to teach physics concepts such as friction. When students manipulated figures to represent a change in the friction of a surface, the programme showed how the movement of an object changed as the forces on an object moving across the surface changed. In the photograph below (Figure 6.6), the student was able to predict what would happen to an object’s movement if conditions of friction changed, then use the simulation software to make those changes, finally watch the movement of the object when the simulation was run to check if her prediction was correct. This is in line with the principles a teaching strategy known as Predict, Observe, and Explain (POE) commonly used in science lessons.

Figure 6.6: Student using simulation software at Mrs Putten's school

Simulations were very useful but Mrs Putten was often not able to use them with her classes as the slow Internet connection would not allow for online manipulation of variables. To overcome this, she used open-source screen capture software to capture photographs of different parts of the simulations, added a voice-over to explain what was happening, and then presented these to the students. These sorts of lessons were watched frequently by students after classes as revision lessons. This use of screen capture software was one example where Mrs Putten overcame obstacles that prevented her from implementing ICT in the way that she would have liked to. Her innovative solutions show behaviour in line with that of personal entrepreneurship, teacher characteristics discussed in section 8.5.

The third teacher, Mrs Marley, was at a school which had a computer room funded and managed by private sponsorship as part of the public-private partnership arrangement at the school. It had 40 desktop computers positioned in rows and a teacher's desk with the main computer, a printer, and data-projector connected to the teacher's computer. The computer room had an Internet connection which allowed each computer to access the WWW (Figure 6.7).

Figure 6.7: Computer room at Mrs Marley's school

There was an IWB at the front of the classroom (Figure 6.8). Mrs Marley, together with the CAT teacher at the school, had given a presentation showcasing their use of ICT at a similar provincial competition as in the case of Mr Sogo. Their use of ICT and presentation was rewarded with a prize of the interactive whiteboard. During my time at the school, the interactive whiteboard was never connected but was instead used as a data projector screen.

Figure 6.8: IWB in the computer room at Mrs Marley's school

The subject areas of Science and Mathematics at the school were supported by a microchip manufacturer that had provided software and technical support for proprietary curriculum-based educational software. That proprietary software was the basis for use of the computers in the subjects, Mathematics and Science. According to Mrs Marley, that software was a fundamental part of her teaching resources and it formed the major part of her ICT use with her science students. The software had subject content and learning activities addressing most of the Mathematics and Natural Sciences curricula. The science teacher had been trained in the use of the software by a company representative. While much of the curriculum was covered, Mrs Putten was anticipating the parts not covered to be updated when they became available. In addition, the computers were loaded with a proprietary encyclopaedia which allowed Mrs Marley to research information for topics to be covered as part of the learning programme. The third and final application she used was a widely used Internet search engine which she used as a research tool to get information on different sections not covered by the other programmes. As in the cases of the other two teachers, Mrs Marley had her own personal computer at home, and used her home or school Internet connection to access and download information. She had a laptop computer and a cellular phone.

6.2 Scheduled learning time and use of ICT

Even in cases where teachers have access to few technology resources, as in the three cases discussed in the previous section, some teachers are able to use those resources in ways that extend the curriculum with their learners. In addition to finding out what technology infrastructure they had available to teachers, it was important to find out from teachers how they used their time and whether they were able to use ICT in that time. The mean scores on the 4-point Likert scale for scheduled learning time have been re-coded and converted to a score out of 100 (as discussed in section 4.4.5). This allows a comparison of the mean score for how the scheduled learning time is used and the use of ICT reported as a percentage during that scheduled learning time.

When the data was collected from the sampled South African science teachers asking them to indicate how often they used 13 possible teaching and learning activities, the highest response was for *short-task projects*. Responses are shown in Table 6.2 (Appendices E, F, and I).

Table 6.2: Scheduled learning time and ICT use

	In your teaching of the target class in this school year, (a) How often is the scheduled learning time used for the following activities? (b) Do you use ICT?	Often OR Nearly Always (%)	Mean Score %* (SE)	% using ICT (SE)
A	Extended projects (2 weeks or longer)	31	40 (1.95)	15 (2.12)
B	Short-task projects	62	58 (2.09)	15 (1.94)
C	Product creation (e.g. making a model or a report)	34	42 (2.04)	14 (2.03)
D	Self-accessed courses and/or learning activities	46	47 (1.97)	9 (1.67)
E	Scientific investigations (open-ended)	47	48 (2.01)	16 (2.17)
F	Field study activities	25	34 (1.74)	11 (1.94)
G	Teacher's lectures	58	58 (2.09)	17 (2.32)
H	Exercises to practice skills and procedures	60	58 (2.00)	5 (2.27)
I	Lab experiments with clear instructions and well-defined outcomes	32	36 (2.06)	10 (1.59)
J	Discovering mathematics principles and concepts	46	49 (2.01)	9 (1.71)
K	Studying natural phenomena through simulations	46	46 (2.03)	14 (1.96)
L	Looking up ideas and information	61	58 (2.24)	21 (2.24)
M	Processing and analyzing data	52	51 (2.23)	18 (2.45)

* This conversion was made so that the mean score could be compared to the percentage of ICT use.

Some 62% of South African science teachers responded that they often or nearly always spent their lesson time for *short term projects*. There was also a high response to using class time for *looking up ideas and information* (62%), and for *lecturing* (58%). This response confirms the high teacher response to *present information/demonstrations and/or give class instructions* indicative of the traditional pedagogical orientation of South African science teachers. Only a small number of teachers (25%) reported that they spent a lot of their teaching time outside the classroom on *field trips,* and *lab experiments with clear instructions and well-defined outcomes* (32%). The low response to *conduct laboratory experiments with clear instructions and well-defined outcomes* was expected as access to stocked and functioning science laboratories in South African schools is limited. In instances where schools have science laboratories, teachers often lack sufficient training and confidence to conduct practical investigations with their students.

The responses have been ranked from the highest ICT use to the lowest as a way of better understanding what teachers use ICT for when they are able to use it. The three highest and three lowest responses for ICT-use in the scheduled learning time are plotted on a graph (Figure 6.9).

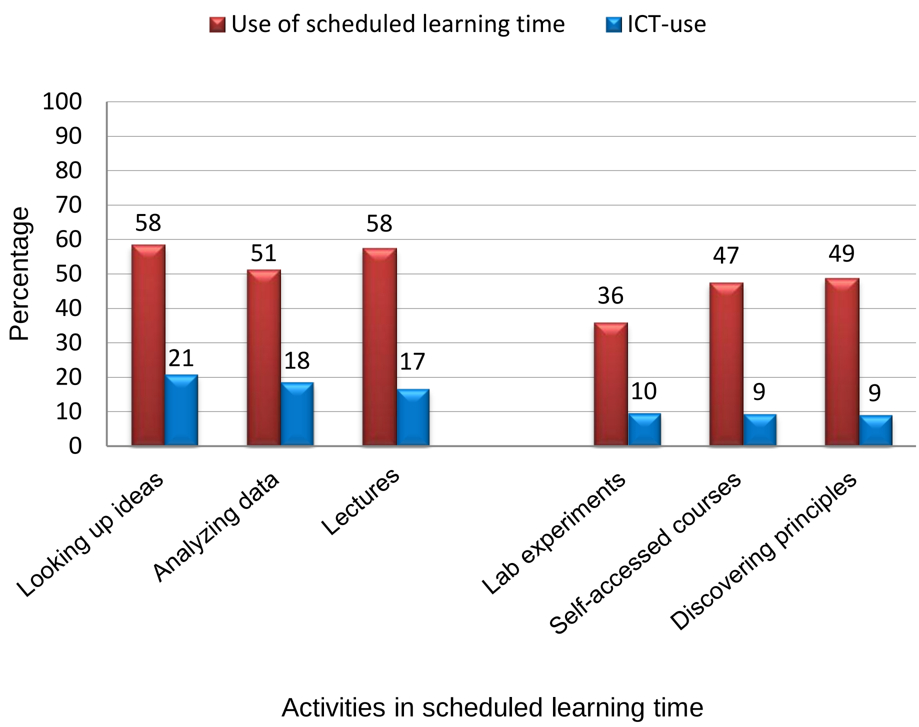

Figure 6.9: Three highest and three lowest South African teacher scores for use of scheduled learning time and ICT-use in that time

Only 21% of teachers were able to use ICT for looking up ideas and information, and less than 10% of science teachers responded that they used ICT for *self-accessed courses and/or learning activities*, for *laboratory experiments with clear instructions and well-defined outcomes*, and *discovering mathematics principles and concepts*.

When exploring the scheduled use of ICT with the three teachers, it was difficult to obtain detailed schedules of their specific ICT practices for an entire year. It was, however, possible to get an overview of their ICT-using practice from short, in-depth visits to the schools. The snap-shot of teaching and learning activities obtained during the time spent observing each teacher were enhanced through the interviews, which helped me to understand how they each used ICT when teaching Science.

In the times that I spent with Mr Sogo and through the interviews I had with him, I was able to gain some insight into how he spent his teaching time with his class. Mr Sogo spent a lot of his teaching time "teaching" his students where "teaching" indicates a teacher-centred, lecture-dominated delivery of subject content knowledge. Since the first uses of ICT in education, it has offered opportunities for students to control their own learning. ICT can provide students with greater flexibility in terms of learning time, location, and pace of content delivery. At the level of the classroom, this involves students having access to computers beyond the scheduled learning times to practice skills such as writing chemical formulae, balancing chemical equations and such drill-and-practice exercises. This aspect of self-regulated learning was a strong feature of Mrs Putten's teaching. Mr Sogo, on the other hand, tended to stay in control of the learning environment, leaving little room for student initiative. While Mr Sogo described his teaching style as "learner-centred," his use of PowerPoint presentations to deliver the curriculum content suggested otherwise.

To deliver this content knowledge, Mr Sogo developed PowerPoint presentations covering the subject content and then used the presentations in a lecture-style format. His chalkboard in the class had been covered by an ordinary whiteboard (not interactive) which he used as his projector board on a permanent basis. He did allow for interactions with his students and encouraged them to ask questions throughout the lesson. He addressed questions to the students but stayed focused on the lesson content and was guided by his presentation. His teaching style of talking, asking questions of the students to see if they understood the work, and answering questions that the students may have on the topic was what he understood as "learner-centred".

The classroom in which he taught appeared to be a science laboratory but the limited equipment that was in his classroom was broken, as were some of the desks and chairs. The science laboratory had been converted into a classroom and science practical work was not a significant part of his teaching strategy repertoire.

Figure 6.10: Unused ammeter boxes in laboratory store room at Mr Sogo's school

Figure 6.11: Unused equipment in laboratory store room at Mr Sogo's school

When asked why he did not use the science laboratory for practical work he replied "*Yes, we do have a science laboratory but it is empty [laughs].*" When I asked about the equipment and chemicals in the store room (Figure 6.10 and Figure 6.11), he responded "*We do have a few chemicals, just to show students the reaction of chemicals*". This response is typical of many science teachers in South Africa. A recent study of 18 schools in Gauteng Province found that science teachers in some of those schools also reported having no equipment for science practical work, despite the school having a well-stocked laboratory. The reasons for this sort of response from Mr Sogo are complex. One possible interpretation could be that the unopened and unused equipment is indicative of a lack of skills or confidence to perform practical work. This sensitive issue was not explored further with Mr Sogo as firstly, his use of science practical equipment was not the focus of my study, and secondly, I was aware that I had been invited into his classroom. To maintain a good relationship with Mr Sogo, I did not want to ask him questions which may have made him feel uncomfortable or threatened in any way.

Mrs Putten had a large repertoire of teaching strategies, for most of which she used and integrated ICT. Short and long-term projects featured strongly with her project-based learning style. Here is one of our discussions about how Mrs Putten's students spent their class time during a short-term project.

> What they have to do is they have to plan a diet. The diet must be balanced, they have to show that it is, and it has to be under a certain amount, financially [reasonable]. They've got to work that out. But then to get the syllabus [content] across, they've also got to learn about the digestive system. So that is pointing on the liver [showing me a picture of the liver on the screen] and you've got to write [type] there that the organs name is liver. It [feedback from the computer] tells you if you are right or wrong. [She had learnt the hyper-linking at a course she had attended] This is using comments [showing me another part of the programme]. They have to write [type] notes about the oesophagus. Then they save it on the network [intranet] and I go and access it. So you can navigate through the whole thing [using hyperlinks]. They have to write notes about the digestive system and answer questions which they get feedback for. Then we get to this thing ... they have to design this diet. So they write what food type it is and how much each one is going to eat and then they look on the label how much protein [it contains]. Now this then will work out automatically. And there is a comment, if they don't know what it is, then it [the name] pops up like that. There are equations in here [referring to the spreadsheet]. Then from that they can see if it's [the diet] balanced or not, and it also draws a graph. It gets the percentages and then it [the spreadsheet software] draws a graph for you. From that they've got to decide if it's balanced or not. So what they do is they manipulate their diet, "No we've got to give them more of this and less of that" in order to get it balanced. I allowed them to discuss with one another, to help one another, but each one had to do it individually. Some are faster, there's a big range of ability and speed with the computer and so on, so I then also had this

> extension thing where they have to put their thing-a-ma-jiggy [foodstuff] and then also the price, the cost, and the total cost. Now here there are no formulae so they have to calculate it. What I found they would do is that they go to the previous one and they look at the formulae, how I worked it out, how these calculations work and that way they also learn how to work in excel. So actually I found that almost all of the children, although it's an extension, almost everyone did it because then they helped one another. Then at the end there's the rubric that I mark on. This also has a hard copy book as well, all about food (extract from an interview with Mrs Putten).

She encouraged frequent use of presentations by students as a way of getting them to report on their research and investigation work. Scientific investigations also featured as dominant in the scheduled learning time for her students. Mrs Putten was a keen advocate of using scientific investigations in science and had written an activity-based book on investigations in the curriculum which she had published and sold to other teachers. Mrs Putten's school had recently upgraded the science laboratory and it was reasonably well stocked, thus allowing her students to do the prescribed practical work specified in the science curriculum. Typically, the outcomes were well defined by Mrs Putten and given her highly organised project-based and learner-centred teaching style, I was intrigued by her answer to the most obvious question: so do you ever just teach?

> ... sometimes I've wondered, spending so much time on project-based learning, and especially with ICT and whether they actually learn as much content as they should. Sometimes I think that I should rather just *teach* them straight. I don't know. But that's why in FET, I do basically just teach them all the time. Not only, but I do a lot of just lecturing there, but then they use the computer more for just reinforcement (extract from interview with Mrs Putten).

Mrs Marley, like Mr Sogo, had a more teacher-centred approach to teaching. She relied on access to the computer room to use any ICT in her teaching, so her traditional teaching practice was supplemented with the use of technology. When she was able to plan ICT use in scheduled learning time, she worked with the students on the curriculum-driven software. For this sort of work, she moderated the activities, guided students by telling them what to click on next, and made sure that they remained focused on the task. Her position in the class was very authoritarian and she kept very firm control of what the students did throughout the lesson. Her students were also expected to use the available technology to look up ideas and information and present the findings in the form of a report. These reports were typed and submitted for assessment purposes. She had high expectations of quality assignments and was extremely proud of the products created by her students using the computer. She too spoke about the short-term projects that her students did.

> … we were doing fossils. Most unfortunately we don't have that in the *Learn Things* Programme. But then we took them out to Sterkfontein caves. They were studying archaeopteryx. It was a research project so they came here [computer lab] to do that research, and to get pictures and all that.... They do their researches so good … most of their work is typed (extract from interview with Mrs Marley).

> … like this one [showing example of student work], they were doing HIV and AIDS, they go in there [computer room], some of them even type it, you know.... when I say for example, medication, ARV's and all that, they know, even the dosages. I'll also do the research. There is no way that a student can come and say, "Yes, you take one, AZT". They have to give the proper doses, you know. So that after writing this research, they know everything about HIV and AIDS, the side effects and everything and. [They get the information] from the Internet, magazines. I give them two weeks to complete this. [Shows me a file] ...even the graphs were typed. We were doing the skeleton and they have to get students [classmates], take their measurements, to see if their schoolbags are very heavy for their backs, you know. What effects does it have, how can a parent see if their children are carrying heavy schoolbags. The Grade 8s, Grade 9s, how many Grade 8s feel comfortable and all that (extract from interview with Mrs Marley).

The SITES 2006 data suggested that scheduled learning time was spent lecturing to their students, giving them exercised to practice skills and procedures (worksheets), and looking up information, but ICT use for these activities was low. When the scheduled learning time of the three teachers was explored, a similar pattern was found in the cases of Mr Sogo and Mrs Marley. Mrs Putten showed evidence of high use of ICT for science investigations, and studying phenomena using simulations, two activities not well represented in the SITES 2006 data. The relatively high percentage reported for ICT use for lectures (17%) can possibly be explained through

Mr Sogo's use of ICT as presentations. His use of the laptop and data-projector offered his students a teaching experience very similar to that if an overhead projector or traditional chalk-board had been used.

6.3 ICT and assessment

Assessment is an integral part of teaching and learning in the South African curriculum. The National goals for assessment with ICT outlined in the e-Education Policy are to provide teachers and students with immediate feedback on their learning, identify areas of weakness and design necessary and appropriate support systems, and to increase the administration of assessment (DoE, 2004b, p. 20). The policy document is not specific about the sorts of ICT-based assessment methods to be used by teachers. The SITES 2006 teacher data was used to understand the extent to which a variety of assessment methods are used in science education.

As with the teaching strategies, the questionnaire data collected allows the different methods of assessment to be categorised into three orientations: ***traditionally important*** assessments (written tests/examinations, written tasks/exercises); ***products*** (Individual oral presentation, Group presentation, Project report and/or (multimedia) product); and ***reflection or collaboration*** (Students' peer evaluations, Portfolio/learning log, Assessment of group performance on collaborative tasks) (Law et al., 2008). In order to ascertain the assessment orientations of the South African science teachers, they were asked to respond to question 15 on the teacher questionnaire: In your teaching of the target class in this school year: (a) Do you use the following methods of assessing student performance? (b) Do you use ICT to carry out these assessments? Teachers were asked to respond "yes" or "no" to each of those questions (Figure 6.12). The responses have been plotted on the graph below showing the types of assessment methods used by the sampled South African science teachers (red bar Figure 6.12) and their use of ICT for those methods of assessment (blue bar Figure 6.12).

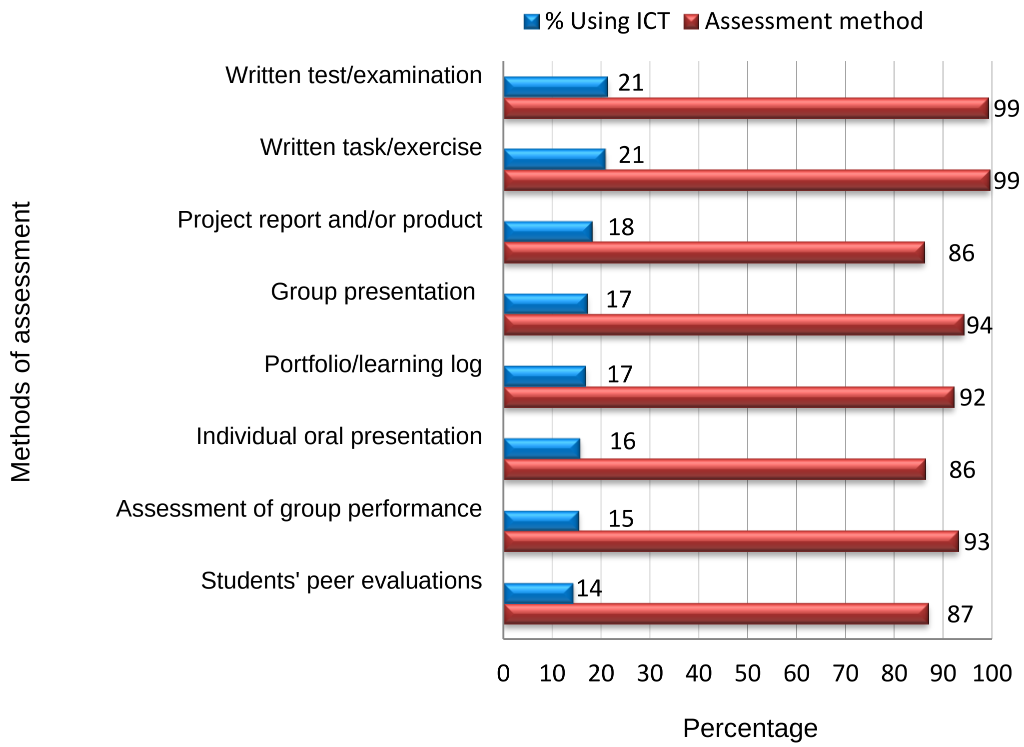

Figure 6.12: South African science teachers' assessment strategies and ICT-use

The most used methods of assessing students were *written tasks or exercises* and written tests or examinations, both being reported by nearly 100% of teachers. ICT use in these activities was low in all, with the highest ICT use of just over 21% being reported for written tests or examinations. Not unsurprisingly, the traditionally important assessments were used by nearly all South African science teachers. Perhaps less expected is the high reported use of other forms of assessment by South African science teachers such as group presentations (just over 94%), portfolios (just over 92%), and the assessment of a group performance on collaborative tasks (just over 93%). Perhaps this is an indication of the assessment strategies of the NCS (DoE, 2002a) filtering into schools.

