

The Pedagogical Use of ICT in Grade Eight Natural Science Classes in South African Schools

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Abstract

Traditionally schools in the South African education system follow a paper-based approach. ICT use as teaching and learning tool expanded in developing countries during the last decade, especially with regard to pedagogical practices in educational environments. The aim of this study was to investigate the ICT pedagogical practices of science teachers in grade 8 classes through a SD analysis SC of the Second Information and Technology in Education Studies (SITES) 2006 data. South African science teachers formed the basis of the dataset for this study. Questionnaires were submitted to grade 8 science teachers of approximately 504 South African schools. During October 2006 the data was collected through a stratified and randomly selection method. In this SDA the pedagogical use of ICTs in grade 8 science education was explored by means of percentages and frequencies. Spearman's effect sizes were used to identify meaningful correlations between variables in an attempt to determine the contribution of ICT towards science education. The study found that the pedagogical uses of ICT in grade 8 natural science can contribution towards science education although the pedagogical uses of ICT are way below the expected standard. Results indicate that there are strong practically significant correlations between ICT skills and specific abilities and skills (i.e. learning motivation, learn at own pace, communication skills, info handling skills, collaborative skills and self-esteem) that narrow the achievement gap experienced in science education in South Africa. Promotion of these abilities and skills with the support of ICT skills indirectly narrow the achievement gap that may be associated poor grade 12 science learners. Finally a framework is proposed which apply ICT skills to address the abilities and skills (i.e. learning motivation, learn at own pace, communication skills, info handling skills, collaborative skills and self-esteem) that can narrow the achievement gap, experienced in grade 8 natural science. Although this study focused on grade 8 natural science, ICT skills can possibly be used to narrow the achievement gap for all school science curricula in South African schools.

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Table of Contents

Abstract	i
Acknowledgement	ii
List of Figures	vi
List of Tables	vii
List of Addendum	viii
List of Acronyms	ix

Chapter one: Orientation

1.1	Introduction	1
1.2	Problem statement.....	1
1.2.1	ICT in general	3
1.2.2	Pedagogical use of ICT in science education.....	4
1.3	Purpose and research aims.....	7
1.4	Research design.....	7
1.4.1	SITES 2006	7
1.4.2	Population and sample	8
1.4.3	Variables.....	8
1.4.4	Measuring instrument	8
1.4.5	Data analysis	8
1.4.6	Ethical aspects.....	9
1.4.7	Data collection	9
1.5	Contribution of the study.....	9
1.6	Chapter outline	9

Chapter two: The use of ICT in science education

2.1	Introduction	11
2.2	Science education	11
2.2.1	International views on science education	11
2.2.1.1	Science education in Norway	12
2.2.1.2	Science education in Canada	13
2.2.1.3	Science education in Hong Kong	16
2.2.1.4	Science education in Australia	18
2.2.2	National view on science education	20
2.3	ICT in education.....	23
2.4	ICT in science education	31
2.5	Pedagogical use of ICT	35
2.6	International significance of ICT policy	44
2.7	White Paper on e-Education.....	46

2.8	Policy recommendations.....	47
2.9	Contribution of ICT towards success n science education.....	48
2.10	Summary	59

Chapter three: Overview of SITES modules

3.1	Introduction	51
3.2	Background.....	51
3.3	SITES Module 1: Indicators module	52
3.4	SITES Modules 2: Innovative practices.....	55
3.5	Conceptual framework.....	56
3.6	Research questions	58
3.7	SITES 2006 sampling	59
3.8	SITES 2006 field trail	60
3.9	Aims of the SITES 2006	61
3.10	SITES scale indicators.....	62
3.11	Countries participating in SITES 2006.....	63
3.12	Summary	68

Chapter four: Research design and methodology

4.1	Introduction	69
4.2	Research design and methodology.....	69
4.2.1	Research design.....	69
4.2.2	Methodology	69
4.3	Research tool: SITES 2006 Science Teacher Questionnaire	70
4.4	Variables for the SDA	71
4.5	Study population for the SDA	72
4.6	Ethical aspects.....	72
4.7	Statistical analysis	73
4.8	Summary	74

Chapter five: Research findings and the discussion of findings

5.1	Introduction	75
5.2	Rationale and aim.....	75
5.3	Research design and methodology.....	76
5.3.1	Advantages and Disadvantages of self re-reported data	76
5.4	Results: Demographics.....	77
5.5	Results: Descriptive data analysis.....	78
5.5.1	Teachers' pedagogical uses of ICT in grade 8 natural science	78
5.5.1.1	Proportion of learners that are competent in ICT	78
5.5.1.2	Teachers' indicators that they use ICT for specific activities	79

5.5.1.3	Science teachers who indicated that they use ICT to carry out assessment	81
5.5.1.4	Science teachers who indicated that the learners use ICT to perform activities	82
5.5.1.5	Science teachers indicated that they incorporated ICT in their classes	83
5.5.1.6	General use of ICT and pedagogical use	84
5.5.2	ICT contribution towards science education in South African schools	87
5.5.2.1	Science teachers who indicated the impact of ICT on their teaching and learning activities	87
5.5.2.2	Computer competencies of science learners' operation skills according to science teacher responses	88
5.5.2.3	Use of ICT in pedagogical practice to change teaching	89
5.6	Findings: Factor analysis	91
5.6.1	Factor analysis of teacher questionnaire items 19 A-L (positive and negative ICT impact)	91
5.6.2	Factor analysis of teacher questionnaire items 20 (General learners skills developed via ICT)	92
5.6.3	Factor analysis of teacher questionnaire items 21 I-P (Teachers confident pedagogical use of ICT)	92
5.6.4	Factor analysis of teacher questionnaire items	93
5.7	Findings: Correlations	93
5.8	Summary	105

Chapter six: Conclusions and recommendations

6.1	Introduction	107
6.2	Outline of study	107
6.3	Review of Literature	107
6.3.1	Descriptive data	110
6.3.1.1	Proportion of learners that are competent in ICT	110
6.3.1.2	Teachers' indication that they use ICT for specific activities in the target classes	111
6.3.1.3	Science teachers who indicated that they use ICT to carry out Assessments	111
6.3.1.4	Science teachers who indicated that the learners use ICT to perform activities	111
6.3.1.5	Science teachers indicated that they incorporate ICT in their classes	111
6.3.2.6	General use of ICT and pedagogical use	111
6.3.2	Factor analysis and correlations	112
6.4	Proposed framework for pedagogical uses of ICT in grade 8 natural science	112
6.5	Eminent conclusion of the study	114
6.6	Limitations	114
6.6	Recommendations	115

List of Figures

Figure 3.1	SITES 2006 Conceptual framework.....	58
Figure 6.1	Framework for the pedagogical use of ICT in grade 8 natural science .	113

List of Tables

Table 4.1	Component of teacher questionnaire (science).....	71
Table 5.1	Demographical information about the learners in the target classes	77
Table 5.2	Proportion of learners that has competence in ICT according to the teacher participants	79
Table 5.3	ICT use in teaching activities by science teacher.....	80
Table 5.4	ICT used to carry out assessments according to science teacher respondents.....	81
Table 5.5	ICT used in teaching activities by learners according to science teacher respondents	82
Table 5.6	ICT incorporation of learning resources and tools in target class according to teacher respondents	84
Table 5.7	Percentage frequencies: general and pedagogical use of ICT in schools	86
Table 5.8	Impact of ICT use on science teachers indicated that they use ICT for teaching and learning activities.	88
Table 5.9	The extent to which the use of ICT impacted on the ICT competencies of the learners	89
Table 5.10	Use of ICT on pedagogical practice to change your teaching of the target class	90
Table 5.11	Positive and negative ICT Impact on teachers	92
Table 5.12	General learner skills developed via ICT	92
Table 5.13	Teachers' confident pedagogical use of ICT	93
Table 5.14	Teachers' pedagogical practice contribute to their teaching	93
Table 5.15	Spearman correlations	95

List of Addenda

- Addendum 5.1 SITES 2006 teacher grade 8 science education questionnaire
Addendum 5.2 SITES 2006 statistical data

Addendum available on CD-ROM at the back of the dissertation.

List of Acronyms

ICT	Information Communication Technology
SITES	Second Information Technology in Education study
OCED	Organisation for Economic Co-operation and Development
OBE	Outcomes Based Education
ODC	Online Data Connection
SDA	SD Analyses
SD	SD
DVD	Digital Versatile/video Disc
NSES	National Science Educational Standards
IEA	International Association for the Evaluation of Education Achievement
UNESCO	United Nation Educational Scientific and Cultural Organisation
ERT	European Roundtable of Industrialist
TIMMS	Trends in International Mathematics and Science Study
WWW	World Wide Web
ICC	International Coordinating Committee
BECTA	British Educational Communications and Technology Agency
CFA	Confirmatory Factor Analysis
RMSEA	Root Mean Square Error of Approximation
TLF	Tiger Leap Foundation
TELI	Technology Enhanced Learning Initiative
MPITE	Master Plan for IT in Education
HSRC	Human Science Research Council
IWB	Interactive White Board
TSW	Transforming School Workforce
MBL	Micro-computer Based Laboratory
NCTE	National Council of Educators
ISETT	Information System Electronics and Telecommunications Technologies
CPTD	Continuing Professional Teacher Development
CAL	Computer Assisted Learning
LMS	Learning Management System
IT	Information Technology
RBL	Resource Based Learning
ISBE	Inquiry Based Science Learning
PBL	Problem Based Learning
RBL	Resource Based Learning
ITMF	IT, Medier og Folkeskolen (In English: ICT, Media and Primary and Lower Secondary school)