The three individual cases allowed more insight into how South African science teachers use ICT for assessment. All three of the science teachers in the case studies used ICT for assessment with their students and this categorisation was valuable in understanding how each of the three teachers used ICT for assessment. Mr Sogo had a strong traditionally important orientation and while his students did not have access to computers at the time of the study, he was learning how to use a freely available programme which allowed teachers to set up simple multiple choice questions for the different sections of work. The teacher could use the programme and set up all the questions with possible responses. Mr Sogo anticipated that once he had the necessary knowledge about the programme and once his students had access to the computers in the computer room, he would find such an assessment strategy very useful for his students. Mrs Marley had a functioning computer room and her students had access to the propriety software loaded on the computers. The software was designed for interactive use and at the end of each section of work there was a short multiple choice test which allowed students instant feedback on what they knew about the content. While Mrs Marley found this use of the computer valuable, it remained informal as there was no way of printing out the computer-based tests for marking and filing. In addition, the programme was set up to give instant feedback for self-assessment. Both Mr Sogo and Mrs Marley used ICT to replace conventional testing in a way that did not change the assessment criteria in any way. They were able to assess learning using ICT and not assess learning with ICT.

Mrs Putten had the most sophisticated use of ICT for assessment as she was able to design her own assessment tools using software such as Microsoft Excel and PowerPoint. Her advanced level of technical skills with the computer allowed her to use ICT for assessment for all the examples suggested in the SITES 2006 Teacher questionnaire (traditional use, generating products, and reflection or collaboration). Mrs Putten did use simple drill and practice assessment with her students, simply replacing traditional assessment with the use of a computer but was also able to use ICT to assess aspects of learning that would not have been possible without the use of technology, such as that described below

> [using a camera and Photostory for assessment] What they do is, they have to plan, so it's also trying to teach them self-direction. I give them a Photostat of a recipe of an experiment. Then they have to plan exactly what they need and where they're going to get it, and they must make sense of it and know how they are going to go about it. They work in pairs.

.... Then they give that in to me, and they say what they already know about the topic and what they need to know in order to be able to explain it fully. Then I mark that section and give them a list of what topics they need to research because otherwise they end up just floating. At the moment... they're on the Internet and in the library and on Encarta... so that they'll understand why the experiment results are as they are. Then on Friday, we are going to go to the [science] lab, and I'm going to bring my digital camera, and they have to bring all that apparatus. I mark them also, while they are doing it, did they bring all the apparatus, did they plan, were they prepared to be able to do it? Then they actually set it up and I photograph it as they do it. They tell me "I want a photograph now", and so on. Then I put it on the intranet and they can take their pictures. Then they put it in Photostory... it's very easy to make movies with, you take still images, then you can add text, you can speak to it, you can put music on, you can bring about transitions and so on, so then they make a movie of that. So it's like a teaching video saying what happened in their experiment and why it happens. Last year, I compressed it so that it can go on a phone so I don't know if you are going to see it very well. I've got a section where they assess one another on their final movie, so then I gave each of them a few movies they have to watch and then they have to tick that. Then I took the average for each child, it's quite complicated... so this is the part that I assess, whether they can plan the apparatus, say what they know at the beginning and what questions need answering, what resources they should use and then how they process the information, they've got to select the information, the key words, then make it into a mind map and then re-write in their own words (extract from interview with Mrs Putten).

Teacher guided peer assessment also featured in Mrs Putten's teaching strategy as can be seen from the extract below

... this part, if they want they can do it on the computer but mostly I found them just doing that on paper. ... but then here we start with the ICT stuff, while they're working on the production, I look at how they do it and then this here is the presentation itself [shows me an example of a presentation]. So I don't really give marks for whether it's flashy or whatever but rather the content of how they speak [present]. But when they speak, their assessment of one another will be affected by flashy things because they have got to say whether it is interesting, and I suppose it's more likely to be interesting if it is flashy, maybe. So it does come in a bit in their peer assessment. But generally I tend to downplay appearance and look at the content (extract from interview with Mrs Putten).

Mrs Putten understood what aspects of the assessment using ICT were simply replacing traditional methods and what aspects enhanced her assessment strategies.

6.4 Discussion

The quantitative data from the SITES 2006 survey and the qualitative data from the case studies were integrated to address themes around teachers' use of ICT in Science. The combined data provides evidence of the limited extent to which South African science teachers in general are able to effectively incorporate 21st century pedagogical practices in their teaching. The observed teacher practice together with the teacher responses on the SITES 2006 Teacher Questionnaire provided evidence that the sampled South African science teachers showed a predominantly traditionally orientation in their teaching practice. Even when they were able to adopt ICT in their practice, their ICT-using pedagogical orientation remained predominantly traditional.

A very small percentage of science teachers in South Africa have access to technology infrastructure, and even when they do, their use of that technology is limited. Only one of the three teachers in the case studies was able to use a full repertoire of technologies and use them in a way that added to and extended learning beyond the requirements of the curriculum. Her students experienced a level of integration of ICT into their learning which provided opportunities for learning that would not have been possible without access to ICT. For the other two teachers, the use of ICT remained at a level of supplementing the curriculum.

Each of the three teachers highlights different levels of availability of technology resources combined with varying level of expertise in the use of those resources. Mr Sogo had access to the most basic level of technology resources (laptop, data-projector, digital camera, electronic dictionary), but his students did not have access to a functioning computer room and were not able to use the computers themselves. However, they were exposed to teaching using ICT and the teacher's use supplemented the curriculum. Mrs Marley also had access to a limited number of resources (laptop, and data-projector) but a functioning computer room for students with curriculum-supporting software allowed her students to use ICT for learning.

Mrs Marley used ICT to supplement, enrich, and reinforce the existing curriculum. Mrs Putten used her personal experience and interest in computer technology to capitalize on the potential of technology to take students beyond the curriculum through her use of ICT in her project-based learning activities. Her use can be described as sophisticated and innovative.

The very low use of web-based learning environments, data-logging tools, and multi-media production tools reported by the teachers in the SITES 2006 study (Table 6.1) supports what was observed with the three teachers. The surprisingly low use of a General Office Suite (word-processing, spreadsheet, presentation software) was, however not a finding that was supported by the three cases as all three teachers were proficient at these applications. Even Mr Sogo, the teacher who showed the simplest level of ICT use reported using a word-processing and presentation package. Like most other science teachers in South Africa, none of the three teachers in the case studies had access to data-logging tools or an IWB (Mrs Marley had an IWB which was not connected). Only Mrs Putten was able to use simulation software in her teaching and only Mr Sogo had access to and used a digital dictionary.

South African science teachers generally used a wide variety of assessment strategies in their teaching, and this is testimony to the success of a new assessment policy which has a component of continuous assessment. This was evident in the three individual teachers as well as the teacher population in general. However, there was very little evidence of use of ICT for those assessment strategies. To the extent that teachers were able to use ICT for assessment, drill and practice and self-assessment dominated. Lack of technical support and connectivity problems prevented even the most sophisticated ICT user of the three teachers from using ICT for assessment in any significant way.

South African science teachers' use of ICT compared to other science teachers internationally

The SITES-M2 framework was developed by looking at teacher ICT practice in the 174 innovative uses of to identify seven patterns of ICT use (section 3.1.1).While the cluster analysis in the SITES-M2 study created distinction among groups of cases, there was a great deal of commonality among them. The major finding of the SITES-M2 study was that in a large majority of cases in all countries in the study, teachers engaged in a common set of innovative pedagogical practices (bearing in mind that these pedagogical practice were reported in classrooms in which access to technology resources was not limited). In almost all the cases, the teachers acted as student advisors, created structure for student activities, and monitored and assessed progress, rather than adopting the traditional role of knowledge provider. In many of the cases, the ICT-supported practices allowed students to work with each other on collaborative projects which cut across subject areas, and allowed teachers in the same school to collaborate with each other. There were, however, few cases in which teachers and students collaborated with others outside the classroom and very few examples of innovative ICT use involved teachers or students collaborating with scientists, professors or business people (Kozma, 2003). The findings reported in the SITES-M2 study provided an interesting point of comparison between those cases and the three explored in this study. From the three teachers observed in this study, there was no evidence of their collaborating with other teachers, even in the same school and each of the three cases acted as isolated users of ICT in their schools. Only one of the three teachers in this study (Mrs Putten) acted in a less traditional teacher-centred role, and acted more as a facilitator of learning.

Table 6.3 Three case study teachers' patterns of ICT use

Pattern	Characteristics	Mr Sogo	Mrs Putten	Mrs Marley
Tool use	A strong emphasis on the extensive use of technology tools, such as e-mail and productivity tools, to communicate, to search for information and to create products. These tools include word processing.	√	√	√
Student Collaborative research	These cases were characterized by students working collaboratively in pairs or groups to conduct research, less frequently to collect and analyse data. Information and communication technologies were used to conduct research or create a presentation on the group's ideas or their solution to a problem.		√	
Information Management	The primary use of information and communication technologies in this cluster was for the purposes of searching for – organizing, managing and using – information for teaching and learning purposes. Some use of productivity tools was apparent, particularly for the purposes of presenting information gleaned from information searches.	√	√	
Teacher Collaboration	Emphasis on teacher collaboration with both students and other teachers often for the purposes of designing instructional materials or activities.		√	
Outside Communication	Characterized be the tendency for student to make use of communication technologies such as e-mail, the Internet, conferencing software or listservs to work with other students outside of the classroom environment.		√	
Product creation	The primary use of information technology in this cluster was to facilitate the design and creation of digital products using software packages	√	√	√
Tutorial Projects	Characterized by the use of tutorial or drill-and-practice software to allow students to work independently, to receive feedback on their performance and to refine their skills.		√	√

The characteristic of Mr Sogo's ICT use was dominated by Tool Use (Table 6.3) although the use was not considered to be "extensive". Mr Sogo did use productivity tools such as word processing and presentation software packages for Product Creation (Table 6.3) to deliver his lessons. To a limited extent his teaching reflected some level of Information Management as he was able to use the Internet as a research tool to supplement the content knowledge for his lessons. His teaching practice would most likely have been dominated by Tutorial Projects if his computer room had been functioning. Mrs Putten, meanwhile, had an extensive repertoire of ICT use and her teaching included aspects of each of the possible patterns of ICT use identified in the SITES-M2 study. It is not possible to select a single aspect of her ICT use as dominant in her teaching. Mrs Marley, like Mr Sogo, had one dominant pattern of ICT use, Tutorial Projects, which characterised her teaching. Her practice included some level of Tool Use, Information Management, and Product Creation.

One of the most significant findings of the SITES-M2 study was that in less than 20% of the 174 international cases, both the goals and content of the curriculum changed, and ICT added value to these changes (Kozma, 2003). In these cases, the curriculum change was most often related to achieving new goals or offering existing content in a different way. This was only apparent in one of the three cases in this study (Mrs Putten). In the 174 SITES-M2 cases, one of the primary impacts of the innovative use of ICT was the increase in student and teacher ICT skills. In all three of the cases in this study, the teachers were long-time users of ICT and none of them reported that their use of ICT in their science lessons had improved their ICT skills. The students of Mr Sogo were not able to use the computers themselves and Mrs Marley felt that her students were adequately skilled at using ICT. Mrs Putten felt that her students' ICT skills improved during the year as they spent an increasing amount of time using the computer. Her initial frustration at having to teach the students how to manipulate the mouse eased as the year progressed and they spent more time in her science classes.

CHAPTER SEVEN

Why science teachers use ICT in the ways they do

There are a number of factors which influence the ways teachers use ICT and can be used to predict differences between teachers who successfully integrated computer technology from those who do not (Mueller, Woods, Willoughby, Ross, & Specht, 2008). Some of these are extrinsic factors such as access to resources and school environment, while others are intrinsic, such as teachers' personal ICT competence and their attitudes and beliefs to teaching with technology. This chapter explores some of those factors as a way of understanding the reasons that South Africa science teachers use ICT in the ways that they do, providing breadth and depth of understanding in the South African context. As in Chapter 6, this chapter brings together the quantitative and qualitative data collected in this study. An analysis and interpretation of both data-sets is used to answer the second sub-question: *Why do science teachers use ICT in the ways that they do?* The question is answered by bringing both sets of data together, analysing the data, and making interpretations based on the evidence presented in this chapter. A summary of the findings are presented in the final part of this chapter.

7.1 Teachers' ICT competence

A teacher's technical and pedagogical ICT competence is a key factor in whether or not a teacher uses ICT on their practice (Law et al., 2008). This was explored with South African teachers through the questionnaire and the case studies. Science teachers were asked to indicate how they perceived their level of competence in the general and pedagogical use of ICT. The results are presented in Table 7.1 (Appendices E and F).

Table 7.1: Teachers' self-reported Technical and Pedagogical ICT confidence

	To what extent are you confident in accomplishing the following?	Somewhat OR a Lot (%)	Mean Score (SE)
Technical Use of ICT			
A	I can produce a letter using a word-processing program	54	2.67 (0.07)
B	I can e-mail a file (e.g., the notes of a meeting) to a colleague	37	2.16 (0.07)
C	I can take photos and show them on the computer	31	1.96 (0.07)
D	I can file electronic documents in folders and subfolders on the computer	43	2.33 (0.08)
E	I can use a spreadsheet program for budgeting or student administration	40	2.24 (0.08)
F	I can share knowledge and experiences with others in a discussion forum/user group on the Internet	30	1.95 (0.07)
G	I can produce presentations with simple animation functions	27	1.92 (0.07)
H	I can use the Internet for online purchases and payments	25	1.84 (0.07)
Pedagogical Use of ICT			
I	I can prepare lessons that involve the use of ICT by students	28	1.88 (0.06)
J	I know which teaching/learning situations are suitable for ICT use	30	1.93 (0.06)
K	I can find useful curriculum resources on the Internet	34	2.05 (0.07)
L	I can use ICT for monitoring students' progress and evaluating learning outcomes	33	1.97 (0.07)
M	I can use ICT to give effective presentations/explanations	31	1.94 (0.07)
N	I can use ICT for collaboration with others	29	1.90 (0.07)
O	I can install educational software on my computer	29	1.89 (0.07)
P	I can use the Internet (e.g., select suitable websites, user groups/discussion forums) to support student learning	31	1.95 (0.07)

Some 54% of South African science teachers reported that they were somewhat or very confident at word-processing. However, only 28% felt confident in their ability to prepare lessons that involved the use of ICT with their students. When the technical and pedagogical competencies for the South African science teachers are plotted graphically in decreasing order of mean score (Figure 7.1), most of the technical competencies (red) ranked higher than the pedagogical competencies (blue).

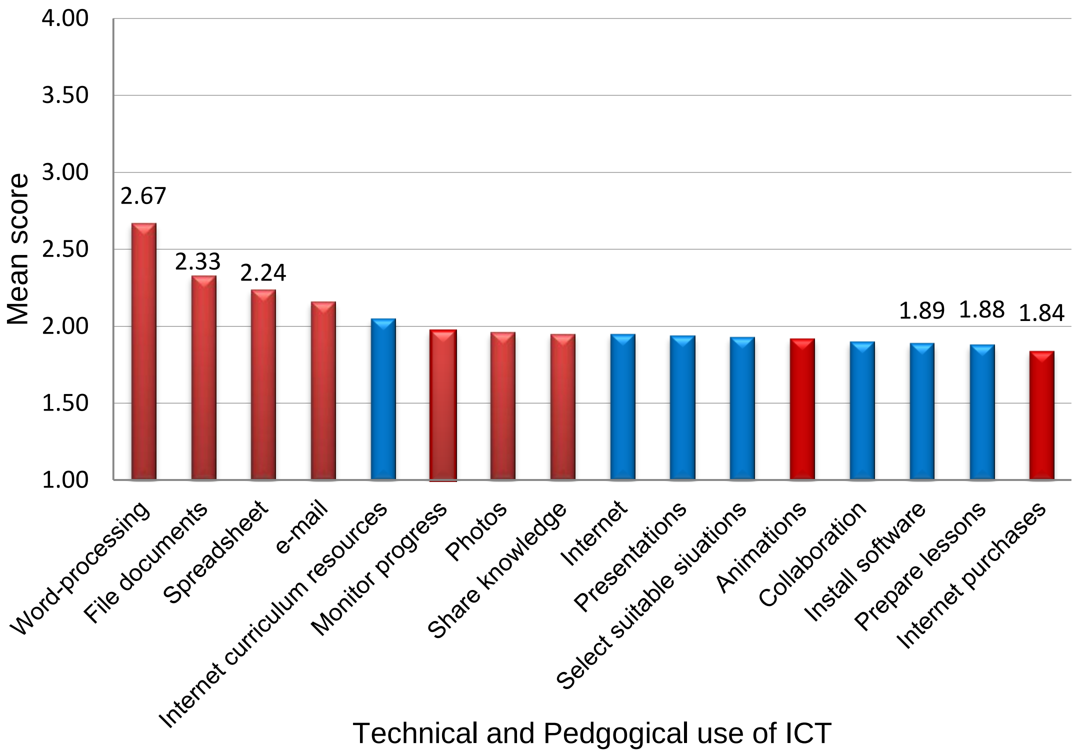

Figure 7.1: South African science teacher mean scores for confidence in technical and pedagogical ICT use

The sampled South African science teachers reported the most confidence in their *word-processing* ability (mean of 2.67), *filing electronic documents* (mean 2.33), and *e-mailing a file* (mean 2.24) and least confident about *using the Internet for preparing lessons that involved the use of ICT with their students* (mean 1.88) and *using the Internet for online purchases and payments* (1.84). The average mean for competence in technical use of ICT (2.14) is higher than the average mean for competence in pedagogical use of ICT (1.94), showing higher competence in skills such as word-processing and the use of spreadsheet and presentation software, than the use of ICT is a way that integrates it into teaching and learning. This was the case in most education systems internationally, with the mean for teachers' self-perceived general ICT competence reported as higher than the respective mean for pedagogical ICT competence (Law et al., 2008).

While great variations existed across different systems internationally, South African science teachers had the second lowest confidence in the technical use of ICT (behind the Russian Federation) and the lowest confidence in pedagogical use of ICT (Law et al., 2008). The systems with the highest reported general ICT competence are not the same as those having the highest reported pedagogical ICT competence, which indicates that higher general ICT competence alone is not sufficient to build up teachers' pedagogical ICT competence.

Technical and pedagogical ICT competence was a theme common to all three teachers in the case studies but each showed competence to varying degrees. All three teachers had produced electronic presentations showcasing their use of ICT with their students. All three had been the recipients (together with others in their schools in the case of Mr Sogo and Mrs Marley) of a reward or prize for their presentations. They all used a spreadsheet to record their students' assessment marks. Mrs Putten, unlike the other two teachers, was competent in online discussions and forum discussions, which were a feature of her daily ICT use. She was also competent in the use of "wikis", websites that allow several users to easily add, edit and remove content in a collaborative way (Cych, 2006). The main learning opportunity of wikis is that "each person shares a part of what they know to construct a whole – in another form of peer-to-peer constructivist learning" (Cych, 2006, p. 35). Although the other two teachers said that they could use wikis, there was no evidence that they used them as part of their teaching. In all three cases I was able to communicate with the teachers, although somewhat erratically with Mr Sogo and Mrs Marley, using e-mail and cellular phone communication.

7.2 Students' ICT competence

Teachers' ability to use ICT effectively with their students depends to some extent on their students' competence with ICT applications. ICT competence of students was very low across all competencies. Teachers were asked to respond to the question: *What proportion of students in your class has competence in the following*? In terms of perceived student ICT competence, the teacher responses are indicated in Figure 7.2 (Appendices E and F).