DfES	Department for Educational and Skills
NSW	New South Wales
PPS	Probability Proportional to Size
DST	Department of Science and Technology
DoE	Department of Education
WISE	Web-based Inquiry Science Environment
ATM	Automatic Teller Machine
WCED	Western Cape Education Department
VCR	Video Cassette Recorder
SSPS	Statistical Package for the Social Sciences
LCD	Liquid crystal display
EMB	Education and Manpower Bureau
NNFI	Non-normed Fit Index
ISCED	International Standard Classification of Education
PISA	Programme for International Student Assessment
CoP	Community of Practice
TELS	Technology-Enhanced Learning in Science
NCD	National Curriculum Statement
PIRLS	Progress in International Reading Literacy Study

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

1.1 INTRODUCTION

The use of ICT as teaching and learning tool expanded in developing countries during the last decade, especially with regard to practice in educational environments. The interaction between teachers and learners escalate when they increase the chance of expanding their own knowledge, as much of learning inevitably takes place within a social context, a process which includes mutual construction of understanding (Law, Lee, Chan, & Yeun, 2008a). ICT is a deficit model for teachers, who are described as technophobic and traditional in their teaching styles. Teachers are reluctant to adopt new methods, such as computer technology and other ICT tools (Law, Pelgrum, & Plomp, 2008d), to teach their learners. Teachers and learners in science education¹, where knowledge and reflection are important, should be encouraged towards the application of ICT within a pedagogical cultural agenda of ICT-supported learning and ICT pedagogy approach.

1.2 PROBLEM STATEMENT

It is a worldwide concern in contemporary education that schools should prepare self-regulated learners, learners who show independent ideas and enquiring minds and who participate actively in the learning process by communicating and collaborating with experts and peers (Yoon, 2009). Self-regulated learners rise to academic success when they have the opportunity to take on various challenging tasks, practice their learning strategies, and develop a deep understanding of subject matter through perseverance (Perry, Phillips, & Hutchenson, 2006). Currently, the teaching-practice of many teachers remains a problem as it is still largely teacher-centred where knowledge transfer consists of the transfer of information from books. South Africa, like most of the African counties still is paper-bound. Learners easily get uninterested in the traditional teaching and learning strategies followed. Learners and schools perform differently in science; some learners and schools excel while other learners and schools perform below the expected norm. The poor performances indicate that there exist a large achievement gap between learners and the science subject matter knowledge. The South African science education system is challenged to introduce ICTs as support to science learners to narrow the achievement gap. Learners learn in a rote fashion and do not evolve to 21st century learning skills essential to survive in a technology-driven era (Law, et al., 2008d).

Historically, the primary educational technique of traditional teaching was simple oral recitation. In a typical approach learners sat quietly and listened to one individual after another recite his or her les-

¹ The term "science education" used in SITES2006 is similar to "natural science" in the South African grade 8 curriculum

son. A teacher-centred teaching-practice demands that learners follow the teacher passively, while they prefer to be actively engaged with the learning environment. Yelland, Neal & Dakich (2008) maintain that the basic school curriculum has remained unchanged for many decades and reform is a slow process. Learners are often bored with their school subjects, because teaching and learning are teacher-centred, while they are growing up in a technology-based environment preferring learner-centred classroom environments (Tapscott, 1999).

Learner-centred teaching focuses on the needs of the learners, rather than on the teachers involved (Estes, 2004). The learner-centred approach is also based on the learners' abilities, interests and learning styles with the teacher serving as facilitator. This teaching method acknowledges the learner's voice as central to the learning experiences for every learner and requires learners to be active, responsible participants in their own learning (Estes, 2004). Learner-centred education can be characterised by the following goals: a climate of trust in which curiosity and the natural desire to learn can be nourished and enhanced; a participatory mode of decision making in all aspects of learning in which learners and teachers share in uncovering the excitement of the intellectual and emotional discovery, which prompts learners to become lifelong students (Rogers, 1983). By means of learner-centred classroom environments, learners may be stimulated to develop a passion for their school subjects.

The Natural Science Policy envisages a teaching and learning milieu which recognises that the people of South Africa operate with a variety of learning styles as well as with culturally influenced perspectives (Department of Education, 2003b). The policy originates from the premise that all learners should have access to a meaningful science education. Meaningful education should be learner-centred and should help learners to understand not only scientific knowledge and how it is produced, but also the contextual environment and global issues that are intertwined within the learning area (Department of Education, 2003b). The teaching methodology for science entails that teachers act more as facilitators of learning than instructors. The teacher must never teach something without creating a clear context, the learner should be able to relate what he or she has been taught to his or her own frame of reference (Department of Education, 2003b).

Over many years, curriculum policy challenges have resulted in various unmanageable changes. Given the historical and situational constraints, most South African schools were not well placed to take on an innovation as radical as an outcomes-based education (OBE), without first putting in place some of the basic requirements of effective schooling. South Africa is using the implementation of an OBE both as an end in itself, with its associated learning outcomes, and as a means to the end of school improvement (Todda & Mason, 2005). Yelland et al. (2008) reports on major concerns about teachers' knowledge, disciplines and subjects—especially where science education is concerned. Previously, teachers encouraged students to study science through didactical practices and traditional texts. The Internet provides numerous interesting options and incorporates new teaching strategies, such as ICT, that can augment learners' interest and understanding of sci-

ence. These new and dynamic strategies that can enthrall learners to generate unique and personal knowledge are often overlooked. The sharing of their learning experiences with peers can function as additional motivators for learning (Yelland, et al., 2008). Law et al. (2008d) and Chandra and Loyd (2008) uphold that ICT can be instrumental in fostering teaching and learning in the 21st century. ICT may assist learners to develop their ability for lifelong learning, to undertake collaborative inquiry, and learn from experts and peers in a connected global environment.

Linn (2003) reports on a project that investigated pedagogical issues for science education in ICT-enhanced classrooms. He has compiled a list of pragmatic principles to encourage learners to build scientific ideas while they develop strong and useful pragmatic scientific principles. These principles included (i) encouraging learners to personally investigate relevant scientific problems, (ii) encouraging learners to regularly revisit their scientific hypotheses, (iii) scaffolding activities so that learners can readily participate in enquiry processes, (iv) modelling scientific processes, (v) considering alternative explanations for phenomena, (Khvilon & Patru, 2002) the early diagnosing of mistakes, (vii) engaging learners in reflection of their scientific ideas and progress of their understanding of scientific concepts and phenomena.

The findings of Linn (2003), Yelland, et al. (2008) and N Law, Pelgrim, & Plomp (2008b) have motivated me to investigate the pedagogical use of ICT in natural science classrooms in South African schools.

1.2.1 ICT in general

During the late 1980s, the use of the term *computers in education* was replaced by *information technology* (IT) in education. This signified a shift in focus from computing technology to the capacity to store, retrieve and use information (King, 2002, p. 233). Around 1992, the term *Information and Communications Technology* (ICT) came to the fore when *e-mail and virtual communication* became a general mode of communication (Kong, 2008, p. 130). Pelgrum (2008), Pelgrum et al. (2003) and Loveless and Dore (2002) define ICTs as the use of electronic information handling through an array of applications of *inter alia* computer equipment, multimedia productions, digital resources, mobile devices, digital video disks (DVDs), tutorial software, general software, data logging, simulations, communication software, smart boards, learning management systems (LMSs), Internet, email, modems, television, and other sophisticated laboratory equipment.

A benefit of ICT is that it demands that teachers employ more creative classroom practices. ICT can augment the quality and quantity of information available to learners and broaden the scope of learning resources. In addition, learning materials enriched with multimedia provide opportunities to accommodate learners' different learning styles. This includes the use of text, animated images, sound, hypertext, video and online interaction that can be adapted for individual, group and mass teaching

and learning (Pelgrum, 2008). According to Newton and Rogers (2003) ICT also allows teachers to modify teaching and learning materials for different contexts.

1.2.2 Pedagogical use of ICT in science education

Pedagogy entails the various forms of interaction between three agents: the teacher, the students and the knowledge domain (Czerniewicz, Ravjee, & Mlitwa, 2006). Watson (2001) describes pedagogical use of ICT as not only ICT, but a technique that ICT use to convert and to support learning cognition and meta-cognition, in order to create environments where people are given the tools to negotiate information and convert it to knowledge. Watson (1993, p. 254) claims that *... the use of ICT in the curriculum and schools will also be helping pupils become knowledgeable about the nature of information, comfortable with the new technology and able to exploit its potential.*

Science teaching is traditionally based on the use of two contrasting pedagogical approaches, the so called *deductive* and *inductive* approaches. The deductive approach may be identified as a traditionally applied model in the school environment that expands the standard knowledge base, while the inductive approach, more commonly employed in third level educational settings, anticipates that learners already have a certain level of knowledge and can have a certain degree of autonomy/self direction within the learning process (eLearning Papers, 2010). The inductive or bottom-up approach provides greater opportunity for observation, experimentation and self-driven knowledge acquisition. Within particular subject areas particularly that of science, the approach has been championed and refined and is commonly referred to as Inquiry Based Science Learning (ISBE). ISBE tackles some of the aforementioned difficulties associated with the deductive approach and is commonly applied within areas of study related to science, nature and technology. It is more commonly referred to as Problem Based Learning (PBL) when applied to the science of mathematics and engineering (eLearning Papers, 2010). In addition to the common use of both approaches in teaching science, the technological advances that have occurred during the last 15-20 years have revolutionised how modern learning environments are being defined and perceived by educationalists as a direct consequence of the approaches to knowledge creation and transmission (eLearning Papers, 2010). The rapid and ever increasing application and adoption of information based technologies, such as the Internet and the World Wide Web (WWW), prevents both an accurate distinction between different pedagogical strategies, as well as the application of presupposed constraints on the type of learning environment for which they are considered appropriate. The increased application of ICT has led to the introduction of new pedagogical approaches such as Resource Based Learning (RBL), which supports varied learning needs with a wide range of available ICT assets (eLearning Papers, 2010). Science subjects in particular are extremely amenable to the advantages offered by RBL and its associated ICT assets. One of the advantages associated with RBL for science teaching includes the use of computer simulation. Computer simulation permits users to operate in a safe virtual environment. The nature of computer simulations allow experimentation with the choice and use of rules, procedures and activities in various scenarios (eLearning Papers, 2010).