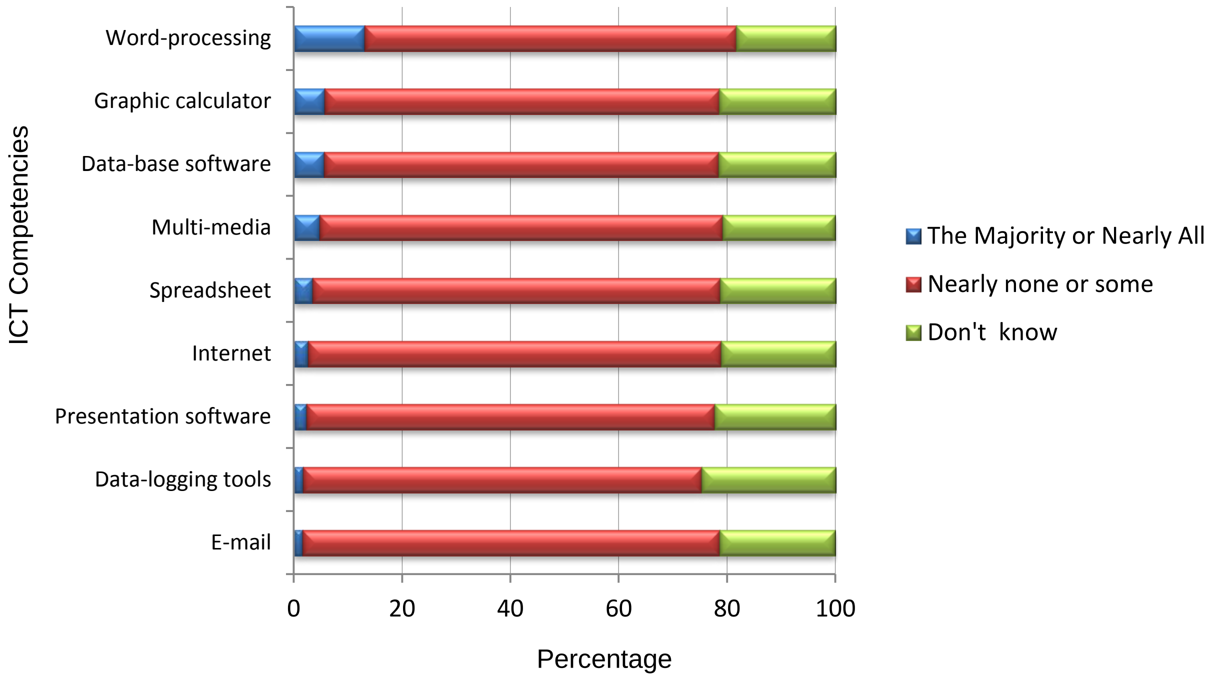

Figure 7.2: South African science teachers' reported level of Student ICT Competence

The graph shows how the teachers reported the ICT competencies of their students, ranked from highest competency to lowest. The most likely ICT competency, word-processing, was ranked as the highest level of student competency, yet only 13% of science teachers reported that the majority or nearly all of their students were competent in word-processing. Data-logging tools, a technology which many South African science teachers do not know, was not surprisingly ranked as lowest with less than 2%. Competency in the use of the Internet was also ranked low with less than 3% of teachers reporting that the majority or nearly all of their students were competent. This low competency is more likely owing to low Internet access, than low Internet ability.

The low ICT use for student activities can perhaps be better understood when combining that data with the data which indicates very low student ICT competence. Even when teachers have access to ICT for tuition, there is a very limited ICT use possibly as a result of very low reported ICT competence. The evidence presented in this study appears to show that low student ICT competence affects to some extent a teacher's ability to successfully integrate ICT into teaching and learning practices.

Despite the Gauteng Online computer room at Mr Sogo's school, his science students did not have an opportunity to use the computers owing to connection problems. It meant that the level of ICT competence of the students at this school was very limited. The school timetable did have a CAT lesson scheduled for the students in Grades 9-12, but during these lesson times, the students filed into the computer room and sat at the computer stations with the computers in plastic (Figure 6.2), effectively making it a "free" lesson. They were supervised by the CAT teacher but no work was done, a situation which had persisted for some time prior to my visit.

The students of Mrs Putten also had varying levels of ICT competence but generally improved over the years spent with her. She raised the issue in an interview:

> When they come to us they can't even use a mouse. So they are very slow. It is incredible how difficult it is to use a mouse [laughing]... the class I've got now, the weaker ones they are very slow. It does definitely limit what you can do (extract from interview with Mrs Putten).

The students of Mrs Marley had frequent access to the computers in the computer room, both as CAT students learning skills such as word processing and presentation skills, and as science students, navigating through the curriculum-based software package that formed the basis for the science lessons.

7.3 Attendance at ICT-related professional development activities

Providing professional development activities to improve teaching practice is a strategy commonly advocated by the DoE. Such activities which focus on teachers' competence and confidence at using ICT in their teaching may need to receive departmental attention as data collected in this study suggests that teachers have very low attendance at ICT-related professional development activities. The SITES 2006 data shows that the professional development activity which had the highest attendance among South African science teachers was *introductory courses for Internet and general ICT applications* (22%). Overall, South Africa reported the lowest attendance (8%) in pedagogical ICT-related and technical ICT-related activities of all the participating systems (Law et al., 2008) (Figure 7.3).

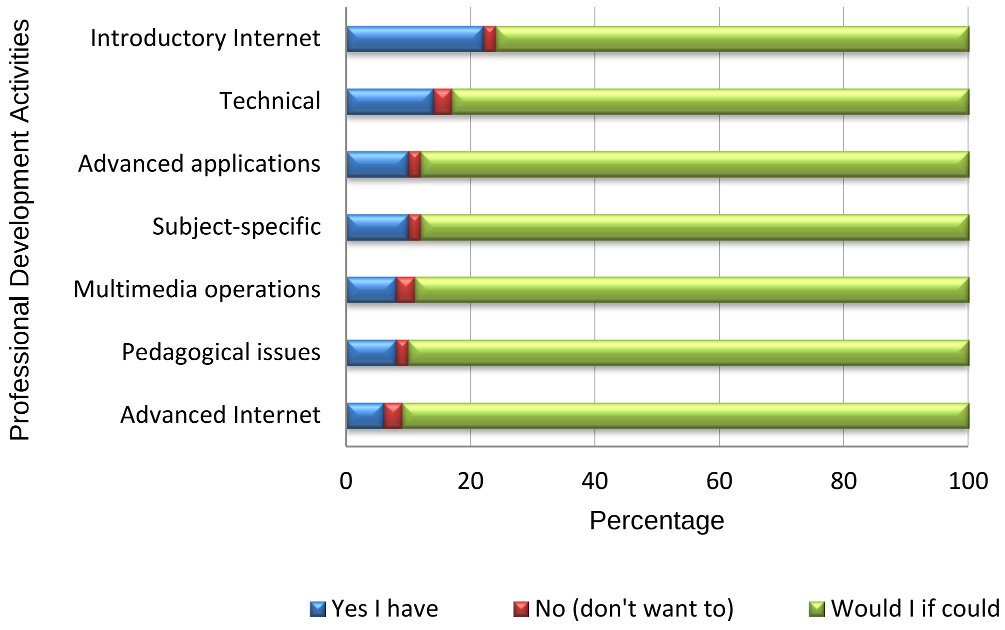

Figure 7.3: Teacher Participation in Professional Development Activities

The desire to participate in these professional development activities was, however, the highest (together with the Russian Federation) of all the participating systems. This suggests that teachers' low attendance at professional development activities was more a consequence of access than of desire.

Attendance at ICT-related professional development activities was a theme that emerged with two of the three teachers in the case studies. Both Mr Sogo and Mrs Putten had been actively involved in a variety of professional development activities. In addition to his teaching diploma, Mr Sogo had taken an additional course in Information Literacy [InfoLit] as well as qualified as a teacher-trainer in IT. The programme was intended to allow teachers like Mr Sogo to teach computer literacy skills to members of the local community. Insufficient funding meant that the programme was no longer financially viable and training at his school had ceased. When describing his level of qualification, Mr Sogo said "*I still have only the diploma … but so many other courses*". When I met Mr Sogo, he had just begun an Advanced

Certificate in Education (ACE) in Educational Computing (2 years part-time). The ACE was funded by the Department of Education.

Mrs Putten had voluntarily participated in a variety of ICT training courses. She had enrolled for a month-long *Intel Teach* course in which she developed her skills in using ICT for project-based learning, and had participated in courses run and sponsored by a computer company in which she trained as an ICT teacher-trainer. She was a frequent participant and presenter at education conferences where she disseminated her personal work as a teacher and shared the lessons she had learnt with other teachers. She was a highly motivated student and teacher in many matters relating to the educational use of ICT, and was strongly influenced in her practice by her attendance at workshops, conferences, and courses. All of the professional development activities she attended had two noteworthy features: they were voluntary; and they had a strong emphasis on pedagogical use of ICT, rather than on technical use. The influence of what she learnt was clearly evident in her teaching practice.

Mrs Marley was less active in the area of professional development. The school had been the recipient of an IWB but during the time I spent at the school, it was not connected or used. The reason for this was that the training that had been scheduled was postponed then cancelled and neither Mrs Marley nor any of the other staff at the school knew how to connect or use the IWB. Instead, it was used as a white data-projector screen. One year after leaving the school I enquired about the board and was told that training had still not occurred and the very expensive piece of technology remained unused because of lack of skills on the part of the teacher and training from the service provider.

7.4 Obstacles to using ICT

Even when teachers recognise the importance of integrating technology into their teaching, successful implementation is often hampered by obstacles, which have been the focus of research for many years (Becta, 2003; Cox, Preston, & Cox, 1999; Jones, 2004). As outlined in section 2.6, a summary of research on this topic conducted by Becta suggests four categories of obstacles: resource-related factors;

factors associated with training, skills, knowledge and computer experience; attitudinal (including beliefs about teaching and learning) and personality factors; institutional and cultural factors (including policy) (Becta, 2003). The teacher responses on the SITES 2006 teacher questionnaire where organized along the same four themes discussed above. Table 7.2 shows the responses to the question about obstacles they experienced to using ICT in their teaching. Twelve were listed and teachers were asked to respond using "yes" or "no" to the list of obstacles. The mean scores were calculated on a 2-point Likert scale (Appendix F).

Table 7.2: Obstacles to ICT use

Category of Obstacles	Specific obstacle included within each category	% Yes (SE)	Mean Score (SE)
Resources	(J) My school lacks digital learning resources	77 (2.51)	1.60 (0.03)
	(L) I do not have access to ICT outside of the school	57 (3.29)	1.57 (0.03)
	(G) Students do not have access to the required ICT tools outside of the school premises	77 (2.72)	1.77 (0.03)
	(B) My school does not have the required ICT infrastructure	66 (2.64)	1.67 (0.03)
Skills and Training	(C) Lack of ICT-related skills	60 (3.17)	1.60 (0.03)
	(D) Lack of ICT-related pedagogical skills	66 (2.86)	1.67 (0.03)
	(I) Unable to identify which ICT tools will be useful	56 (2.87)	1.56 (0.03)
	(F) Students do not possess the required ICT skills	75 (2.76)	1.75 (0.03)
Attitudes and Beliefs	(E) Insufficient confidence to try new approaches alone	40 (3.23)	1.40 (0.03)
	(H) Lack of time to develop and implement ICT-using activities	36 (3.07)	1.36 (0.03)
Institutional	(A) ICT is not considered to be useful in my school	26 (2.60)	1.26 (0.03)
	(K) I do not have the flexibility to make my own decisions when planning lessons with ICT	53 (3.42)	1.53 (0.03)

Not surprisingly, the obstacles that the sampled South African science teachers rated as greatest related to resources and access to ICT. The greatest reported obstacle was a lack of student access to ICT outside of school (77%), a lack of digital resources at school (77%), and a lack of student ICT skills (75%). Figure 7.4 shows how the teachers ranked the issues which they perceived as obstacles to their use of ICT in teaching and learning (Appendices E and F). The three highest scores are shown in red and the three lowest in green.

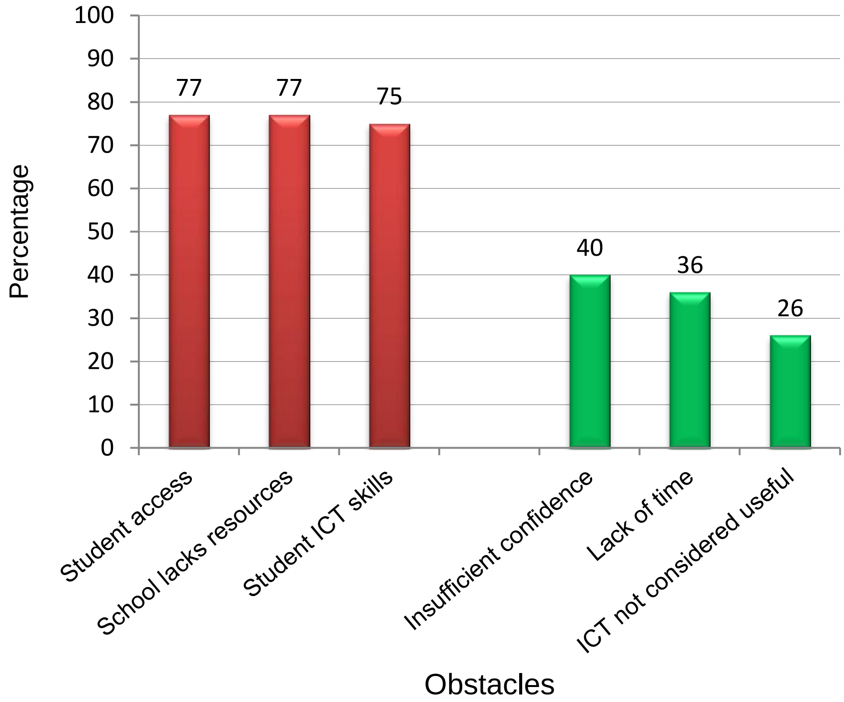

Figure 7.4: Three highest and three lowest teacher-reported obstacles to ICT use

When the mean scores on the 2-point Likert scale of teacher responses to questions about obstacles to their own ICT use are grouped into categories that corresponded to the themes emerging from the case studies, the relative value ascribed to each category can be better understood. The average mean for each category of obstacle is calculated and plotted in decreasing order of response, as shown in Figure 7.5 to show how the teachers rate the significance of the obstacles.

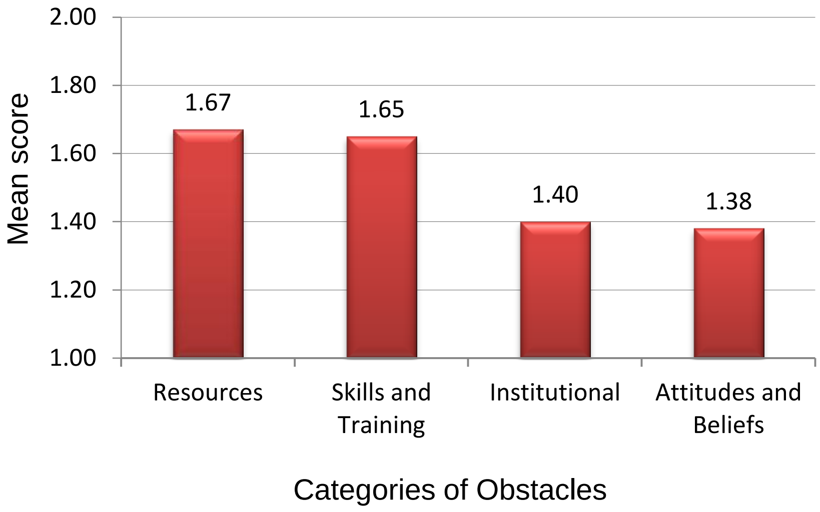

Figure 7.5: Categories of obstacles experiences by South African science teachers in their use of ICT in teaching

On average, South African science teachers rated resource and skills and training obstacles as the most significant. This is most likely owing to the low percentage of South African schools in general with access to ICT for pedagogical use. The science teachers rated obstacles related to their institution as well as obstacles related to their personal attitudes and beliefs as least significant (Figure 7.5). Obstacles related to resources i.e. school infrastructure, availability of digital resources, and access to ICT outside school are all perceived as being very significant obstacles to ICT use by the three South African science teachers in the individual cases as well.

These four themes were explored with the three teachers. Each experienced the obstacles differently and to different degrees.

Resource related obstacles

All three teachers had access to their own ICT resources outside of school, and all had their own laptop computer loaded with word processing, spreadsheet, and presentation software which they used to support their teaching. Mr Sogo did not have access to a computer room and depended entirely on using his laptop and data-projector. Mrs Marley had access to a well-equipped computer room but it was set primarily for CAT, which was scheduled on the time-table. These lessons took priority and if Mrs Marley wanted to use the computer room, she needed to work around the CAT timetable and book the computer room in periods that it was free, which she did in the afternoons after school. Mrs Putten had the most flexibility with the computer room. While it too was available to all teachers, "... well in the case of the [computer] lab, I just by default have it. If other people want it, they book it." All three teachers felt that their schools lacked sufficient technology infrastructure. Mr Sogo said that getting the computers in the computer room connected and functioning would help a lot as the students would then be able to use them. Mrs Putten had everything she needed in terms of resources but still felt that additional resources would be favourable, albeit not a great obstacle to her use of ICT if she did not have them.

> ... it would be nice for the children to be able to write as well. So with the smart board [IWB] they can actually go and plot points or whatever. They can do simulations and adjust things... I suppose... it's more of an interactive feel, especially with the children... I've never worked with a smart board really, but I've just heard that it is nice (extract from interview with Mrs Putten).

While Mrs Marley felt that she had the necessary resources, her greatest frustration (one also felt by Mr Sogo and Mrs Putten) was the lack of a fast and reliable Internet connection. All three teachers were visibly frustrated by the lack of access to the Internet. In the case of Mr Sogo, the collaboration with a partner school in the UK had been terminated owing to the lack of a reliable Internet connection. Mrs Putten felt that she was significantly hampered in getting her students to use "blogs" (web logs on which individual regularly post their opinions) and "wikis" because of the slow and erratic Internet connection.

> ... and there's a teacher [from another school], he was one of them, there were four of them that won the innovative teachers award [*Microsoft*], and there are no barriers because they just do everything because their Internet connection is so fast. So they use blogs, wikis all the time. They use *Google Earth* and stuff that we just can't. But I think that is the way to go (extract from interview with Mrs Putten).

One year after the last visit to the schools, Mr Sogo reported that the Gauteng Online computer room that was "almost complete" when I visited the school was still not functioning. Despite being promised by the e-learning directorate, no progress had been made and it still could not be used for teaching and learning. All three of the teachers used what they had access to, but all three felt that they could do more if they had more resources at their disposal. The evidence from this study suggests that teacher access to a personal computer, either a desktop or laptop computer is a key factor in successful teacher ICT-use.

Training and skills as obstacles

All three of the teachers were skilled at using their available ICT and used PCs for typing notes, recording student marks and researching subject content knowledge on the Web. This was not the case with other teachers in the schools of their three teachers. Mr Sogo attributed the low ICT use of the other teachers in his school to low ICT skills.

> You know I was shocked yesterday. A teacher came to ask me to help her type a letter using 'Word' [word-processing software]. I said, 'don't you know how to use these programmes? You can type your own letter'. Then she said 'no, I can't type, so can you please type for me because when I type I mix small letters and capital letters'. Then I said 'OK, I'll help you' and I showed her (extract from interview with Mr Sogo).

Mrs Putten thought that a certain level of technical expertise was essential for effective ICT use and that a lack of expertise was a barrier to many teachers:

> I dislike paper very much, so I thought this is my opportunity to go electronic. I set up all my files [mark sheets] electronically and I asked the rest [of the teachers] "would you like to also, I'll set up a generic thing for you and then you just have to make alterations". So I spent hours doing that where all they [the teachers] needed to do was just alter something. Everything was hyperlinked as well. All they needed to do was go in there, there was a header, and just type their things [marks]. I made it available on the intranet for everybody. The mark sheets were also set up with the calculations done. Except for a few who are very good with computers, it was a bit of a flop because they [the teachers] don't work with computers every day. So then they don't know where they put this thing. With the marks it was really dreadful because they had to make some adjustments because it was just a generic thing and they had to tailor make it [to their own needs/requirements]. That messed up the calculations, so I don't know... I don't know if really using a computer for admin if you don't

> really know how to use it is a good idea. It seems to me not (extract from interview with Mrs Putten).

This teacher saw the importance of technical skills but had not been successful in convincing the other teachers at the school that technology could assist them in basic administrative tasks:

> … computer-use is optional and dependent on the teacher, and not stipulated by any policy. I must just add that I have been pushing for all teachers - or at least some - to do the *Intel Teach* course, and have offered my services to do the training. I've been making this request over the past two years. The principal is very eager and so are some of the staff members. However, it is just never happening. I think there are three problems: One, teachers just don't have 4 days to set aside for it; two, many of the teachers aren't computer literate enough for it and three, since I'm not some amazing speaker coming from somewhere else for a limited period of time, paid dearly for my services, there's just no urgency about the matter - so it can always be postponed (e-mail communication with Mrs Putten).