ICT benefits learners through individual and group activities (Sandholtz, 2001). ICT is explicitly designed for use in educational contexts, such as science teaching and learning. Scientific software form part of laboratory equipment, but are also encountered in more general contexts, such as classrooms. Word processing, spreadsheet calculation, database analysis, graphical presentations with data projectors, and working with scientific calculators add to the value of everyday science teaching. For example, while some learners collect data to perform experiments on an interactive Smart-Board, the science teacher could support other learners with their scientific thinking and planning (Cox & Abbott, 2004). Simulations assist learners in their understanding of scientific concepts, as well as the developing of their investigative skills (Kim, Hannafin, & Bryan, 2007). Computer modelling enable them to investigate and understand more complex models and processes, e.g. the structure of atoms and molecules (Osborne & Henesey, 2003). Sharing these ICT-integrated experiences with their peers enhance learners' experiences (Cox & Abbott, 2004).

McFarlane and Sakellariou (2002a) advocate the use of the Internet and other ICTs in the development of scientific literacy and learners' understanding of scientific concepts. According to Betts (2003) ICT can enhance the quality of science teaching and learning, especially when used for tailoring learning objectives for specific contexts. Furthermore, McFarlane and Sakellariou (2002a) argue that ICT could act as a tool for practical investigations, substitute the laboratory-based experiments, or assist in the theoretical understanding of complex issues. Although ICT in science education can substitute laboratory-based experiments science teachers generally do not have the time to prepare ICT based learning material to replace the table top experiments. Teachers should still facilitate the learners in the science laboratory, with or without ICT support, as teachers stay the gateway to knowledge. In many countries, globally teachers may criticize the substitution achievability within the context of their teaching environment known for teaching in over-crowded classrooms, outside classroom and so forth. An amended curriculum by unambiguous integration between the software and the curriculum can propose the possibility of incorporation of ICT in the science classroom environment for pedagogical use. Laboratory-based experiments if informed by the DoE will guide for consistent introduction of ICT for pedagogical use in laboratory-based experiments. Research clearly indicates that Internet provides a broad range of information and educational resources that may make science classrooms current and authentic (Osborne & Henesey, 2003). Osborne and Henesey (2003) argue that access to scientific texts, news, hypertext, hypermedia, and scientific data are necessary for interactive and relevant science teaching and learning.

ICT provide tools for teachers to present and demonstrate scientific activities and exercises as part of their teaching. Web-based materials suitable for science education provide opportunities for visual representation of scientific phenomena. The centre for Technology-Enhanced Learning in Science (TELS) at the University of California, Berkeley, has developed instructional programs for science classes which use multimedia simulations of real-world phenomena for learners to engage in scientific inquiry. Learners learn how to define magnitude, direction, measure, position, time, and velocity.

They also integrate Web-based learning experiences with classroom learning. The findings of the TELS on improved knowledge retention is related to the advantageous use of ICT (Linn, Lee, Tinker, Husic, & Chiu, 2006). Through the use of simulations, tutorials and practice programs learners can virtually interact with dangerous chemicals, phenomena can be repeated as often as needed and large and small objects can be scaled for easy visibility (McFarlane & Sakellariou, 2002a).

Cox and Abbott (2004) maintain numerous advantages for both teachers and learners when ICT is used in science teaching. Murphy (2003) is of the opinion that ICT enhance the development of learners' science skills, concepts and attitudes. He argues that ICT support both investigative skills, as well as knowledge-based skills of science learners. Cox and Abbott (2004) claims that ICT has a positive influence on the achievement of learners across all learning areas and subjects, especially in core subjects such as english, mathematics and science. They further argue that ICT improved learners' understanding of scientific concepts, development of problem-solving skills, formulation of hypotheses on scientific relationships and processes, and scientific reasoning and explanations. As early as 1991, Crook (1991) argued that the use of a variety of ICT throughout the curriculum enhanced learners' acceptance of responsibility for their learning and in 2009 Yoon (2009) still supports this notion.

Watson (1993) investigated the impact of ICT on learners' achievement in science and provides evidence that learners spend more time-on-task while engaging with ICT. The learners were able to complete tasks of cognitive complexity with less support from educators. More recently BECTA (2003c) indicated that change in learners' attitudes and motivation for learning increased when learners interacted with artificial intelligence tutors. Learners also tested their own hypotheses through informed predictions while interacting with ICTs (Linn, 2003). Morrisen, Gardner, Reily and McNally. (1993) showed an enhanced sense of achievement in learning amongst learners, when they engaged with computers across the curriculum. McFarlane and Friedler (1998) indicated the benefits of enhanced learning through the use of data-logging. Simulated learning environments, modelling tools and micro-worlds permitted manipulations of variables to observe effects, support tests, reveal complex scientific relationships and enabled students to gain a wider range of learning experiences (Webb, 2005).

To summarise, it becomes evident from the literature review that various scholars promote the use of ICT for pedagogical purposes in science education. The following research questions come to mind and guided this study:

- What are the pedagogical uses of ICT in grade 8 natural science in South African schools?
- How do the pedagogical uses of ICT in grade 8 natural science contribute towards science education in South African schools?

1.3 PURPOSE AND RESEARCH AIMS

The main purpose of this study is to investigate the ICT pedagogical practices of science teachers in grade 8 natural science classes through a SD analysis (SDA) of the Second Information and Technology in Education Studies (SITES) 2006 data. In order to accomplish the main purpose, the following research aims determined to:

- investigate the pedagogical uses of ICT in grade 8 natural science in South African schools
- determine how the pedagogical uses of ICT in grade 8 natural science contributes towards science education in South African schools.

1.4 RESEARCH DESIGN AND METHODOLOGY

This study followed a basis SDA methodology of the South African data of the comparative Second International Information Technology in Education Study (SITES 2006). SD can be numeric or non-numeric (Smith, 2006). The SITES 2006 international project report provides a comprehensive frequency analysis of the data of 22 countries and education systems (Law, et al., 2008d).

1.4.1 The SITES 2006

The central theme of the SITES study is to understand how ICT affect the way teachers use ICT as part of their daily teaching and learning practices. SITES 2006 is the third international comparative study that focuses on the way in which teachers and schools in different countries and educational systems use ICT in teaching and learning. SITES 2006 was a survey of schools and teachers that examined the pedagogical practices adopted by countries and education systems during their use of ICT. The study administered three questionnaires: to principals, to ICT coordinators at the schools, and to mathematics and science teachers in a stratified probabilistic sample of more than 400 schools per education system. The SITES 2006 required from school principals, technology coordinators and teachers in mathematics and science to provide data by means of a self reported questionnaire. The SITES 2006 comparative study required data directly from the participants and not from another source, as the focus was on the individuals' perception or belief. Although some researchers recognize self reported data as softer more subjective measures, other focus on the value of this form of data (Gonyea, 2005). Given the expansive use of self-reported data from surveys like the SITES 2006 it is can be concluded that self-reports can be trusted as valid and reliable. The data collection officially started in October 2004 and the process was completed towards the end of 2006 (SITES 2006, 2008b). SITES 2006 also examined how teachers used ICT and whether ICT contributed to learning activities geared towards the development of 21st century learning skills. Analyses were also conducted to identify conditions in a system, school and teacher levels associated with different ways of using ICT in teaching and learning. The study produced international comparisons of the various indicators, made recommendations on ICT education policies, and provided quantitative understanding of the way in which ICT impacted on teaching and learning processes (Law & Chow, 2008a). A selection of relevant questions from the SITES 2006 questionnaire for the science teacher was used

for the interpretation of the South African data. A two-way frequency analysis was conducted to investigate the relationship between the pedagogical use of ICT and effective science education in schools.

1.4.2 Population and sample

The South African data from the questionnaire for science teachers formed the basis of the dataset for this study. However, where appropriate, data from other participating countries, as well as data from the questionnaire for science teachers were used. The questionnaires were submitted to grade 8 science teachers of approximately 504 South African schools as part of a stratified and randomly selected sample during October 2006.

1.4.3 Variables

A variable is any quality or characteristic in research investigation that has two or more possible values (Leedy & Ormrod, 2010). The variables used in the SITES 2006 data are categorical of nature, i.e. it has a categorical response. The variables used for this study relates to the questions in the questionnaire used for the data collection of SITES 2006. The questions pertain to the grade 8 teachers' practices and some pertain to the pedagogical use of ICT in science classrooms.

1.4.4 Measuring instruments

The SITES 2006 questionnaire administered to the science teachers was the original survey instrument. This study used the South African SD.

1.4.5 Data analysis

Descriptive statistics were interpreted to provide an overview on ICT pedagogical practices in South African grade 8 science classrooms. The SDA of specific variables within the indicator fields, as indicated in the questionnaire, added useful insights into the grade 8 teachers' practices and the pedagogical use of ICT in science classrooms. The four main indicator fields included in the teacher questionnaires were:

- target class information, e.g. students' ICT competencies
- core indicators, e.g. ICT-using teacher-practices
- supplementary indicators, e.g. ICT and learning resources
- explanatory indicators, e.g. teachers' self-reported ICT competencies.

From the above indicators, different variables that contributed to the aims of this study were identified. Where appropriate, comparisons were made to international countries, to illustrate any similarities or differences that existed. Due to the categorical nature of the variables, two-way frequency tables and

a Chi-square test, for the association between grade 8 teachers' practices and pedagogical use of ICT were conducted (Wegner, 1993). These tests reveal whether there exist statistical significant relationships between the variables pertaining to grade 8 teachers' practices and those pertaining to the pedagogical use of ICT in science classrooms. The researcher used an effect size measure to indicate practical significance (Steyn, 2002).

1.4.6 Ethical aspects

The dataset of SITES 2006 is available in the public domain. Therefore, this study acknowledges the source of data, and will respect the integrity of the dataset. No indicative information is available regarding the schools that participated in the main study, and no participants can be identified through the data. The SITES sample design can be described as a stratified two-stage sample, with level one comprising schools and level two comprising teachers. Therefore, the researcher adheres to ethical standards of the original study and no ethics clearance was necessary.