Lack of ICT technical expertise proved to be a problem for one teacher in particular. Mrs Marley did not have the technical skills to solve any of the technical difficulties which arose in the computer room. Her frustration lay in the way in which the technical support was organised in the school. The management and technical support for the computers and the computer room had been outsourced. The private company that had funded the computer room took full responsibility for maintaining the computers and other infrastructure. All technical faults were reported to them and the time delay between reporting the fault and getting it fixed proved to be an on-going frustration:

> We cannot get a proper reason for us being offline, because our computers are actually from Oracle and they are the one that is responsible to. They send their technicians here and as a licensed educator, they are not at a level where I can ask them what the problem is. But CAT educators can do that, but still, because if I'm frustrated, obviously I would want to find out from them what the problem is and it seems to me that they actually don't know. It means the guy who services the computer cannot just say to them, this is the problem. You know, he was here last week. He has been servicing these computers from last year December and he was here last

> week. I think there's a bit of a problem. I don't know why, because he cannot actually say what the problem is... he does come and try and fix it, but still it will run for some time and then one day there's no Internet and then when you go there, it shows that you are connected, but then you cannot actually get into the Internet (extract from interview with Mrs Marley).

An exploration of the experiences of the three teachers, and some cases the other teachers at their schools, suggests that even when teachers have a reasonable level of ICT skills, the lack of sufficient technical skills can be an obstacle to ICT use.

Attitudes and beliefs as obstacles

Teacher beliefs are significant determinants in explaining why they adopt computers in the classroom (Hermans, Tondeur, van Braak, & Valcke, 2008). According to Hermans et al. (2008), constructivist teacher beliefs were found to be a strong predictor of classroom use. In some instances, where there are conditions for successful integration of technology, including access to technology, training, and a favourable policy environment, high level technology use remains surprisingly low. In these cases, it may be that additional barriers, specifically related to teachers pedagogical beliefs may affect the level of ICT integration (Ertmer, 2001, 2005; Ertmer, Addison, Lane, Ross, & Woods, 1999). Examining the relationship between teachers' pedagogical beliefs and their technology practices may assist in understanding to some degree why they use ICT in the ways that they do. It is not an area that is well understood and was only explored to a limited extent in this study.

There was a strong belief from Mrs Marley that the computer was a stand-alone tool as a substitute for the teacher, a belief which directly contradicts current research-based thinking about the value of ICT in teaching and learning:

> You know when they use the computer, they work on their own but I give them instructions. I explain wherever necessary because the computer actually does the job. I'm just there to monitor. When they click on the cell, it says "cell wall, made of cellulose, gives shape..." I'm just there to monitor... all the learning comes from the computer programme, so I can actually stand there and not do anything, unless they have got questions (extract from interview with Mrs Marley).

In some instances, teachers' beliefs about classroom technology use did not always match their classroom practices (Ertmer, 2005). Despite all three teachers describing themselves as having teaching philosophies in line with constructivist philosophies, even the teacher who used ICT in the most sophisticated way, used technology that might best be described as representing a mixed approach, at times engaging her students in authentic, project-based work, but at other times asking them to complete tutorials, practice skills, and learn isolated facts. This inconsistency was most noticeable with Mr Sogo, who showcased his e-Learning approach at the school in a presentation entitled "*e-Learning: Learner-centred instead of teacher-centred*", yet described the learner-centred approach as one in which a teacher's job was to make sure that the students understood the work:

> You see in the old education, it wasn't learner-centred because a teacher would take a textbook and read to the students... whether they understand or not, it wasn't his business or her business as a teacher. So it wasn't learner-centred. But with e-Learning, with e-Learning here it's learner-centred... In e-Learning, students are our clients, in fact. Students are our clients so we must make sure that whatever we give to them, they understand fully... [we know they understand fully] by giving them homework, controlling the homework. Giving them feedback. Because those time [old education], they never gave us feedback. We give them [students] feedback. They go through their feedback and see where they went wrong. That is why I said it's learner-centred. It's a learner-centred approach instead of a teacher-centred approach. Those days, eish... you'd be just given a chapter and be told go and read chapter 5. We are writing a test. Teachers would do that. But now we can't do that. [Now] the students who didn't achieve, you would go to them, trying to find out what was the problem. They tell you the problems and then you try to solve the problems, and assist them in achieving (extract from interview with Mr Sogo).

Explanations for these inconsistencies included references to contextual constraints, such as a content-dominated curriculum, or resource constraints such as lack of access to adequate technology. Although all these teachers experienced obstacles to integrating ICT into their teaching, they each responded differently, in part depending on their individual beliefs about what constitutes effective classroom practice.

Institutional and cultural related obstacles

It was clear for all three teachers that the schools in which they taught were very supportive of their use of ICT and to the use of ICT in the school in general. They were able to make their own decisions about the use of ICT for their teaching. With the framework for analysis of ICT policies in education by Kozma (2008) discussed in 2.2, I was particularly interested in the role the school ICT Policy together with National e-Education Policy (DoE, 2004b) played in guiding the teachers' use of ICT in Science.

The school ICT policy of Mrs Marley lacked policy strategic-operational alignment (not aligned with national e-Education policy), horizontal alignment (not aligned with other policies in education system), and vertical alignment (not aligned with provincial e-learning policy), diminishing the likelihood that the policy goals would be achieved. Mrs Marley's school ICT policy lacked detail which might commit the school to meaningful integration of ICT into teaching and learning as specified by the national policy. The policy vision for the school was "*ICT is aimed at all students when they leave the school should be computer or ICT literate. All educators and the school staff benefit from the ICTs"* [extract from school ICT policy document]. Most of the policy detail referred to the use and management of ICT resources, including the strict monitoring of ICT access for inappropriate use. The focus on control dominated the policy. The policy lacked any articulation of ICT-related changes in curriculum, pedagogical practices, and assessment strategies, most likely diminishing its usefulness in actively directing ICT integration into teaching and learning.

The school ICT policy of Mr Sogo's school was quite the contrary and strongly aligned with parts of the national e-Education policy. The policy was guided by a template that the GDE had given the school from which it could write it. This school ICT vision was "*to provide Educators, Students and Members of the community an opportunity to achieve excellence in Academic and Computer skills for future benefit*", which would be achieved by "*promoting the culture of learning and teaching and offering quality and balanced computer skills amongst all stake holders*" [extracts from school ICT policy document]. The school's use of ICT would:

- Promote active and autonomous learning in students;
- Provide students with competencies and technological skills that allow them to search for, organize, and analyse information, and communicate and express their ideas in a variety of media forms;
- Enable teachers, students, and their parents to communicate and share information on-line;
- Engage students in collaborative, project-based learning in which students work with other classmates on complex, extended, real-world-like problems or projects;
- Provide students with individualized or differentiated instruction, customized to meet the needs of students with different achievement levels, interests, or learning styles; and
- Allow teachers and students to assess student and peer academic performance.

Despite the stronger strategic-operational policy alignment, there was an obvious mismatch between the policy and practice at the school as the key element, the Gauteng Online computer room, was not functional and none of the policy goals could be achieved with the ICT set-up which Mr Sogo used.

Policies with too little detail (as in the case of Mrs Marley) do not guide teachers enough in aspects of integration but rather focus on management of ICT resources, and policies with ideals that are too ambitious (as in the case of Mr Sogo) set standards which can never be met. None of the three teachers made any reference to the national e-learning policy in our discussions and none knew the details of the e-learning policy or had a copy on hand. Mrs Putten summed up the general attitude to the school policy for all three teachers. When I asked if her school had a policy on ICT use she replied "*Yes, there is somewhere in one of the files* [laughs]". When asked if her school had developed that policy with reference to the e-Education White Paper she replied "*probably, I don't know* [laughs]". Each of the school ICT policies, while perhaps not an overt obstacle to ICT use in the schools, did not act as the enabler that ICT policy is intended to be.

7.5 The presence of a community of practice (school support)

The presence of a community of practice is often considered to be an important enabling factor in supporting pedagogical innovation and change in schools. The idea underpinning this concept is that teachers work with colleagues in a school context and that the beliefs and practices of teachers are strongly influenced by the cultures and practices of the school within which they operate. Four key aspects were identified in the SITES 2006 study pertaining to the presence of a community of practice for teachers, namely (i) whether there is a shared vision among teachers and the leadership in the school, (ii) whether teachers have opportunities to take part in the decision making of the school, (iii) whether there is the presence of a strong culture for professional collaboration and in the case of ICT implementation, (iv) the availability of technical, administrative and infrastructural support (Law et al., 2008). When these four aspects were explored with South African science teachers, school vision was felt most by the majority of teachers (Appendices E and F).

Table 7.3: Aspects of Community of Practice

Aspects of a community of practice	Specific statements listed	Somewhat OR a lot %	Mean Score (SE)
School vision	Teachers discuss what they want to achieve through their lessons	84	3.37 (0.05)
	Teachers are constantly motivated to critically assess their own educational practices	82	3.33 (0.06)
	Teachers are expected to think about the school vision and strategies with regard to educational practices	87	3.47 (0.05)
Decision making	Teachers can influence the development of the school innovation implementation plans	77	3.09 (0.05)
	When implementing innovations, the school considers teachers' opinions	78	3.15 (0.06)
	Teachers are able to implement innovations in their classrooms according to their own judgment and insights	86	3.38 (0.05)
Professional collaboration	Teacher co-teaches with colleagues	83	3.26 (0.06)
	Teacher discusses problems experienced at work with colleagues	93	3.58 (0.04)
	Teacher works with teachers in other schools on collaborative activities	79	3.19 (0.06)
	Teacher work with teachers in other countries on collaborative activities	13	1.68 (0.07)
Support	Teacher receives sufficient technical support from the school/region/state	30	1.89 (0.06)
	Students can access computers easily outside scheduled class time without the teacher's help	12	1.38 (0.04)
	Administrative work arising from ICT use in teaching is easy to do	18	1.59 (0.06)

The low mean score for *I work with teachers in other countries on collaborative activities* (1.68) is consistent with low mean score for *Liaise with collaborators (within or outside school) for student collaborative activities* (2.47) reported as Teacher Practice and low mean score for *Collaborate with peers from other schools within and/or outside the country* (1.87) reported as Student Practice. These three aspects reported on the teacher questionnaire make for a consistently low connectedness orientation of ICT use in the South African landscape. The four aspects of community of practice are presented on Figure 7.6:

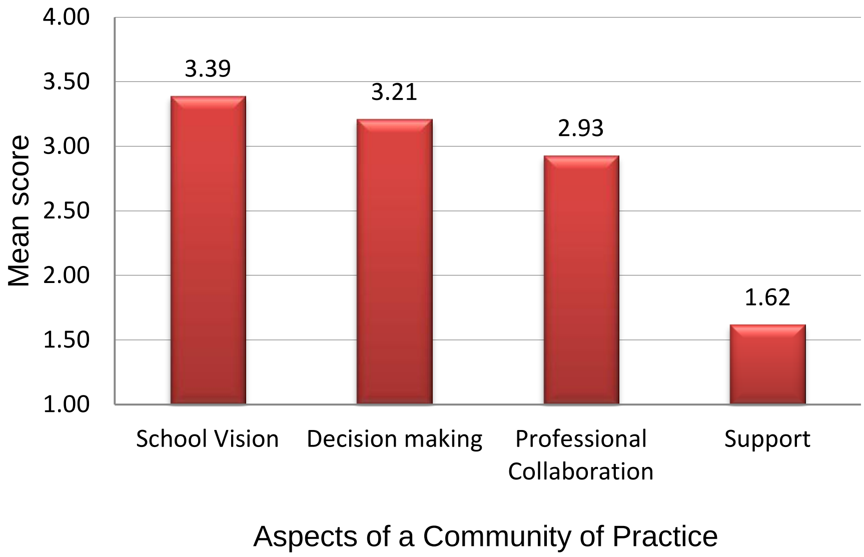

Figure 7.6: Different Aspects of the presence of a community of practice in schools as reported by South African science teachers

Of the four aspects of a community of practice, South African science teachers scored the presence of school vision as highest with an average mean score of 3.39, suggesting that teachers felt as though they were working within a community with a vision that is shared among the teachers (Figure 7.6). The teachers however, felt that there was little support, with an average mean score of 1.62. This perceived lack of support may be a significant contributing factor to the low ICT use by South African science teachers.

These four aspects of a community of practice were explored with each of the three teachers to understand their experiences of each. It was of particular interest that each of the three teachers worked within schools that at one level supported their use of ICT in their teaching practice but on the other hand, left them to practice as isolated islands of ICT use. Other than CAT, in all three cases, these teachers were the sole users of ICT in subject teaching. Mr Sogo had offered the laptop to other teachers but found that the interest waned after a few weeks. The equipment was available for all teachers to use but none took up the offer. Mrs Putten was the only teacher in the school who used the computer room for subject teaching, as was the case for Mrs Marley.

7.6 TPCK of science teachers

The pedagogical use of ICT was the focus of the SITES 2006 study but the concept TPCK was not specifically addressed in the questionnaire. It was, however, a theme which featured strongly in the three case studies as contributing to the reasons that teachers use ICT in the ways that they do. TPCK (section 3.3.2), is the basis of good teaching with technology. Each teacher who uses technology may do so in a different way to achieve different learning objectives (Mishra & Koehler, 2006). Each teacher is different and should develop their own understanding of the relationship between the content they teach, the pedagogy they use to teach, and the technology which supports the teaching appropriate to their students and specific classroom context. Neither Mr Sogo, nor Mrs Marley displayed an understanding of connections, interactions, affordances, and constraints between and among content, pedagogy, and technology sufficient to use it in a way that would add value to their teaching. This claim is supported by teacher comments such as:

> Ay, really I don't know. But it [the computer] does add something. And I can feel it that it does add something. My students, when I use the computer ......they grasp what I am talking about easily. Unlike when I am using the [chalk] board and writing. I just also want to find out, what makes them to understand what makes them understand better when I use the computer, unlike the chalk and the board. My feeling is...I feel they do understand better, when I use the computer and the whiteboard. But I still have to find out ...what makes them ...what is it that is different? I don't what make them... (extract from interview with Mr Sogo).

With a limited understanding of child-centred learning (section 7.4), together with a low TPCK, Mr Sogo was unable to fully integrate ICT into his teaching practice and uses ICT to supplement the existing curriculum. This was similar in the case of Mrs Marley. Mrs Putten, on the other hand, had a much greater knowledge of the research literature on the subject of how to use ICT in education, the value that it added, as well as possible issues which still form part of the current debates in the field of research:

> But what I've also got from reading in preparation for writing that chapter [for a book], is that apparently there is very little evidence that using computers actually improves education, except with higher order thinking, yes, and with collaboration. So they [researchers] say actually sometimes it's better if you don't have enough computers so that people have to share. That's what they [researchers] say. Now I find it difficult to believe that it [using computers] doesn't help with lower order things such as drill. Because I know myself that computers helped a lot with drill (Extract from interview with Mrs Putten).

Judging from the large variety of ways in which Mrs Putten was able to use ICT in teaching Science, she had a high TPCK and was able to use ICT successfully to extend the teaching and learning in her class beyond the current curriculum. Part of Mrs Putten's high TPCK was as a result of her being best being described as a 'Digital Native' (section 2.5.3). The interview with Mrs Putten suggested that she was a "native speaker" of the digital language of computers (Prensky, 2001). This situation provides an interesting scenario as the digital divide between the Digital Natives and Digital Immigrants is usually used to describe the divide between teachers (Immigrants) and students (Natives), not the other way around. Yet the students in Mrs Putten's classes, although from a younger generation than hers, had not grown up immersed in digital technology and were shaped by the predominantly text-based, simpler, predictable, relatively stable, low-tech world in which they grew up. Mrs Putten used technology in her teaching in the way that she does because she is a Digital Native. She had a computer for as "long as I can remember" and had learnt her typing skills on a computer programme written for her by her father.

7.7 Perceived impact of ICT on teaching and learning

In most cases, teachers use ICT because they believe that its use will have an impact on either their ability to teach, or for their students to learn more effectively. The teacher questionnaire was designed to elicit some understanding of how teachers saw the impact of ICT when they were able to use it. Teachers were first asked if they used ICT with their science class for teaching and learning. More than 85% of the sampled South African science teachers answered "no" to this questions. This South African response was the lowest in all 22 systems participating in the survey (Law et al., 2008). This result is not unsurprising as it is reasonable to expect that the level of ICT infrastructure available within a system will influence the extent to which teachers adopt ICT into their pedagogical practice. The 15% of science teachers who answered "yes" answered the questions about the impact of using ICT on their teaching practice and on their students.

Impact on teachers

Teachers who indicated that they had used ICT when teaching Science were asked to indicate the extent to which they perceived that ICT use had impacted on 12 specified aspects related to themselves and their teaching. The responses are indicated on Table 7.4 (Appendices E and F).

Table 7.4: Impact of ICT on teachers

Kind of Impact	Specific Impact	Somewhat OR A lot (%)	Mean Score (SE)
Empower teaching	(D) Incorporate new teaching methods	51	2.55 (0.12)
	(B) Incorporate new ways of organizing student learning	53	2.49 (0.12)
	(F) Access more diverse/higher quality learning resources	46	2.36 (0.11)
Better monitoring/feedback to students	(C) Provide more individualized feedback	49	2.49 (0.11)
	(E) Monitor more easily students' learning progress	57	2.62 (0.12)
Enhance collaboration	(G) Collaborate more with colleagues	60	2.71 (0.11)
	(H) Collaborate more with peers and experts outside school	49	2.55 (0.12)
ICT-skills	(A) Improved ICT skills	42	2.40 (0.12)
Administrative efficiency	(I) Able to complete administrative tasks more easily	54	2.64 (0.12)
Negative impacts	(J) Increased workload	49	2.50 (0.12)
	(K) Increased work pressure	53	2.53 (0.12)
	(L) Have become less effective as a teacher	22	1.74 (0.10)

The highest reported impact with a response of 60% was for *collaborating more with colleagues within my school*. None of the three teachers in the case studies felt that using ICT resulted in an increase in collaboration with their colleagues. In fact, all three operated largely as islands of ICT use within their schools. *I monitor more easily students' learning progress* was also perceived to have impacted on teachers with a positive response of 57%. This is perhaps indicative of the limited instances in which teachers do have access to ICT, and is typically used to keep track of student marks though DoE issued software, such as the South African Management System (SAMS). All three of the teachers in the case studies used some sort of spreadsheet to keep a record of student marks and all felt that this was a valuable aspect of ICT use.

When the mean scores of teacher perceived impacts are ranked from highest to lowest and plotted, the spread is quite small (from 2.71 to 2.36) suggesting that teachers don't feel the impact of ICT use in one particular area of their teaching practice significantly more than another. Except for a few cases, the mean impact lies between "a little" and "somewhat" on the 4-point Likert scale indicating that teachers experienced some, if limited, extents of impacts as a result of ICT use, when they were able to use it. When the highest three mean scores (red) and lowest three (green) mean scores of the teacher perceived impacts are ranked and shown graphically (Figure 7.7), the low spread is noticeable. The three highest scores are shown in red and the three lowest in green.

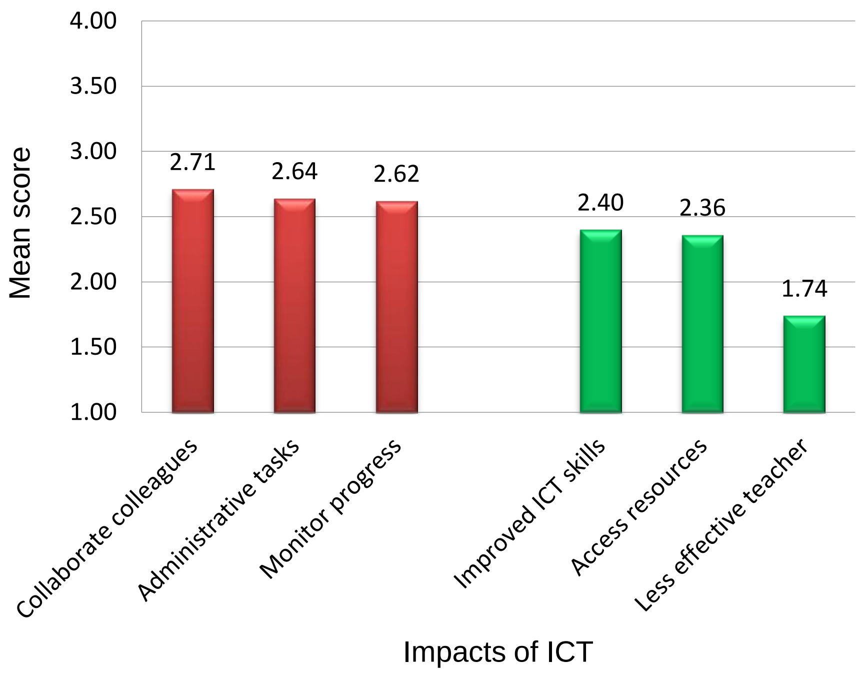

Figure 7.7: Three highest and three lowest South African science teacher-reported impacts of ICT-use

These 12 aspects can be categorised into six categories to give six impact indicators (Law et al., 2008). The average mean score for each of these categories was calculated, ranked and plotted graphically (Figure 7.8), the three highest in red and the three lowest in green. The highest perceived impact was for the category of increasing administration efficiency (2.64) and the lowest was for the category of negative impacts (2.26). The three highest scores are shown in red and the three lowest in green.