1.4.7 Data collection procedure

No new data was collected and the study follows a SDA. The researcher maintained the integrity of the data and also provided acknowledgement to SITES 2006 for the use of the dataset.

1.5 CONTRIBUTION OF THE STUDY

This study provides information about the pedagogical use of ICT by grade 8 teachers, as well as ICT practices that contribute towards effective teaching of science. This study falls within the North-West University's Research Niche Area of Educational Technology for Effective Teaching, Learning and Facilitation, and it relates to the sub-program ICT in schools. This study therefore also contributes towards the research output of this program.

1.6 CHAPTER OUTLINE

Chapter two is a literature review that focuses on ICT use in science education. The chapter concluded with a discussion of the factors that can contribute towards the successful implantation of ICT in science education.

Chapter three comprised a discussion of SITES 2006 unfolding against the South African background. The SITES modules were discussed and conceptual framework for the SITES 2006 was explained.

Chapter four concerned the research methodology and the research design of SITES 2006. This included the discussion of the sample and the collection of the SD data was made clear.

The most important research findings, as analysed, were discussed in chapter five. The chapter introduced the in-depth discussion of the descriptive statistical results, and interpreted the Spearman correlations calculated.

Finally, in chapter six the implications of the research were considered. A framework proposed for the pedagogical uses of ICT in grade 8 natural science were developed.

CHAPTER 2

THE USE OF ICT IN SCIENCE EDUCATION

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2.1 INTRODUCTION

Chapter one provided orientation and background to the research problem, research questions, research methodology and overview to the study on the pedagogical use of ICT in grade 8 natural science classes. Chapter two present a review of the literature on the use of ICT in science education from an international and national perspective. It provides an overview of the international and national views regarding science education. This is followed by a discussion on ICT in education in general and in science specifically. The significance of e-Education white paper is explored before the remainder of the chapter focuses on factors that influence the success of ICT. A summary of the literature review concludes this chapter.

2.2 SCIENCE EDUCATION

The nature and aims of the science curriculum and how it will be attained act as the backdrop for addressing the pedagogical uses of different ICTs. Science education can be seen as theoretical knowledge of a specific reality, including the scientific process of information gathering (Kok, 2007). It is important to understand the nature of science education in a national and international context, before the pedagogical use of ICT in science education can be examined. Science education forms part of the human quest for understanding and wisdom. It reflects human's wonder about the world (Association for Science Education, 1999). Furthermore, science education is a way of knowing and doing that assist learners in attaining a deeper understanding of their immediate surroundings (Association for Science Education, 1999). According to the Australian Government, Department of Education (2000), scientific literacy is increasingly described as the overall aim of science education. Science education demands a specific approach that is determined by the nature of science and the pedagogical aims of teaching and learning (Kok, 2007).

2.2.1 International views on science education

The nature of science determines the way in which knowledge in science education is structured and processed. The science education teacher should take cognisance that learners should not only assimilate facts and information, but should develop the ability to understand and apply scientific concepts in their everyday lives (Kok, 2007). Stears (2009) indicates that learners make sense of

scientific concepts more easily when they build upon informal and unstructured ideas. Learners learn to separate conceptual understanding gained in the home environment from that specific context, and connect it to more general concepts in a scientific context. The nature of science and the pedagogical use of science lie at the core of science education. The aim with this section is to unpack pedagogical approaches to science education of three countries that participated in SITES 2006, as well a non-participating country, Australia. The three countries that will be discussed are Norway, Canada and Hong Kong. The countries were selected according to teachers' report of ICT use in their classrooms. The researcher furthermore focuses on Australia because of their extensive adoption of outcomes-based education.

2.2.1.1 Science education in Norway

Between 1993 and 1997 primary and lower secondary education participated in comprehensive education reform and in Norway, this resulted in a new science curriculum (Van Marion, 2003). Until 1993 science was a compulsory subject for all learners in primary and lower secondary schools, except for grade 11 learners who followed a general curriculum in the upper secondary school. Since 1994, Norway introduced a compulsory science education curriculum for all grade 11 learners in their general and vocational training programmes. Before 1997 science in primary schools was part of an integrated subject that also included social studies. Van Marion maintains that these reforms resulted in the re-establishment of science as a separate school subject. Subsequently, in the Norwegian school system from grades 1 to 11, science education became a compulsory subject. The science curriculum for grades 1 to 11 includes elements of biology, physics, chemistry and earth science. It is only from grades 12 and 13 that this science curriculum develops into the three separate units of chemistry, physics and biology. The science courses are therefore presented as integrated courses (Van Marion, 2003). The aim is to integrate the elements into a coherent curriculum so that it would provide learners with knowledge and understanding, as well as a holistic view. Environmental issues, biophysics and biochemistry that do not readily fit into traditional science subjects are addressed from relevant contexts. This approach also links other important issues, for example the nature of science, the role of scientific evidence and ways in which scientific claims are justified to the integrated understanding of the world. With the global and environmental challenges that we face, leaders in science believe that we need a more integrated approach to science education (Zerhouni, 2009).