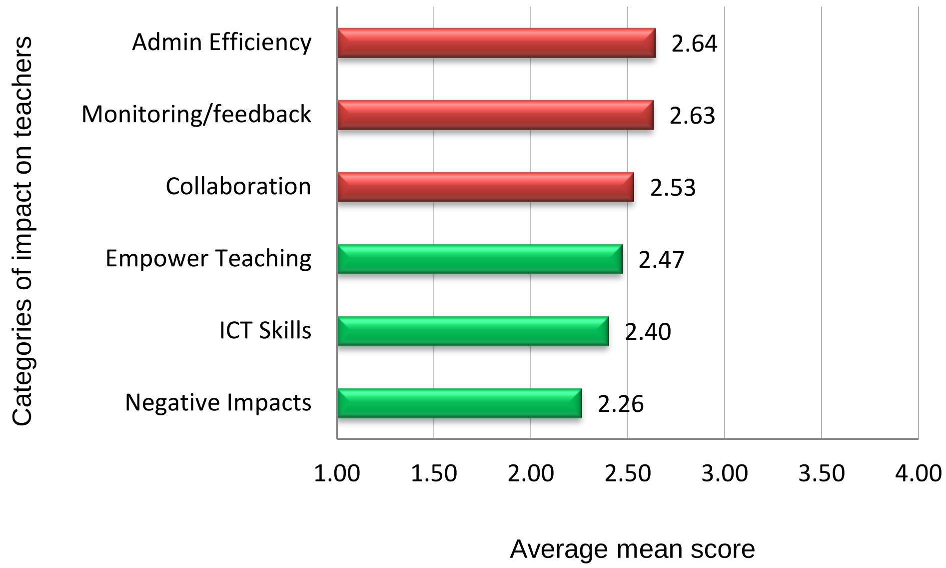

Figure 7.8: Three highest and three lowest three categories of South African science teacher-reported of impacts

Negative impacts obtained the lowest response indicating that when teachers were able to use ICT in their teaching they generally saw the impact as positive.

All three teachers in the case studies experienced a positive impact on their teaching when able to use ICT. They had a high personal motivation to use ICT in their teaching practice. Different aspects of ICT use motivated each of these teachers. Mr Sogo saw ICT as tool which made his preparation and day-to-day teaching easier. He accessed information and pictures from the Internet, made PowerPoint presentations of the lesson topics in the same way that one might make overhead projector slides of the lesson content, and then taught the lesson as a presentation. For this teacher, using the computer made his preparation easier, he could re-use the lessons year after year instead of having to write and re-write the lesson content on the board, and he could show the slide show to those students who had missed the lesson or needed to see it again.

> ...the motivational thing I got in England. When I went into their computer room, I found that they have got everything. They have got whiteboards, they've got smart boards. Then I became interested. I talked to the educator who was responsible for that, and I saw that it was easier for him making things (extract from interview with Mr Sogo).

Impact on students

Teachers who indicated that they had used ICT when teaching Science were asked to indicate the extent to which they perceived that ICT use impacted on 15 specified aspects related to their students.

Table 7.5: Impact of ICT use on Students

Type of impact	Specific impact	Increased a little OR a lot %	Mean Score (SE)
Traditionally important skills	(A) Subject matter knowledge	60	3.68 (0.10)
	(N) Assessment results	45	3.79 (0.10)
Inquiry skills	(C) Information-handling skills	63	3.78 (0.09)
	(D) Problem-solving skills	62	3.77 (0.09)
	(E) Self-directed learning skills	59	3.68 (0.09)
Collaboration	(F) Collaborative skills	58	3.69 (0.09)
	(G) Communication skills	62	3.77 (0.09)
ICT skills	(H) ICT skills	58	3.61 (0.10)
Self-paced learning	(I) Ability to learn at own pace	61	3.72 (0.09)
Affective impact	(B) Learning motivation	63	3.80 (0.09)
	(J) Self-esteem	66	3.87 (0.10)
	(L) Time spent on learning	58	3.64 (0.10)
	(M) School attendance	58	3.67 (0.10)
Achievement gap	(K) Achievement gap among students	59	3.69 (0.10)
Socioeconomic divide	(O) Inequity between students from different socio-economic backgrounds	49	3.42 (0.11)

South African science teachers responded that the greatest impact on their students was an increase in their *self-esteem* (66%) while the lowest impact was on *assessment results* (45%). In each case, a small group of teachers reported that their use of ICT actually decreased the time their students spent on learning (13%), their learner' subject matter knowledge (10%), student school attendance (10%), and ICT skills (10%). Figure 7.9 shows the spread of teacher responses. The three highest scores are shown in red and the three lowest in green.

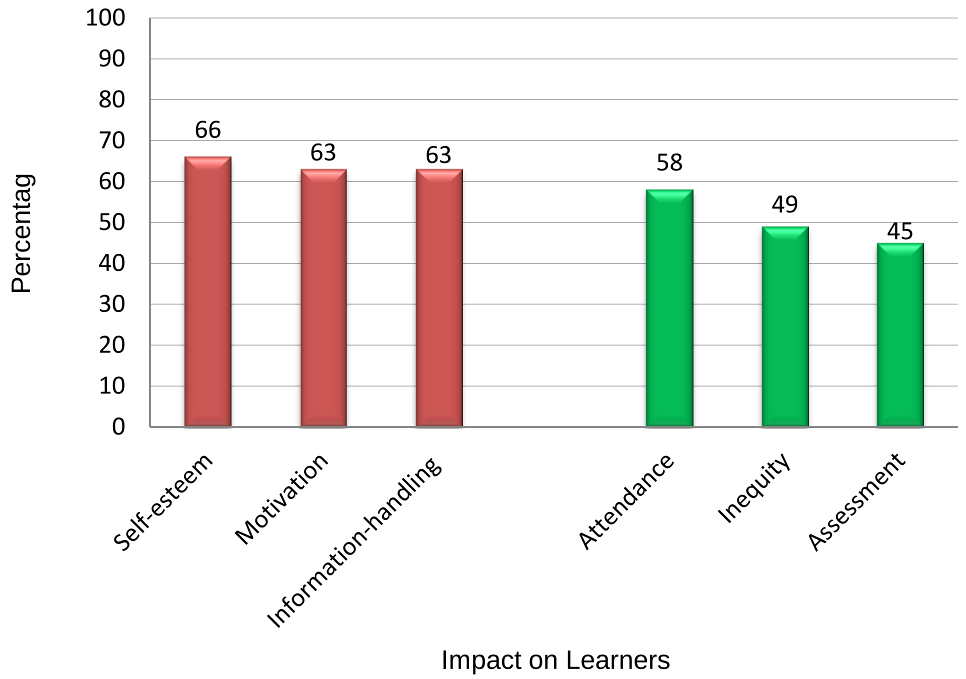

Figure 7.9: Three highest and three lowest South African science teacher-reported impact of ICT-use on students

These 15 aspects were categorised into eight categories to give eight impact indicators (Law et al., 2008). In this instance, the teachers responded using a 5-point Likert scale (1=decreased a lot, 1=decreased a little, 3=no impact, 4=increased a little, 5=increased a lot), not a 4-point scale as in other questions. When the average mean scores on the 5-point Likert scale of these eight categories was calculated and plotted in rank order of teacher-reported impact (Figure 7.10), it is evident that the range of average mean scores is small (between 3.74 and 3.42) suggesting that South African science teachers do not feel that their students' use of ICT impacts on one aspect of teaching and learning significantly more than any other. The four highest scores are shown in red and the three lowest in green.

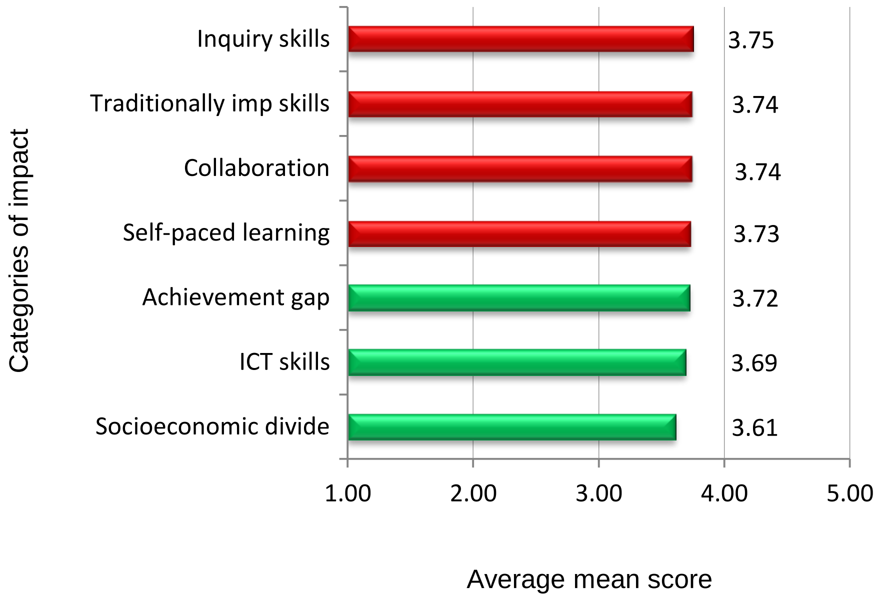

Figure 7.10: Four highest and three lowest categories of South African teacher-reported impacts of ICT-use on students

The high collaboration category is perhaps surprising as teachers reported low scores for two similar aspects of student-practice, namely to *collaborate with peers from other schools within and/or outside the country and to communicate with outside parties* (Table 5.9).

The case studies allowed for an in-depth exploration into the three teachers opinions on the impact of ICT use on their students. Perhaps the most controversial area of impact of ICT lies around the issue of improved achievement and this was a theme that was explored with each of the three teachers to ascertain their own perceptions of this sort of impact on their students. There was no attempt in this study to gather quantitative evidence for improved student achievement or otherwise but rather, the perceptions of the individual teachers were explored. Mrs Marley was convinced that learning through using a computer would improve student achievement, although her evidence was anecdotal:

> Normally when you assess, lessons that were done on the computer, they get very high marks. They enjoy that. The lessons which were done... [not using the computer], they still perform well but when you compare, you actually pick up [an improvement]... [if you could compare a class using a

> computer and one which didn't]... The marks of the computer class would be higher (extract from interview with Mrs Marley).

Ironically, the teacher with the most sophisticated use of ICT and had successfully integrated the ICT into her project-based teaching style had the least confidence in the contribution of her use of ICT to student achievement. She felt strongly that when it came to the important FET years of the science curriculum, reverting to a more traditional teacher-dominated and content-driven approach was necessary. In an e-mail communication with this teacher, she deliberated over whether her students learnt more when using technology:

> Yesterday I got 'blasted' because the Grade 10s, who came from doing Natural Science with me since Grade 7, and with whom I've done the most project-based learning, most being ICT-integrated, don't know basic knowledge like what a tap and adventitious root is. So, back to your question of whether they learn... well I don't know. Maybe more direct instruction and knowledge drill is the wiser 'root'! (E-mail communication with Mrs Putten)

The strongest theme emerging from the interviews with teachers was around student motivation. Mr Sogo was in a school which had a history of poor student attendance and high truancy rate typical of many township schools. He showed me where the school had reinforced the perimeter fence to prevent the students from 'escaping' from school:

> [when I use the computer]... they never forget. We talk about different planets. And when they see this [referring to his lesson notes on the *PowerPoint* presentation] these small children, they never, they don't forget. When you give them a test, most of them get more than 50%. They enjoy coming... they're ***never*** [his emphasis] absent themselves from coming to my class. They can bunk other classes but when it's my period, they come (extract from interview with Mr Sogo).

Mrs Marley had an opinion similar to that expressed by Mr Sogo. She too felt that the students were more motivated to learn when they had access to the computers:

> ... the thing is they get very bored. This morning they were here [in the lab]. They get very excited now. Tomorrow they will still want us to come back [to the lab]. ... So tomorrow if I have to teach them without showing

> them, they will be bored. They will be forced to learn with or without the computer, but they enjoy it [computer work] most (extract from interview from Mrs Marley).

A teachers' belief that ICT will improve their teaching and the learning of their students is key to their use of ICT. It is unlikely that a teacher will take on the additional work load associated with integrating ICT into practice if they do not perceive there to be benefits, even if those benefits are only their personal motivation and that of their students.

7.8 Discussion

An important influence on the use of ICT in subjects such as science is the amount and range of ICT resources available to the teachers (Cox et al., 2004). Where there are limited numbers of computers, a limit to the Internet access and other technology resources, the impact of ICT on teaching and learning is limited. While the level of access to technology resources differed in each of the three cases, the teachers in this study were all constrained to some degree by their limited access to digital resources. More than simply access to resources, a teachers' ability to use the resources depends on that teachers' confidence and competence at using that resource. In the case of Mrs Marley, access to an interactive white board, a resource that Mrs Putten had on her wish-list of technology resources, remained unused during the time of the case study owing to her lack of competence in whiteboard use. She thought that it would be very helpful in her teaching but did not know how to operate it so it remained unused.

The use of ICT has a low impact on teaching and learning where teachers fail to appreciate that interactivity requires a new approach to pedagogy, lesson planning and the curriculum. Some teachers reorganise the delivery of the curriculum, but the majority use ICT to add to or enhance their existing practices. Teachers need to employ proactive and responsive strategies in order to guide, facilitate and support appropriate learning activities.

CHAPTER EIGHT

Conclusions and Recommendations

Science learning over the past few decades has been recognized as the social construction of knowledge of meaning in context (Driver et al., 1994; Duit, 1994). During the time in which an understanding of science learning has developed, there has been a rapid advance in technology and its use in education. There is now a wealth of research on the effects of technology on learning, as well as on the contexts in which it is of the greatest benefits. This research is summarized in Chapter Two. The purpose of this study was to gain insight and understanding of the value that ICT adds to the teaching and learning processes in Science, given the context of limited resources in most South African classrooms. As a means of understanding the value that ICT adds to science teaching and learning, this study explored the ways in which South African science teachers used ICT when they taught Science (Chapter Six), and some of the reasons that they used ICT in the ways that they did (Chapter Seven).

This chapter begins by giving a summary of the research process and the mixed methods design chosen to best address the research question: *What is the value that using ICT adds to the teaching and learning of Science when teachers use ICT in a context of limited resources, typical of a developing country?* It serves to consolidate the findings from the data presented using the Four in Balance Model as a way of understanding the evidence as a whole, rather than as a collection of unrelated findings. In addition, the chapter presents four conclusions inferred from the data presented about the value of the pedagogical use of ICT in developing countries such as South Africa. It discusses five specific areas of ICT use explored in this study which add value to the teaching and learning process in developing country contexts such as South African science classrooms. These areas include the development of ICT skills, computer-supported curriculum coverage and teacher and student motivation. Computer-supported cognitive development through the use of computer simulations, while limited to only one teacher in this study, still has the potential to add value to teaching and learning in the context of developing countries such as South Africa.

Lastly, based on the evidence presented in this thesis, the chapter concludes by making recommendations to inform future policy debates and discussions about how best to use limited financial resources to add value to science teaching and learning through the investment in technology resources in South African school.

8.1 Summary of the research processes

This study was designed as a mixed methods study, combining the quantitative data collected from 267 South African science teachers in the SITES 2006 Teacher Questionnaire and qualitative data collected from three science teachers in three separate cases. The questionnaire data was collected from South Africa science teachers in 2006 and the case study data was collected from the three teachers during a number of visits to classrooms in 2009, one of whom also participated in the SITES 2006 study. For both the quantitative and qualitative data, those teachers who taught in classrooms with limited access to resources were identified and purposefully selected for the study (section 4.4.4). Secondary analysis was done using selected data from the SITES 2006 questionnaire data to highlight some of the ways in which science teachers in South Africa use ICT when they teach Science, as well as some of the possible reasons their particular use of ICT. These data were integrated with the interview and observation data collected from the three case study science teachers (Chapters Six and Seven). The quantitative questionnaire data allowed a landscape view of ICT use among South African science teachers and the qualitative case study data allowed a more nuanced understanding of how and why teachers use ICT in the ways that they do. The Four in Balance Model (section 3.2) of assessing the value that ICT adds to education used in the Netherlands proved a valuable initial framework for this study. It allowed me to identify particular aspects which influence ICT use (vision, expertise, digital learning material, ICT infrastructure) within a context of leadership and support, and to explore the value that ICT adds to teaching and learning Science in South Africa.

8.2 Summary of the research findings

Despite the low availability of ICT infrastructure in schools in South Africa, when teachers do have access to ICT resources, either through their own personal acquisition or through the resources available through government funding, they are able to use those resources in their subject teaching. In some of those instances, teachers are able to use the resources available to them in ways that provide their students with opportunities to learn that would otherwise not be possible, and in a way that adds value to teaching and learning in those classrooms. As value is not an easy concept to access, the research question of this study was operationalized through two sub-questions: *How do science teachers use ICT in a context of limited resources?* addressed in Chapter Six and, *Why do science teachers use ICT in the ways that they do?* addressed in Chapter Seven. Both of those chapters synthesised and analysed the quantitative and qualitative data collected in this study. A summary of that analysis is given here to answer the overall research question by discussing the ways in which the use of ICT in South African classrooms adds value to teaching and learning Science.

The value of using ICT in science teaching and learning in developing countries

The evidence collected and analysed in this study showed that South African science teachers in the majority of schools have a very traditionally orientated practice when teaching (section 5.1) and when using ICT to teach science (section 5.2). This pedagogical orientation was measured through the SITES 2006 questionnaire data in terms of teachers curriculum goals, teaching practice and student practices (sections 5.1. and 5.2). In addition, the evidence collected in this study showed that South African science teachers have very limited access to technology resources (section 6.1). The government-funded computer rooms, such as those provided as part of the Gauteng Online initiative, have been ineffective in giving science teachers' access to ICT for use in subject teaching. In instances where the rooms have fully functioning computers, CAT lessons are scheduled as a priority. Even when teachers have access to technology resources, their use of those resources is limited (section 6.1). Lack of teacher ICT competence (section 7.1) and student ICT competence (section 7.2) are certainly contributing factors. There was evidence of ICT being use for assessment (section 6.3) but this use was dominated by drill-and-practice self-assessment assessment strategies.

ICT competence among South African science teachers is low, but in instances where teachers are competent, they are more likely to be competent in the technical use of ICT than in the pedagogical use of ICT. Students' ICT competence was significantly lower than that of their teachers (sections 7.1 and 7.2). In cases where students are competent in using ICT, they are most likely to be able to use word-processing software. A very small percentage of students are able to use ICT to communicate using, for example, e-mail. The teachers in the case studies reported a wide range of ICT-competence among their students. Many students struggled with typing and moving a mouse and this limited the pedagogical use of ICT. Attendance at professional development activities was also low (section 7.4). This was largely owing to a lack of access, rather than a lack of will to participate, as the majority of teachers reported that they would attend professional development activities if they had to opportunity to do so. In the three cases, teachers were self-motivated to attend professional development activities and participated freely for their own personal development. Two of the three teachers had been particularly active in finding opportunities to develop their ICT-practice themselves.

A lack of ICT skills and training was recognized by teachers as an obstacle to their use of ICT (section 7.4). The lack of access to technology resources were noted as the most significant category of obstacles to ICT use. The teachers in the case studies were in a position to provide their own technology resources but despite this, lack of a reliable Internet connection proved to be the greatest obstacle. It was not one that they had any control over and this provided an obvious frustration for the teachers. Institutional obstacles, such as lack of school support for ICT use was not considered to be a significant obstacle to ICT use. In most cases, school management supported the use of ICT. Unfortunately, even when support was high, lack of ICT expertise among school leaders meant that they were unable to translate that support into action. In all three cases, the teachers were isolated users of ICT within their schools and took responsibility for their use, solving their problems themselves when possible. School vision was reported as being high among the teachers who responded to the questionnaire but there was no evidence of this in the three cases.

In general, South African teachers did not report a high impact on teaching or learning in their school (section 7.7). In cases where they did report an impact, the highest impact was on an increase in efficiency in administration. This suggests that the highest use of ICT is most likely to be the use of word-processing software to type worksheets and test papers, and the use of spreadsheet software to record student marks. Many teachers felt that the use of ICT empowered them and made them better teachers. Those teachers who did use ICT to teach science reported a high impact on their students. The highest impact was on inquiry skills. This was supported in the three cases where all three teachers used ICT for research, either for their lesson content, or for student projects. There was strong support for the motivational effect of ICT use. All three of the cases study teachers felt that their students were more motivated to learn when they used ICT, but only one of those three teachers showed strong belief in an improvement in achievement with her students. Her evidence for this view was anecdotal and not explored further as achievement was not a focus of this study.

Given the data presented in Chapters Six and Seven, the research question: *What is the value that using ICT adds to the teaching and learning of Science when teachers use ICT in a context of limited resources, typical of a developing country?* is answered. ICT adds value to teaching and learning in developing country contexts by providing opportunities for more effective, more efficient, and more interesting teaching and learning, even when resources are limited. As a way of simplifying an extremely complex issue, these three different aspects of value are explored (Kennisnet, 2009):

More effective teaching and learning*:* using ICT can help improve student performance and skills, provide students with a more student-centred and activity-based pedagogy, and enhance conceptual understanding in science through the use of simulations.

In 2009, an investigation into the implementation of the FET Science and Mathematics curricula was conducted across 18 schools in Gauteng Province (Howie et al., 2010). As part of the data collected in these schools, science teachers were observed and interviewed about their understanding and implementation of the NCS at the Grade 10 to 12 levels. The study revealed a seriously inadequate understanding of the curriculum as well as very low levels of SCK and PCK in many of the teachers teaching Science. The study concluded that low SCK and PCK as evidenced in the eighteen secondary schools visited in Gauteng Province, was most likely widespread in schools in other provinces as well. In addition to the problem of low SCK and PCK in science teachers in South Africa, there is an increasing shortage of science teaching capacity in many schools. This is as a result of skilled science teachers leaving the profession, fewer educators entering it, as well as the significant toll that HIV AIDS was having amongst educators country-wide. Part of the rationale for the Khanya Technology in Education Project (Khanya, 2001) in the Western Cape Province was to explore alternative solutions to the teacher shortage mentioned above. Technology, through the Khanya project, was seen as a tool to augment teaching capacity in schools in the Western Cape and a viable alternative to lack of teaching capacity.

Since the advent of the Internet, students are able to access vast amount of information not previously available. This includes real-time information, for example weather data and real-world information, for example census data. The Internet is an extremely powerful tool which allows both teachers and students to conduct research and build knowledge (Lai, 2008). For Mrs Putten and Mrs Marley, the Internet was both the most useful tool for accessing information, and the greatest obstacle. Both had to work with limited and erratic Internet connections and both were visibly frustrated by the lack of access to the resource that they saw as being of real value to their teaching. Despite this, all three of the teachers were able to access the Internet and used if primarily as a tool for research to augment their curriculum resources. All three expected their students to access information on the Internet for projects. Mr Sogo's students had little or no chance to use the Internet but both Mrs Putten's and Mrs Marley's students had access to the Internet in the computer room outside of scheduled class time. The value of access to quality learning materials and other curriculum related information in an education context of low teacher SCK and PCK should not be underestimated.

Simulations, while allowing students to perform practical investigations not possible in school science laboratories, are a credible tool in assisting in the development of theoretical conceptual understanding in some topics in the science curriculum. Free, downloadable software, such as that used by Mrs Putten, allowed students to explore the effect of friction on surfaces on the motions of objects in ways that would not have been possible without access to technology. The use of simulations in science should be given special attention for the development of concepts in a conceptually difficult subject such as science.

More efficient teaching and learning: using ICT can help maintain the quality of teaching and learning while cutting down on teaching time especially in instances where class sizes are large and teachers' SCK and PCK is inadequate. One example is the use of digital learning materials that allow students to learn independently and that enable the teacher to devote more time to students who require individual attention. A well-equipped and functioning computer room with high quality curriculum-linked software may serve this purpose in schools with limited resources. Access to the computer room and educational software could allow students to learning opportunities when adequately qualified teachers are not available.

The reality of education in South Africa is that class sizes are unacceptably high (section 1.2.2), and this is likely to remain the reality for some time to come. The consequence of large classes is that, among other things, teachers seldom spend quality time with individual students during class time. Mrs Putten's particular use of ICT for the purposes of more efficient teaching is worth mentioning. She video-recorded her lessons, developed learning materials to support them, and developed self-assessment tasks, all of which she made available to her students after school hours in the computer room for self-study and revision. It meant that they could go through the work at a much slower pace and in their own time as a way of increasing their understanding of the work.

More interesting teaching and learning: ICT applications that improve teacher and student motivation, for example by making teaching and learning more varied and interesting. This increases student participation in science lessons which is difficult for students who come from poor communities with little home or community educational support.

Teacher motivation for teaching, as well as student motivation to learn science was perhaps the greatest contribution of ICT in the three schools in this study. All three teachers spoke of high levels of motivation, both for themselves as teachers, and for their students as learners. The high levels of motivation when using ICT were also reported in the quantitative data collected from South African science teachers in the SITES 2006 study. This is especially important in educational contexts with limited resources. In many of the science classrooms in South Africa, access to colourful posters, charts, and diagrams in text books are limited. Mr Sogo spoke of adding colourful pictures to his presentations to show his students things that were not shown in the available text books. He place strong emphasis on the value of seeing pictures as a supplement to texts in Science.

8.3 Reflection on the conceptual framework

In addition to understanding the value of ICT use in terms of more effective, more efficient, and more interesting teaching and learning discussed above, the Four in Balance Model conceptual framework for this study provided a useful way of understanding and exploring the value added to teaching and learning when ICT is used in the classroom. According to this model, a balanced deployment of the four elements: vision; expertise; digital learning materials; and ICT infrastructure, all supported by school leadership, is necessary for the effective use of ICT (Kennisnet, 2009). The Four in Balance Model is a framework used in the Netherlands, a country in which ICT use in education is increasing steadily. Access to ICT infrastructure in schools in the Netherlands is almost universal, with seven out of ten teachers in the Netherlands using ICT applications during their lessons. Teachers in the Netherlands also believe that the amount of time that they spend using computers for lessons will increase significantly in the next few years. Both the number of teachers using ICT, and the frequency of the ICT use is likely to increase (Kennisnet, 2009). This context, typical of a developed country, is not what is found in a developing country such as South Africa.

8.3.1 The Four in Balance Model in this study

Even with the obvious differences in contexts between the Netherlands and South Africa, the model was a useful starting point for understanding the value of ICT in a South Africa. The findings of this study are discussed here, using the Four in Balance Model framework, focusing on the four aspects in the model which contribute to the pedagogical use of ICT: vision; expertise; digital learning materials; and ICT infrastructure.

Vision

The science teachers who completed the SITES 2006 teacher questionnaire reported a high level of school vision (section 7.5) and principals at the three schools in this study all said that the school had an overall set of aims for the use of ICT and a vision which was reflected in the school ICT policy document. Nonetheless, in none of the three schools was there evidence of managerial influence in the use of ICT. All three teachers used the available ICT infrastructure according to their own personal vision (section 7.5). All three were seen as 'islands' of ICT use in their respective schools with no visible school coordination. Despite this isolation, none of the three teachers felt the need for more involvement from management. They were each left to do as they saw fit and enjoyed the freedom of managing their own ICT use.

Each of the three teachers in the case studies had a different personal vision for ICT use and this was reflected in their different ICT practices. Their use of ICT was not confined to any one specific educational approach. In the three cases, ICT was used within a variety of pedagogical methodologies, varying from the transfer of knowledge where the teacher determines the programme (content and pace) to knowledge construction where the students are partly responsible for managing the learning process. For many South African teachers, knowledge transfer plays a greater role than knowledge construction in their general pedagogical practice. The

SITES 2006 study showed that teachers' general pedagogical practice strongly influences their ICT-using pedagogical practice, so a greater emphasis on knowledge transfer is likely to be the same for those teachers when they use ICT.

All three teachers in the case studies had their own personal vision for the use of ICT in their teaching but none of them worked within schools where there was a shared vision for the importance of ICT in designing teaching and learning programmes of the future. In all three of the schools, the ICT vision had been set out in a policy plan but in practice, this was not implemented according to the policy. The data collected in this study suggests that the school's view of what constitutes good teaching and how the school aims to achieve it is not as important as the teacher's personal vision. The gap between ICT policy and ICT practice remains wide and the vision adopted by the school's managers and teaching staff determines both the school's policy and the design, but not necessarily the organisation of its teaching.

Expertise

The SITES 2006 data showed that a small percentage of South African science teachers are capable of using computers, and even a smaller number have the skills necessary to use a computer as a pedagogical aid to designing and organizing the processes of teaching and learning (section 7.1). Of the three teachers in this study, only one provided evidence of understanding how to effectively use ICT in teaching and learning in a way that extended learning beyond what is expected in the curriculum. Developing educational ICT applications, for example digital learning materials, requires specific expertise if it is to create the best possible mix of content, pedagogy, and ICT. The ultimate result of that mix must align with the wishes and capacities of the teacher who uses the applications. This is particular relevant for those teachers who have access to functioning Gauteng Online computer laboratories, as those facilities will have specific applications for teachers to use. Those teachers would not be expected to develop their own applications.

Only a small percentage of South African science students had expertise in ICT use, perhaps partly as a result of lack of access to ICT (section 7.2). This study showed that students of the three teachers in the case studies had some level of ICT skills, but not all at the same level. This made it difficult for each of the teachers to use a single teaching or learning strategy for the whole class. Given the relatively small sample used in this study, it is unlikely that many students in South African schools with limited resources have any computer skills at all. Evidence from this study suggested that this may in some way be addressed through the subject area CAT which is offered at those schools with the necessary ICT infrastructure in the form of computer rooms. Given the lack of ICT infrastructure at the majority of schools in South Africa, it is unlikely that schools which do not have the necessary ICT infrastructure have any planned systematic approach to the acquisition of digital information skills for students. In developed countries, many students acquire the ICT skills necessary to learn with the aid of ICT outside the school, typically at home. This is unlikely to be the case for the majority of students in South African schools as most homes still lack access to a computer or the Internet.

Teachers and students should have sufficient knowledge and skills in order to utilise ICT to achieve educational objectives. This involves not only basic ICT skills, such as the ability to operate a computer. Pedagogical ICT skills are perhaps the most important factor in effective use of ICT if it is to be used to help design and organise learning processes. These additional skills therefore specifically concern the use of ICT to achieve educational objectives. This kind of knowledge is defined in the concept of TPCK, as explained in section 3.3.2 (Mishra & Koehler, 2006). TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. The findings from this study showed that teachers' TPCK was a key factor in using ICT effectively. The teacher who provided evidence of good TPCK showed significantly more innovative uses of the available ICT resources. She was able to provide her students with learning opportunities that would not have been possible without ICT.

Given the importance of TPCK for the effective use of ICT in education, it is an area that requires research attention, especially in the area of teacher development. Mishra and Koehler (2006) argue that the TPCK framework has allowed them to guide curriculum design and help create conceptually and epistemologically coherent learning environments for teachers. Angeli and Valanides (2009) suggest that the TPCK framework is a valuable contribution to the theoretical basis for understanding technology in education, but that it needs further clarification. Their critique of the TPCK framework is based on three grounds: firstly, it does not make clear whether TPCK is a distinct form of knowledge, or whether a growth in TPCK simply means growth in any of the related constructs (i.e. PCK, TCK, or TPK); secondly, the boundaries between some of the components of TPCK, such as TCK and TPK are not distinct, leading to a lack of precision in the framework; thirdly, TPCK is too general because it does not speak explicitly about the affordances offered by IT tools in learning. Angeli and Valanides (2009) thus contribute to the theoretical refinement of the framework by introducing ICT–TPCK as a strand of TPCK. Their conception seeks to address systematically the specificity that they suggest is missing from the conceptualisation of TPCK regarding the dynamic and transactional relationship among content, pedagogy, and various technology affordances. Accordingly, the knowledge bases of ICT–TPCK include the three contributing knowledge bases of TPCK, namely subject knowledge, pedagogical knowledge, and technology knowledge (in this case restricted to ICT), and two additional elements, namely a knowledge of *students* and a knowledge of the *context* in which learning takes place. Their conceptualisation of ICT–TPCK is based on research evidence gathered from studies with in-service teachers (Angeli & Valanides, 2009). At the heart of their conceptualisation of ICT–TPCK is the view that technology is more than a vehicle that simply delivers information. When the construct of ICT–TPCK was explored, Angeli & Valanides (2009) adopted the transformative view of TPCK, concluding that it is a unique body of knowledge constructed from the interaction of individual knowledge bases, the development of one or more of which does not guarantee or imply a concurrent development of ICT–TPCK. The ICT-TPCK framework need to be explored further and can guide future research and curriculum development in the area of teacher professional development around the pedagogical use of technology.

Digital learning materials

The availability, or lack thereof, of digital learning materials that are of practical use for teachers and students is one of the greatest barriers to successful integration of ICT in education (section 7.4). This was certainly the experience of Mrs Marley, one of the teachers in this study. Where available, she relied heavily on the digital materials but complained frequently about the gaps in content, which meant that many sections of the syllabus had to be covered in the "traditional" way, i.e. lecture-style teaching. Only one teacher in the study, Mrs Putten, had the expertise and available personal resources to develop her own digital learning materials. She was most likely one of only a few teachers who had this option available to them. Given the evidence gathered in this study, it is likely that for the vast majority of teachers in South African schools, the provision of high quality curriculum-specific digital learning materials is a key component in their being able to use ICT effectively in teaching. The TLI is designed to address this need by providing teachers with high quality digital learning resources on a government subsidized laptop. The slow uptake of this initiative by teachers and apparent lack of departmental organization regarding the TLI makes this an unlikely solution in the near future.

Mrs Putten, who was able to access her own digital learning material (both formal and informal) and had the necessary skill to design her own learning materials, was able to make the most effective use of those materials. Mrs Marley, who relied on digital materials to be provided, was significantly limited by the lack of flexibility in the materials. Digital learning materials which may be provided by the department seem not to be as important as a teacher's ability to access learning materials through collaboration with colleagues and the use of the Internet.

ICT infrastructure

The findings from this study suggest that despite a major investment in ICT infrastructure over the past few years through the provision of computer laboratories such as the Gauteng Online Project, problems of technical support and management of these facilities has resulted in a many of them standing as "white elephants". The inability of the GDE to get the laboratory functioning with a reliable Internet connection, and keep it functioning, led to the disillusionment on the part of one teacher in particular in this study. This is likely to be the case with other teachers in similar schools. This has resulted in the Gauteng Online project being affectionately referred to as “Gauteng Offline” among many teachers in the province, Mr Sogo being one of those. Even with functioning computer laboratories, the computer-student ratio remains high, keeping individual computer use by students low. The improvement of Internet connection in schools with the Seacom fibre optic cable has also proved to be problematic. Of the three teachers in this study, only Mrs Putten who was self-sufficient in terms of ICT skill and ICT resources, and was not forced to rely on infrastructure to be provided and maintained by external sources, was able to use her ICT resources in ways she felt were most suitable.

The availability and quality of computers, networks, and Internet connections is an important component in effective ICT use. The management and maintenance of the school’s ICT facilities are also important. However, even when access to high quality ICT infrastructure is limited, high levels of teacher competence and ICT expertise are enabling factors in innovative and effective ICT use.

8.3.2 Adjusting the Four in Balance Model for use in developing countries

The findings from this study suggest that the Four in Balance Model of ICT use suggested in the Kennisnet monitor be adjusted to be useful in understanding value added with the pedagogical use of ICT in developing country context such as South Africa. In many instances in South African schools where resources are limited, one teacher may typically be an island of ICT use in the school. While school support and vision assists in the pedagogical use of ICT, many of the school principals and other manager are themselves not ICT literate and are unable to provide the necessary support to teachers. A teacher with a personal vision, as reported in this study, will use ICT in ways that add value to his or her specific subject, regardless of whether other teachers use ICT. Given the findings of this study, it is suggested that the Four in Balance Model may be more useful in understanding the value of using ICT in developing countries if the elements are understood within an overall personal teacher vision, rather than a school or leadership vision. Furthermore, teachers’

TPCK is perhaps one aspect which was a significant contributing factor to how and why science teachers in South Africa use ICT in the ways they do which was not emphasized enough in the Four in Balance Model. Again, the Four in Balance Model may be more useful in a developing country context if the aspect of teacher expertise (knowledge and skills) reflects the concept, TPCK, which better explains the pedagogical use of ICT.

An alternative to the Four in Balance Model is shown diagrammatically in Figure 8.1.

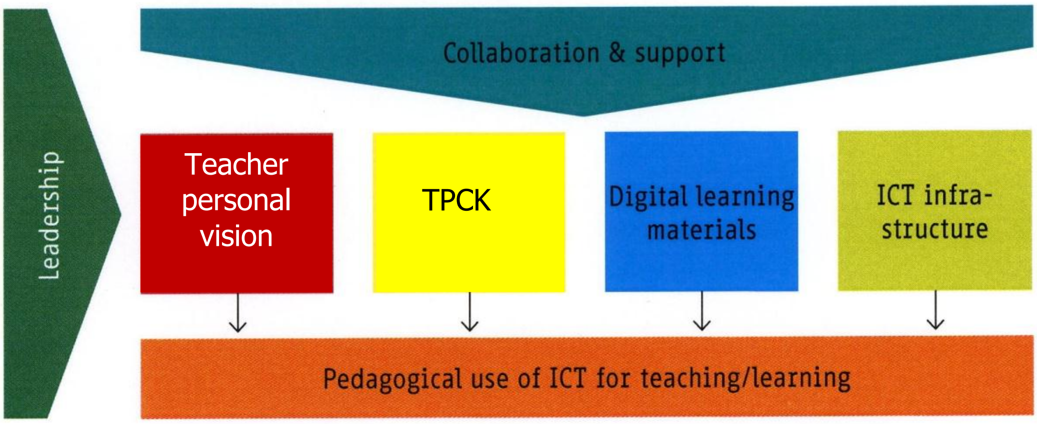

Figure 8.1: Model for understanding the value of ICT use for developing country contexts (adapted from Kennisnet Four in Balance Model)

Having a means of understanding the value of the pedagogical use of ICT is extremely important to justify the financial investment in ICT in countries where the need for investment often outstrips the financial resources. It may be worth testing the robustness of this model in other developing countries in further research.

8.4 Reflection on the design and methods

This study used quantitative data collected from 622 science teachers in South Africa through the teacher questionnaire, as part of the international SITES study, under the auspices of the IEA. The SITES 2006 study allowed me access to data collected through high quality instruments and processes. The value of this quality and quantity of data is discussed in section 4.4. SITES 2006 made available a large quantity of reliable statistics which could be used to understand the pedagogical use of ICT of South African science teachers. Qualitative data through interviews, observations, photographs, and field notes were collected from three science teachers, all of whom taught science in classrooms where access to resources were limited. Both sets of data were integrated in the analysis and interpretation. Using this combination of quantitative and qualitative data for this study raised some issues worth mentioning here.

Firstly, while a valuable source of information, the SITES 2006 teacher data also had limitations for this study as it was collected in classrooms with all levels of resources, i.e. well-resourced classrooms, classrooms with limited resources, and classrooms in school which have been classified as poor or very poor. As the focus of this study was the value of ICT in developing country contexts, this limitation was overcome by sub-sampling the teacher data to reflect teachers in a developing country context. Details of this reorganization are fully discussed in section 4.4.4. The sub-sample consisted of 267 science teachers, all of whom had access to ICT for teaching science, but none of whom taught in schools which were well resourced.

Secondly, a limitation of using the SITES 2006 data was that the quantitative data was collected in 2006 while the case study data was collected in 2009. This time delay was kept in mind throughout the collection of the qualitative data and was judged to have minimal impact on the findings as no significant policy changes regarding the implementation or use of ICT were made during that time.

Thirdly, the SITES 2006 research questions were not the same as the question focusing this study. This meant that the quantitative data used to answer the research question of this study had to be extracted from the SITES 2006 teacher database to make it valuable in answering the research question of this study. The findings presented in Chapters Six and Seven, which consisted of an integrated approach to data analysis, meant that matching the quantitative and qualitative datasets was challenging. The challenge was in assimilating the individual bits of data from each dataset to present common findings. The nature of the case studies in this research meant that themes and issues unique to each teacher were explored. Integrating the qualitative data with the quantitative data was challenging.

Lastly, the original intention for this study was to select three teachers identified as participants in the SITES 2006 study and explore their practice using ICT in more detail than the questionnaire would allow. Circumstances which have been discussed in section 4.5.1 meant that only one teacher could be identified from the questionnaire data and, as such, the other two teachers were sampled conveniently and opportunistically. The value of a pragmatic approach to the research was that the flexible research design was easily modified to accommodate this limitation.

8.5 Conclusions

The findings articulated to this point are based on the integration and synthesis of both quantitative and qualitative data collected from science teachers in South Africa. In each case, the evidence that supports the findings has been presented or referred to. Given the data collected in this study, it is possible to move beyond the specific evidence-based findings to culminate the findings from this research in four conclusions. Each of these conclusions is inferred from the wealth of evidence gathered and interpreted in the research. Where applicable, I have referred to research in this field to show how these conclusions support the conclusion by other studies.

Conclusion 1:

When science teachers have access to ICT for teaching and learning in classrooms typical of developing country contexts, they are able to use that ICT effectively to add value to teaching and learning, particularly when the teacher has a high technological pedagogical content knowledge.

The Four in Balance Model was a useful framework for understanding the value that ICT adds when it is used by teachers. However, the particular aspect of teacher expertise was better understood in this study as TPCK and an adjustment was made to the Model to make it more useful in a developing country such as South Africa. TPCK is not an aspect of teacher practice that can be measure directly. The evidence for this conclusion comes from exploring how each of the three science teachers in the study used ICT when teaching science (Chapter Six). The concept of TPCK has been developed to capture some of the essential qualities of teacher knowledge required for technology integration in teaching, while addressing the complex, multifaceted, and situated nature of this knowledge (Mishra & Koehler, 2006). The process of unpacking this complex interplay of content, pedagogy, and technology in teaching practice began in this study. TPCK is the basis of good teaching with technology and requires an understanding of a number of separate but interrelated aspects of teaching. These aspects are: the representation of concepts using technologies; teaching techniques which use technology to teach content; a knowledge of the science concepts which are difficult to learn and how technology can be used to assist students with developing a conceptual understanding of these concepts; a knowledge of students' prior knowledge (conceptions and misconceptions) and how technology can be used to address misconceptions where relevant. It became clear through the three cases that only the one teacher, Mrs Putten had a good understanding of all of these aspects, making her pedagogical use of technology the most effective. Neither of the other two teachers had sufficient TPCK to use the technology tools available to them effectively.

Conclusion 2:

Personal entrepreneurship is a key factor in a teacher's ability to use ICT to add value to teaching and learning in a developing context, and to support the educational objectives based on 21st century learning objectives.

This study provided evidence that the teacher who used ICT innovatively in her teaching (Mrs Putten) was characterised by a specific combination of knowledge, skills, attitudes, and competencies that were advantageous for the innovative use of ICT. Even without the availability of school support she was able to find the necessary support in other ways, confirming an 'entrepreneurial' attitude. This 'personal entrepreneurship' which allows for the innovative solutions to problems is particularly important for developing country contexts such as South Africa.

This conclusion is in line with a similar conclusion in a study by Drent and Meelissen (2008). In their study, they evaluated the factors which stimulate or limit the innovative use of ICT by teacher educators in the Netherlands (Drent & Meelissen, 2008). They defined innovative use of ICT as the use of ICT applications that support the educational objectives based on the needs of the knowledge society. More specifically, the use of ICT is innovative if the ICT application facilitates and supports student-centred learning, i.e. students can, to a large extent, influence their own learning by adapting the learning process to their own needs and interests. The data in their study were collected through a large-scale longitudinal study (using the ICT-monitor between 1997 and 2000) in the form of school, teacher and student questionnaires and through case studies of four teacher educators and some of their students. The case studies indicated that teacher educators, who use ICT innovatively, develop their competence based on the educational goals they want to accomplish with the help of ICT. Their attitude and the ICT goals they set for themselves, played an important role in this. This, their study suggests, may also explain the positive influence that ICT competence has on the pedagogical approach. ICT competence was noted as a necessary condition for the use of ICT, but in order to implement innovative use of ICT, other factors were more important. When the interrelationships between the teacher level factors were studied, ‘personal entrepreneurship’ turned out to be the key factor for the integration of the innovative use of ICT into the learning process (Drent & Meelissen, 2008).

Personal entrepreneurship turns out to be an important anchor point for stimulating the innovative use of ICT in education. The teacher educators characterised as ‘personal entrepreneurs’ in Drent & Meelissen’s study (2008), created possibilities to experiment with ICT applications, researched the use of ICT in their education, reflected on their outcomes, and exchanged ideas with colleagues Although ‘personal entrepreneurship’ is mainly an attitudinal characteristic of an individual teacher, teacher education institutes should create favourable conditions that support personal entrepreneurship. Their study showed that the support of the school plays a role in stimulating the personal entrepreneurship of the teacher educator. Personal entrepreneurship can be seen as the catalyst between the endogenous factors on the teacher level and the endogenous factors on the school level. In other words, even though the teacher level factors fulfil a key role in the realisation of innovative use of ICT, the results also show that the school’s support can make an important contribution. This is especially true for the support and stimulation of personal entrepreneurship.

Conclusion 3:

Access to a personal computer, either laptop or desktop, as well as to a data-projector in the classroom is a minimum requirement for ICT use in subject teaching.

All three teachers in the cases studies had access to their own technology and did not rely on technology providers to make available that technology. The two teachers who used technology the most in this study were the two who had their own laptop and data-projector. The data projector should be considered a 21st century alternative to the overhead projector as it allows teachers to share information with their students in the same way that the overhead projector allows teachers to do.

The unlimited access to the technology allowed these two teachers to prepare lessons at home and present lessons at school. They were not restricted by the need to schedule teaching time in the computer room, as was the case with one of the teachers, which prioritised CAT lessons. Based on this, it is my contention that that a one-size-fits-all computer laboratory model, such as that for Gauteng Online, is not the most effective way forward in terms of an ICT roll-out strategy. The provision of a computer room for student-use seems to facilitate the teaching and learning of computer-specific skills in CAT but largely excludes the use of computers for subject teaching. The flexibility of access to the computer at any time, including at home, is what made ICT-use possible for the teachers in this study.

In addition to the provision of computer rooms in schools, the provision of laptops for teachers through the TLI should receive more government support and investment. There are, however, two issues which may impact negatively on the successful implementation of the TLI. The first is that as the initiative currently stands, teachers are required to make a large up-front investment in the purchasing of the laptop. Even with the government monthly rebate, this initial investment may restrict access and deter teachers from buying into the initiative. Secondly, security of technology remains a problem. Township schools are soft targets for the illegal acquisition of computer infrastructure for redistribution to township Internet cafés. The need for security for the computers in computer rooms has been addressed by the installation of well secured rooms with limited access but a similar set-up may not be suitable for portable technology. The threat of theft may deter teachers from investing in expensive technology which cannot be protected.

Conclusion 4:

The gap between ICT policy intentions as outlined in the South African e-Education White Paper (DoE, 2004b) and practice remains large, with policy seemingly unrelated to practice in science classrooms.

In the three individual cases of ICT use discussed in this study, none of the teachers' ICT practice was significantly influenced by either national or provincial policies on ICT in education. Mr Sogo's school ICT policy to some extent mirrored national policy intentions but, in reality, national policy had little or no influence on his ICT practice. Despite this, each of the teachers used ICT in ways that were determined by their own personal ICT vision.

The on-going challenge is to narrow the gap to ensure that national policy intentions are realized in classroom practice. One may be tempted to blame the gap on the difficulties typical of developing country contexts but there is no evidence from this research that this is the case. This conclusion supports Howie's (2009) study which compared ICT-supported Policies and Practices in two emerging economies, Chile and South Africa. Using the SITES 2006 data, Howie's showed that while Chile has many characteristics in common with South Africa, the two countries exhibit many differences with regard to the implementation of ICT policies. In Chile, the implementation of ICT in education has been fast and effective. This was achieved by a simultaneous top-down (government-led) and bottom-up (school ownership) strategy of implementation. Howie (2009) attributes in part the apparent success of ICT implementation in Chile to the government's focus, the private-public partnerships, and the simultaneous development and implementation of ICT policy.

8.6 Recommendations

This research was conducted, not to find out what teachers were doing wrong and why technology was not effectively used in South African classrooms, but rather to identify those teachers who were able to make use of technology, even if in a limited way, and see how they are using the available technology, why they are able to use it in that particular way, and what value that use of technology adds to teaching and learning Science. It was research about what works and why, with the aim of firstly understanding what is going on and secondly, making recommendations using the findings, so that the successful use of ICT can benefit teaching and learning in ways that outweigh the cost.

While South Africa has financial constraints associated with being a developing country, being a developing country need not limit ICT policy implementation in schools. Lessons from other countries with similar constraints such as Chile should have a greater influence on ICT policy development and implementation in South Africa. One fundamental difference between the South African approach and the Chilean approach is the phasing in of the ICT implementation, starting with basic resources before installing more advanced ICT equipment and resources. The *Enlaces* Project ("links" in English) in Chile provides a model in how to take a "computers in school" initiative to scale (Budge, 2009). The Project provided important planning and implementation lessons based on the experiences of teachers and students using computers as an additional learning device, even though Internet connectivity was extremely limited at the start of the project. The Enlaces Project has several lessons, some of which are useful for other countries with similar educational contexts (Budge, 2009).

Firstly, the limited financial resources available in a country such as South Africa mean that there is unlikely to be a widespread and extensive increase in available technology infrastructure in schools any time soon. The goal is to use the limited resources optimally. Other studies have shown that optimal results can be achieved by focusing on research and support for teachers and teaching, not the technology. Training and teacher support was central to the success of The Enlaces Project which integrated technology into learning environments. In addition, actively involving teachers in decision-making about using computers and learning networks was critical to the programme's success.

Secondly, pilot projects should be used to test theories and strategies before implementing them on a large scale. New, complex, and technically difficult initiatives are often best started as small, flexible pilot projects designed to test key ideas, refine strategies, and demonstrate potential. The provincial Gauteng Online Project has provided enough evidence of an efficient and effective ICT strategy to support a revision of the strategy of ICT access for education be adopted moving forward.

Thirdly, projects will benefit significantly from a well-developed power and telecommunications infrastructure. Access to the Internet was a key theme which allowed teachers to access high quality educational resources which emerged from this study. However, the absence of this should not preclude such initiatives. For a country like South Africa it may be too expensive and take too long to establish a conventional power and communications infrastructure to reach all communities, especially the poorest and most remote rural areas. Solar energy is one possible technology that needs to be explored in South Africa. In remote areas it may be possible to create clusters of linked schools or learning network cells via wireless technologies, a strategy currently not well supported in South Africa.

Fourthly, computers should be gradually introduced into schools and into teaching and learning activities. It takes time for teachers and schools to adjust to using computers and communications tools and integrate these technologies into educational programmes. The Khanya Project in the Western Cape can provide some useful lessons in this regard. The project has nine primary objectives outlined in section 1.2.4, and a clear implementation framework (available at http://www.khanya.co.za/projectinfo/?catid=22.). There are three aspects of this implementation framework which require special mention as being of particular interest as points of recommendation to policy-makers. The first aspect is the need to conduct a full needs analysis of each school prior to the implementation of technology in the schools. This means that each school is assessed for its readiness to receive technology. In the case of a school being identified as unready to receive technology, some preparatory work may be needed before technology is installed. The Khanya Project uses a staged approach to identify the specific level of need of each of the 1,132 schools in the programme. The eight stages are: Identified for inclusion into the Khanya Project; Negotiations phase; Planning phase; Infrastructure phase; Technology installation phase; Software installation phase; Network administrator training; Curriculum delivery. Only when the first seven stages have been complete is the school ready for using technology to deliver the curriculum. Leapfrogging over the initial stages and attempting to use technology to deliver the curriculum has been recognized as fruitless. In a situation of scarce financial resources, as is the case in South Africa, the cost-benefit analysis of technology installation should determine that those schools which have the necessary teacher expertise to fully utilize the technology be prioritized for installation of computer laboratories. The ICT competence of the three teachers in this study, while different in each case, was a key factor in allowing them each to use the technology available to them. Not all three were able to use it to its full potential, but in none of the three cases was the technology lying idle, as is the case in many South African schools. The unused Gauteng Online laboratories in many Gauteng Province schools, while sometimes a function of lack of technical support, is often the result of lack of teacher expertise in ICT use.

Fifthly, technical assistance for ICT needs to be decentralized so that teachers are able to get solutions to technical problems quickly. This is one aspect of ICT implementation which has been particularly problematic in South Africa. The delay in sorting out technical difficulties in many of the Gauteng Online computer rooms has meant that the computers cannot be used for long periods of time, leading to a general disillusionment on the part of the teachers.

Sixthly, ICT initiatives should be driven by curriculum goals. If digital learning materials directly support the curriculum, the teachers are more likely to integrate them into their teaching practice on a regular basis. Mrs Marley was a good example of this. She was able to use the available computer room successfully and frequently because of the availability of curriculum-linked software which had been provided. It meant that even with low TPCK, this teacher was able to support her teaching with

ICT in ways that benefited the students. This alignment with the curriculum is also extremely important as a way of ensuring a level of quality in curriculum delivery, especially in situations where teachers have low SCK, as is the case with many South African teachers.

Lastly, there is a need to ensure effective professional development in the technical and pedagogical use of ICT in conjunction with technology installations. The importance of the concept TPCK has not yet influenced teacher professional development programmes in South Africa (neither INSET nor PRESET) and it is my recommendation that attention needs to be paid to this. This needs to go hand-in-hand with research on how precisely to assist in the development of TPCK to ensure that teachers are effectively trained in how to use and integrate ICT into practice. In the Khanya Project, in addition to a good SCK, teachers need to be sensitised to the use of technology, equipped with the basic technology skills, and provided with functional training in the integration of technology with other modes of curriculum delivery in order to ensure technology is used effectively. The SITES 2006 data suggested that attendance at these sorts of professional development activities was very low, despite a willingness on the part of the teachers to attend. It is a time-consuming and labour-intensive process but is a key aspect of the effective use of ICT in the classroom.

8.7 A final word

Three science teachers invited me into their classrooms to explore how they used ICT when they taught science. All three teachers participated voluntarily and all three were proud teachers who were keen to share their experiences with me. They were enthusiastic and dedicated to their students, wanting to make a difference. During the time I spent at the three schools, I watched and listened. For a teacher, being watched is not easy as it exposes vulnerabilities.

This study started in the classroom and I propose to bring it to a close with a short vignette, an incident which remains a critical insight into teachers and their use of technology. While observing Mrs Marley's lesson one day, I noticed that the IWB standing at the front of her classroom had light green writing on in. It was the sort of writing that is left from white board markers. I asked Mrs Marley about the writing and she looked a little embarrassed as she replied that the CAT teacher had thought that the IWB, possibly the most expensive piece of technology that the school was ever likely to get, was an ordinary white board. He had written all over the board with white board marker and when he tried to erase the writing, he realized what he had done. Mrs Marley may have felt uncomfortable after that incident but she still invited me back.

Teachers who open their classrooms to outsiders like me need to be commended. I can only hope that I left more than I took. We as researchers owe it to teachers to use what we find to make a difference to education in South Africa and I hope that this study is sensitive to that, and that it in some way makes a difference.

REFERENCES

Ainley, J., Banks, D., & Fleming, M. (2002). The influence of IT: perspectives from five Australian schools. *Journal of Computer Assisted Learning, 18*(4), 395-404.

Anderson, R. E. (2008). Implications of the Information and Knowledge Society for Education. In J. Voogt & G. Knezek (Eds.), *International Handbook of Information Technology in Primary and Secondary Education* (Vol. 1, pp. 5-22). New York: Springer.

Andrews, R., & Haythornwaithe, C. (2007). Introduction to e-learning Research. In R. Andrews & C. Haythornwaithe (Eds.), *The Sage Handbook of E-learning Research* (pp. 539): Sage Publications.

Angeli, C. (2005). Transforming a teacher education method course through technology: effects on pre-service teachers' technology competency. *Computers & Education, 45*(4), 383-398.

Angeli, C., & Valanides, N. (2005). Preservice elementary teachers as information and communication technology designers: an instructional systems design model based on an expanded view of pedagogical content knowledge. *Journal of Computer Assisted Learning, 21*(4), 292-302.

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education, 52*(1), 154-168.

Baggott La Velle, L., McFarlane, A., & Brawn, R. (2003). Knowledge transformation through ICT in science education: a case study in teacher-driven curriculum development - Case-Study 1. *British Journal of Educational Technology, 34*(2), 183-199.

Balanskat, A., Blamire, R., & Kefala, S. (2006). The ICT Impact Report: A review of studies of ICT impact on schools in Europe. Brussels, Belgium: European Schoolnet.

Baxter, J. H., & Preece, P. F. W. (2000). A Comparison of Dome and Computer Planetaria in the Teaching of Astronomy. *Research in Science & Technological Education, 18*(1), 63-69.

Becta. (2002). The Impact of Information and Communication Technologies on Pupil Learning and Attainment, *ICT in Schools Research and Evaluation Series No. 7*: British Educational Communications and Technology Agency.

Becta. (2003). What the research says about barriers to the use of ICT in teaching [Electronic Version], 1-3, from http://partners.becta.org.uk/upload-dir/downloads/page_documents/research/wtrs_barriersinteach.pdf

Becta. (2004). What the research says about the use of ICT in science [Electronic Version], 1-3, from http://publications.becta.org.uk/display.cfm?resID=25809

Betts, S. (2003). Does the use of ICT affect quality in learning science at Key Stage 3? *Studies in Teaching and Learning*, 9-17.

Blignaut, A. S., Hinostroza, J. E., Els, C. J., & Brun, M. (2010). ICT in education policy and practice in developing countries: South Africa and Chile compared through SITES 2006. *Computers & Education, in press*, 1-12.

Blignaut, A. S., & Howie, S. J. (2009). National Policies and Practices on ICT in Education: South Africa. In T. Plomp, R. E. Anderson, N. Law & A. Quale (Eds.), *Cross-National Information and Communication Technology: Policies and Practices in Education*: Information Age Publishing.

Bogdan, R. C., & Biklen, S. K. (1992). *Qualitative Research for Education: An Introduction to Theory and Methods* (2nd ed.). Needham Heights: Allan and Bacon Inc.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington DC: National Academic Press.

Brese, F., & Carstens, R. (Eds.). (2009). *SITES 2006 User Guide for the International Database*: International Association for the Evaluation of Educational Achievement.

Budge, E. C. (2009). Chile: Building the National Learning Network “Enlaces”. Retrieved 20 July, 2010, from http://learnlink.aed.org/Publications/Sourcebook/chapter4/chile_casestudy.pdf

Carstens, R., & Pelgrum, W. J. (2009). Second Information Technology in Education Study: SITES 2006 Technical Report (pp. 188). Amsterdam: International Association for the Evaluation of Educational Achievement (IEA).

Cherryholmes, C. H. (1992). Notes on Pragmatism and Scientific Realism. *Educational Researcher, 21*(6), 13-17.

Cohen, L., Manion, L., & Morrison, K. (2003). *Research Methods in Education* (5th ed.). London: Routledge Falmer.

Cox, M., Preston, C., & Cox, K. (1999, September 2-5 1999). *What Factors Support or Prevent Teachers from Using ICT in their Classrooms?* Paper presented at the British Educational Research Association Annual Conference, University of Sussex.

Cox, M., Webb, M., Abbott, C., Blakeley, B., Beauchamp, T., & Rhodes, V. (2004). ICT and Pedagogy: A review of Research Literature. Coventry and London: British Educational Communications and Technology Agency/Department for Education and Skills.

Creswell, J. W. (2002). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*: Merrill Prentice Hall.

Creswell, J. W. (2003). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (Second ed.): Sage Publications.

Creswell, J. W. (2007). *Qualitative Inquiry and research Design: Choosing Among Five Approaches*: Sage Publications.

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (third ed.): Sage Publications.

Crouch, L., & Perry, H. (2001). Educators. In HSRC (Ed.), *Human Resources Development Review 2003: Education, Employment and Skills in South Africa*. Cape Town: HSRC Press and East Lansing: Michigan State University Press.

Cuban, L., Kirkpatrick, H., & Peck, C. (2001). High Access and Low Use of Technologies in High School Classrooms: Explaining an Apparent Paradox. *American Educational Research Journal, 38*(4), 813-834.

Cych, L. (2006). Social networks. In Becta (Ed.), *Emerging Technologies for Learning* (pp. 32-41): Becta.

Denzin, N. K., & Lincoln, Y. S. (2003). *Collecting and Interpreting Qualitative Materials*: SAGE Publications.

Denzin, N. K., & Lincoln, Y. S. (2005). *The Sage handbook of qualitative research* (3rd ed.). Thousand Oaks, CA: Sage.

DoE. (2002a). *National Curriculum Statement Assessment Guidelines for General Education and Training (Intermediate and Senior Phases) Natural Sciences*. Retrieved. from http://www.education.gov.za/Curriculum/GET/doc/ANaturalSciences.pdf.

DoE. (2002b). *Revised National Curriculum Statement Grade R-9 (Schools): Technology*. Retrieved. from www.education.gov.za.

DoE. (2003). *National Curriculum Statement Grades 10 – 12 (General) Computer Applications Technology*. Retrieved. from www.education.gov.za.

DoE. (2004a). EMIS Database. 2007, from http://www.education.gov.za/emis/emisweb/statistics.htm

DoE. (2004b). *White Paper on e-Education*. Retrieved July 2007. from www.education.gov.za.

DoE. (2007). *National Education Infrastructure Management System (NEMIS)*. Retrieved July 2007. from http://www.education.gov.za/emis/emisweb/statistics.htm.

DoE. (2008). Education Statistics in South Africa 2006. Retrieved May, 2010, from http://www.education.gov.za/emis/emisweb/08stats/Education%20Statistics%20in%20South%20Africa%202006.pdf

DoE. (2009). Teacher Laptop Initiative. Retrieved September 2009, from http://www.education.gov.za/dynamic/dynamic.aspx?pageid=310&id=8553

Drenoyianni, H., & Selwood, I. (1998). Conceptions or misconceptions? Primary teachers' perceptions and use of computers in the classroom. *Education and Information Technologies, 3*(2), 87-99.

Drent, M., & Meelissen, M. (2008). Which factors obstruct or stimulate teacher educators to use ICT innovatively? *Computers & Education, 51*(1), 187-199.

Driver, R. (1990). Constructivist approaches to science teaching. *Paper presented at the University of Georgia, Mathematics Education Department as a contribution to the Seminar Series "Constructivism in Education".*

Driver, R. (1994). Constructivist perspectives on learning science. In P. L. Lijnse (Ed.), *European research in Science Education - Proceedings of the first Ph. D. Summerschool* (pp. 65-74). Utrecht: CD Press.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Duit, R. (1994). A constructivist view of learning science, especially physics. In F. G. Brinkman, J. A. van der Schee & M. C. Schouten-Van Parreren (Eds.), *Curriculum research: Different disciplines and common goals* (pp. 105-121). Amsterdam: Instituut voor Didakctiek en Onderwijspraktijk Vrije Universiteit.

Ertmer, P. A. (2001). Responsive instructional design: Scaffolding the adoption and change process. *Educational Technology, 41*(6), 33–38.

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? . *Educational Technology Research and Development, 53*(4), 25-39.

Ertmer, P. A., Addison, P., Lane, M., Ross, E., & Woods, D. (1999). Examining teachers' beliefs about the role of technology in the elementary classroom. *Journal of Research on Computing in Education, 32*(1), 54.

European Union. (2004). Europe needs more scientists: EU blueprint for action [Electronic Version]. Retrieved 25 January 2010, from http://europa.eu/rapid/pressReleasesAction.do?reference=IP/04/444&format=HTML&aged=0&language=EN&guiLanguage=en

Fuchs, T., & Woessmann, L. (2004). Computers and Student Learning: Bi-variate and Multivariate Evidence on the Availability and Use of Computers at Home and at School. Unpublished working paper. CESifo working paper 1321.

GautengOnline. (2003). GautengOnline: Bridging the Digital Divide. Retrieved July, 2008, from http://www.gautengonline.com/

Gibson, I. W. (2001). At the intersection of technology and pedagogy: considering styles of learning and teaching. *Technology, Pedagogy and Education, 10*(1), 37 - 61.

Guba, E. G. (1990). The Alternative Paradigm Dialogue. In E. G. Guba (Ed.), *The Paradigm Dialogue*. Newbury Park, CA: Sage Publications.

Hall, I., & Higgins, S. (2005). Primary school students' perceptions of interactive whiteboards. *Journal of Computer Assisted Learning, 21*(2), 102-117.

Harrison, C., Comber, C., Fisher, T., Haw, K., Lewin, C., Lunzer, E., et al. (2002). ImpaCT2: The Impact of Information and Communication Technologies on Pupil Learning and Attainment. London: Department for Education and Skills.

Hermans, R., Tondeur, J., J. van Braak, & Valcke, M. (2008). The impact of primary school teachers' educational beliefs on the classroom use of computers. *Computers & Education, 51* 1499-1509.

Hermans, R., Tondeur, J., van Braak, J., & Valcke, M. (2008). The impact of primary school teachers' educational beliefs on the classroom use of computers. *Computers & Education, 51* 1499-1509.

Hewson, P. W., & Hewson, M. G. A. B. (1988). An appropriate conception of teaching science: A view from studies of science learning. *Science Education, 72*(5), 597-614.

Hinostroza, J. E., Hepp, P. K., & Cox, K. (2009). National Policies and Practices on ICT in Education: Chile. In T. Plomp, R. E. Anderson, N. Law & A. Quale (Eds.), *Cross-National ICT Policies and Practices in Education* (pp. 153-170). Charlotte, NC: Information Age Publishing.

Hinostroza, J. E., Labbé, C., López, L., & Iost, H. (2008). Traditional and Emerging IT Applications for Learning. In J. Voogt & G. Knezek (Eds.), *International*

Handbook of Information Technology in Primary and Secondary Education (Vol. 1, pp. 81-96): Springer.

Howie, S. J. (2001). *Mathematics and Science Performance in Grade 8 in South Africa 1998/1999*: Human Sciences Research Council.

Howie, S. J. (2009). ICT-Supported Pedagogical Policies and Practices in South Africa and Chile: Emerging Economies and Realities. *Journal of Computer Assisted Learning, unpublished.*

Howie, S. J., E. Venter, Van Staden, S., Zimmerman, L., Long, C., Sherman, V., et al. (2007). Progress in International Reading Literacy Study 2006: Summary Report. South African children's reading literacy achievement. Pretoria: Centre for Evaluation and Assessment: University of Pretoria.

Howie, S. J., Van Staden, S., Draper, K., & Zimmerman, L. (2010). An Evaluation of the Implementation of the FET Curriculum: Gauteng (unpublished). Pretoria: Centre for Evaluation and Assessment.

Huppert, J., Lomask, S. M., & Lazarowitz, R. (2002). Computer simulations in the high school: students' cognitive stages, science process skills and academic achievement in microbiology. *International Journal of Science Education, 24*(8), 803 - 821.

Intel Education. (2003). Intel Teach to the Future. Retrieved September 2009, from http://www.intel.com/cd/corporate/education/emea/eng/za/395993.htm

Jakobsdottir, S. (2001). Some effects of information and communications technology on teaching and learning in Iceland. *Technology, Pedagogy and Education, 10*(1), 87 - 100.

Jita, L. C., & Ndlalane, T. C. (2005, January 10-14). *How much do science teachers know?* Paper presented at the SAARMSTE, Windhoek, Namibia.

Jones, A. (2004). A Review of the Research Literature on Barriers to the Uptake of ICT by Teachers (pp. 29): British Educational Communications and Technology Agency.

Jukes, I., & Dosaj, A. (2006). Understanding Digital Children (DKs): Teaching & Learning in the New Digital Landscape. Retrieved 24 January 2010, from http://www.ibo.org/ibap/conference/documents/IanJukes-UnderstandingDigitalKids.pdf

Kennisnet. (2007). Four in Balance Monitor 2007: ICT in Education in the Netherlands. Retrieved 24 February, 2009, from http://downloads.kennisnet.nl/onderzoek/fourinbalancemonitor2007.pdf

Kennisnet. (2009). Four in Balance Monitor 2009: ICT in Dutch Schools. Retrieved 25 January, 2010, from http://onderzoek.kennisnet.nl/onderzoeken/monitoring/fourinbalance2009

Khanya. (2001). The Western Cape Education Department Technology in Education Project. Retrieved September, 2009, from http://www.khanya.co.za/

Kozma, R. B. (2008). Comparative Analysis of Policies for ICT in Education. In J. Voogt & G. Kozma (Eds.), *International Handbook of Information Technology in Primary and Secondary Education* (Vol. 2, pp. 765-778): Springer.

Kozma, R. B. (Ed.). (2003). *Technology, Innovation, and Education Change: A Global Perspective* (First ed.): ISTE Publications.

Kuiper, E., Volman, M., & Terwel, J. (2005). The Web as an Information Resource in K-12 Education: Strategies for Supporting Students in Searching and Processing Information. *Review of Educational Research, 75*(3), 285-328.

Lai, K.-W. (2008). IT and the learning process. In J. Voogt & G. Knezek (Eds.), *International Handbook of Information Technology in Primary and Secondary Education* (Vol. 1). New York: Springer.

Law, N. (2009). Mathematics and science teachers' pedagogical orientations and their use of ICT in teaching. *Education and Information Technologies, 14*(4), 309-323.

Law, N., & Chow, A. (2007). Pedagogical Orientations in Mathematics and Science and the use of ICT. In N. Law, W. J. Pelgrum & T. Plomp (Eds.), *Pedagogy and ICT Use in Schools Around the World: Findings from the IEA SITES 2006 Study*. Hong Kong: Springer.

Law, N., & Chow, A. (2008). Pedagogical Orientations in Mathematics and Science and the use of ICT. In N. Law, W. J. Pelgrum & T. Plomp (Eds.), *Pedagogy* *and ICT Use in Schools Around the World: Findings from the IEA SITES 2006 Study*. Hong Kong: Springer.

Law, N., Pelgrum, W. J., & Plomp, T. (Eds.). (2008). *Pedagogy and ICT use in schools around the world: Findings from the IEA SITES 2006 study*: Springer.

Lewin, C., Somekh, B., & Steadman, S. (2008). Embedding interactive whiteboards in teaching and learning: The process of change in pedagogic practice. *Education and Information Technologies, 13*(4), 291–303.

Linn, M. C., & Hsi, S. (2000). *Computers, Teachers, Peers: Science learning partners*. Mahwah, NJ: Erlbaum Associates.

Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., & Chrostowski, S. J. (2004). *TIMSS 2003 International Science Report: Findings From IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*.: International Association for the Evaluation of Educational Achievement.

Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., Gregory, K. D., Smith, T. A., Chrostowski, S. J., et al. (2000). *TIMSS 1999 International Science Report: Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade*: International Study Centre.

Mason, J. (2006). Mixing methods in a qualitatively driven way. *Qualitative Research, 6*(1), 9-25.

Maxcy, S. J. (2003). Pragmatic Threads in Mixed Methods Research in the Social Sciences: The Search for Multiple Modes of Inquiry and the End of the Philosophy of Formalism. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of Mixed Methods in Social and Behavioral Research* (pp. 51-89): Sage Publications.

McFarlane, A. (2003). Editorial. assessment for the digital age. *Assessment in Education: Principles, Policy & Practice,* pp. 261-266, from 10.1080/0969594032000148127
http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=11984977&site=ehost-live&scope=site

McFarlane, A., & Friedler, Y. (2003). Where You Want IT, When You Want IT: The role of portable computers in science education. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (Vol. 1, pp. 399-418). Dordrecht: Kluwer Academic Publishers.

McFarlane, A., Harrison, C., Somekh, B., Scrimshaw, P., Harrison, A., & Lewin, C. (2000). Impact2 Project Preliminary Report: Establishing the Relationship between Networked Technology and Attainment. London: Department for Education and Skills (DfES).

McFarlane, A., & Sakellariou, S. (2002). The Role of ICT in Science Education. *Cambridge Journal of Education, 32*(2), 219-232.

Merriam, S. B. (1988). *Case Study Research in Education* (First ed.). San Francisco: Jossey-Bass Publishers.

Mertens, D. M. (1998). *Research Methods in Education and Psychology: Integrating Diversity with Quantitative and Qualitative Approaches* (2 ed.). Thousand Oaks, CA: Sage Publications.

Miles, M. B., & Huberman, A. M. (1994). *An Expanded Sourcebook: Qualitative Data Analysis* (Second ed.): SAGE Publications.

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record, 108*(6), 1017-1054.

Mistler-Jackson, M., & Songer, N. B. (2000). Student Motivation and Internet Technology: Are Students Empowered to Learn Science? *Journal of Research in Science Teaching, 37*(5), 459-479.

Molefe, N. P. J., Lemmer, M., & Smit, J. J. A. (2005). Comparison of the learning effectiveness of computer-based and conventional experiments in science education. *South African Journal of Education, 25*(1), 50-55.

Mueller, J., Woods, E., Willoughby, T., Ross, C., & Specht, J. (2008). Identifying discriminating variables between teachers who fully integrate computers and teachers with limited integration. *Computers & Education, 51*, 1523-1537.

National Science Board. (2008). *Science and Engineering Indicators 2008: Volume 1*. from http://www.nsf.gov/statistics/seind08/pdf/volume1.pdf

National Science Teachers Association. (2003). Standards for Science Teacher Preparation [Electronic Version], 40. Retrieved October 2008, from http://www.nsta.org/pdfs/NSTAstandards2003.pdf

Newton, L. R. (2000). Data-logging in practical science: research and reality. *International Journal of Science Education, 22*(12), 1247 - 1259.

Noss, R., & Pachler, N. (1999). The challenge of new technologies: Doing old things in a new way or doing new things? In P. Mortimore (Ed.), *Understanding Pedagogy and its Impact on Learning* (pp. 195-211): Paul Chapman Publishing Ltd.

OECD. (2001). Learning to Change: ICT in Schools (pp. 118). Paris: OECD.

OECD. (2004). Policy Brief: Lifelong Learning (Vol. 2008, pp. 8). Paris: OECD Observer.

OECD. (2006, 18 December). Recommendation of the European Union Parliament and of the Council on Key Competencies for Life-long Learning. Retrieved 01 July, 2010, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:394:0010:0018:en:PDF

OECD. (2008, 15-16 May). *New Millennium Learners: Initial findings on the effects of digital technologies on school-age learners*. Paper presented at the OECD/CERI International Conference "Learning in the 21st Century: Research, Innovation and Policy", Paris.

Onwu, G. (1998). Teaching large classes. In P. Naidoo & M. Savage (Eds.), *African science and technology education into the new millennium: practice, policy and priorities* (pp. 119-132): Juta.

Onwu, G. (1999). Inquiring into the Concept of Large Classes: Emerging Typologies in an African context. In M. Savage & P. Naidoo (Eds.), *Using the Local Resource Base to Teach Science and Technology: Lessons from Africa* (pp. 122-133).

Onwu, G., & Stoffels, N. (2005). Instructional functions in large, under-resourced science classes: Perspectives of South African teachers. *Perspectives in Education, 23*(3), 79-91.

Osborne, J., & Collins, S. (2000). Pupils' and parents views of the school science curriculum. *School Science Review, 82*(298), 23-31.

Osborne, J., & Hennessy, S. (2003). Literature Review in science education and the role of ICT: Promise, problems and future directions [Electronic Version]. *NESTA Futurelab Series*, from http://www.futurelab.org.uk/resources/documents/lit_reviews/Secondary_Science_Review.pdf

Pelgrum, W. J. (2001). Obstacles to the integration of ICT in education: results from a worldwide educational assessment. *Computers & Education, 37*(2), 163-178.

Pelgrum, W. J., & Anderson, R. E. (Eds.). (1999). *ICT and the Emerging Paradigm for Life-long Learning: A Worldwide Educational Assessment of infrastructure, goals, and practices* (Second ed.). Amsterdam: International Association for the Evaluation of Educational Achievement.

Pelgrum, W. J., & Plomp, T. (Eds.). (1993). *The IEA Study of Computers in Education: Implementation of an Innovation in 21 Education Systems* (First ed. Vol. 13). Great Britain: Pergamon Press.

Piaget, J. (1978). *Success with Understanding*. London: Routledge.

Plomp, T. (2006). *Preparing for teaching in an information society: various perspectives*. Paper presented at the Society for Information Technology in Teacher Education - SITE, Orlando (FL, USA).

Prensky, M. (2001). Digital Natives, Digital Immigrants [Electronic Version]. *On the Horizon, 9 (5)*. Retrieved 24 January 2010, from http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf

Quellmalz, E. S., & Kozma, R. B. (2003). Designing Assessment Tools of Learning with Technology. *Assessment in Education: Principles, Policy & Practice, 10*(3), 389-407.

Raikes, N., & Harding, R. (2003). The horseless carriage stage: replacing conventional measures. *Assessment in Education: Principles, Policy & Practice, 10*(3), 267-277.

Reddy, V. (2006). *Mathematics and Science Achievement at South African Schools in TIMSS 2003*. Cape Town: HSRC Press.

Ridgway, J., & McCusker, S. (2003). Using computers to assess new educational goals. *Assessment in Education: Principles, Policy & Practice, 10*(3), 309-328.

Russell, M., Goldberg, A., & O'Connor, K. (2003). Computer-based testing and validity: a look back into the future. *Assessment in Education: Principles, Policy & Practice, 10*(3), 279-293.

Shindler, J. (2008). Public Schooling. In A. Kraak & K. Press (Eds.), *Human Resources Development Review 2008: Education, Employment and Skills in South Africa*. Cape Town: HSRC Press.

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review, 57*(1), 1-22.

Silverman, D., & Marvasti, A. (2008). *Doing Qualitative Research: A Comprehensive Guide*: Sage Publications.

Slay, H., Siebörger, I., & Hodgkinson-Williams, C. (2008a). A feasibility study on the use of 'smart' pens in South African teaching and learning environments. *South African Computer Journal, 40*, 83-94.

Slay, H., Siebörger, I., & Hodgkinson-Williams, C. (2008b). Interactive whiteboards: Real beauty or just "lipstick"? *Computers & Education, 51*.

Smith, F., Hardman, F., & Higgins, S. (2006). The impact of interactive whiteboards on teacher-pupil interaction in the National Literacy and Numeracy Strategies. *British Educational Research Journal, 32*(3), 443-457.

Songer, N. B. (2003). Can Technology Bring Students Closer to Science? In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (Vol. 1, pp. 333-350). Dortrecht: Kluwer Academic Publishers.

South African Schools' Act, (1996).

Stake, R. (1995). *The Art of Case Study Research*. Thousand Oaks, CA: Sage Publications.

Tashakkori, A., & Teddlie, C. (2003). Major Issues and Controversies in the use of Mixed Methods in the Social and Behavioral Science. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of Mixed Methods in Social and Behavioral Research*: SAGE Publications.

Tashakkori, A., & Teddlie, C. (2009). *Foundations of Mixed Methods Research*: Sage.

Tlabela, K., Roodt, J., Paterson, A., & Weir-Smith, G. (2007). *Mapping ICT Access in South Africa*. Cape Town: HSRCo. Document Number)

Torff, B., & Tirotta, R. (2010). Interactive whiteboards produce small gains in elementary students' self-reported motivation in mathematics. *Computers & Education, 54*(2), 379-383.

Trindade, J., Fiolhais, C., & Almeida, L. (2002). Science learning in virtual environments: a descriptive study. *British Journal of Educational Technology, 33*(4), 471-488.

Twining, P., Broadie, R., Cook, D., Ford, K., Morris, D., Twiner, A., et al. (2006). Educational Change and ICT: an exploration of Priorities 2 and 3 of the DfES e-strategy in schools and colleges: Becta.

Voogt, J. (2009). How Innovative are ICT-supported pedagogical practices in science education? *Education and Information Technologies, 14*(4), 325-343.

Voogt, J., & Knezek, G. (2008). IT in Primary and Secondary Education: Emerging Issues. In J. Voogt & G. Knezek (Eds.), *International Handbook of Information Technology in Primary and Secondary Education* (Vol. 1). New York: Springer.

Voogt, J., & Pelgrum, W. J. (2003). ICT and Curriculum Change. In R. B. Kozma (Ed.), *Technology, innovation, and educational change: A global perspective* (pp. 81-124): International Society for Technology in Education.

Vygotsky, L. S. (1978). *Mind in society : the development of higher psychological processes* Cambridge: Harvard University Press.

Watkins, C., & Mortimore, P. (1999). Pedagogy: What do we know? In P. Mortimore (Ed.), *Understanding Pedagogy and its Impact on Learning* (pp. 1-19): Paul Chapman Publishing Ltd.

Webb, M. E. (2002). Pedagogical Reasoning: Issues and Solutions for the Teaching and Learning of ICT in Secondary Schools. *Education and Information Technologies, 7*(3), 237-255.

Webb, M. E. (2005). Affordances of ICT in science learning: implications for an integrated pedagogy. *International Journal of Science Education, 27*(6), 705-735.

Webb, M. E. (2008). Impact of IT on Science Education. In J. Voogt & G. Knezek (Eds.), *International Handbook of Information Technology in Primary and Secondary Education* (Vol. 1, pp. 133-148): Springer.

Wilkinson, D., & Birmingham, P. (2003). *Using Research Instruments: A Guide for Researchers*: RoutledgeFalmer.

Willig, C. (2001). *Introducing Qualitative Research in Psychology: Adventures in Theory and Method*. Philadelphia: Open University Press.

Wirth, J., & Klieme, E. (2003). Computer-based assessment of problem solving competence. *Assessment in Education: Principles, Policy & Practice, 10*(3), 329-345.

Yin, R. K. (2003). *Case Study Research Design and Methods* (Third ed. Vol. 5): Sage Publications.

Zacharia, Z. C. (2005). The Impact of Interactive Computer Simulations on the Nature and Quality of Postgraduate Science Teachers' Explanations in Physics. *International Journal of Science Education, 27*(14), 1741–1767.

Zhao, Y., & Frank, K. A. (2003). Factors Affecting technology Uses in Schools: An Ecological Perspective. *American Educational Research Journal, 40*(4), 807-840.