Although there are many common features, the scientific community indicates reasons for dividing science into biology, chemistry, physics and other science areas (Van Marion, 2003, p. 22). Based on the Norwegian science education approach, it may appear that the world of science comprises discrete ideas and methods, as well as insufficient coherence. It becomes important that the school science curriculum should emphasise coherence and relevance, and provide learners with sufficient knowledge and understanding to follow scientific debates with interest. Most of the Norwegian teachers support a pedagogical perspective towards science education that is based on *first the basics and then the big pictures*. However, Jorde (1990) reports that the interaction between teachers and learn-

ers contribute towards the understanding of the bigger pictures. This Norwegian curriculum for integrated science, could result in less content knowledge, but could develop the sense of wonder and curiosity of young people towards the natural world. Van Marion (2003) maintains that such a curriculum could more easily develop the ability to understand and interpret scientific information, and gradually develop the ability to understand science in a critical way.

During 2006, Norway has moved towards a major national education reform that focused on the national curriculum for primary and secondary schools, the establishment of a national quality assessment system, and a political will to promote science education. Another aim was to strengthen basic competencies for Norwegian learners with ICT as one of the five basic competencies now integrated into curriculum (Balanskat & Kefala, 2006). The core curriculum of science education in Norway remained unchanged with the five basic competencies (*the ability to express oneself orally, to read, to do arithmetic, to express oneself in writing, to make use of ICT*) integrated into the science curriculum (Ananiadou & Claro, 2008). In order to further strengthen science education in Norway a rolling strategic plan was developed that is subject to yearly revision. Six centres for science and technology (*Vitensentere*) were introduced as part of an effort to heighten the quality of compulsory education and stimulating learners' interest in science and technology (Balanskat & Kefala, 2006). The science and technology centres are laboratories focusing on the development of interactive learning through methods which are motivating and inspiring for both learners and teachers.

Norway was one of the countries that presented high integration of ICT into science classrooms. From the above, the researcher concludes that Norway, like South Africa, is subject to major educational reform. Compulsory integration of ICT into science classrooms only occurred during 2006—the same year as SITES 2006. South Africa strongly resembles Norwegian science curriculum approaches.

2.2.1.2 Science education in Canada

In Canada, education is a provincial responsibility (McEwen, 1995a). The country comprises ten provinces and two territories, so that there are twelve different educational systems, making it very difficult to obtain a coherent picture of science education (Fawcett, 1991). Most provinces in Canada demonstrate accountability by using one or both of the learner assessment and examination programs available through the Council of Ministers of Education in Canada (McEwen, 1995a).

The importance of science and technology has grown enormously in Canada during the past two decades. The developmental increase in information and technology across the globe indicates that science and technology affect most facets of our everyday life. Few aspects of society have not been radically altered by changes in technology. Over the past 20 years, these changes occurred at a particularly rapid pace, which will likely accelerate in the future. The Canadian economy is also strongly influenced by these scientific and technological advances, creating opportunity for Canada to make

an effort to remain on the forefront of technological innovation. To facilitate this, Canada must produce a scientifically and technologically literate workforce, trained both to work with sophisticated equipment and to develop new technologies (Fawcett, 1991). Science education becomes essential if the Canadians want to achieve this goal.

At the end of 1989, the University of Calgary, conducted a survey to determine Canadians' basic scientific knowledge and their attitudes towards science. The results of the survey indicated that nearly two-thirds of the people questioned could not name a single Canadian scientist, while over half did not know of any Canadian scientific achievements (Fawcett, 1991). Basic scientific knowledge was not much more impressive, half of the respondents were unaware that the earth takes a year to go around the sun and nearly half believed that boiling radioactive milk makes it safe to drink (Fawcett, 1991). Although the survey did highlight a dismal lack of knowledge about science and technology, with women scoring worse than men, it indicated that most Canadians see science as a positive force in their daily lives and believe it should receive more support from government (Fawcett, 1991). Despite the apparent interest of some Canadians in science, studies indicate that there are serious problems in Canada's science education system. The importance of strengthening Canada's educational system is increasingly recognised by politicians and policy-makers. In May 1991 a statement made in the Speech from the Throne confirms the close relationship between the countries' economy, teacher education and the educational achievement: *Canada's ability to prosper in a global economy will be determined by the level of Canadians' educational achievement* (Fawcett, 1991).

Fawcett (1991) reports that in the same year the Economic Council of Canada published a Working Paper entitled *Science Achievement in Canadian Schools: National and International Comparisons*. A paper that highlights the fact that *essential characteristic of education in Canada is the exclusive jurisdiction of the provinces over education, and the inherent diversity which this creates*. This is clearly observable in Canada's grade schools that exemplify few similarities in the science curricula offered across the country. In the higher grades this gradually changes, where curricula differ only slightly from province to province. In Canada no specific science training is required for the teachers teaching at elementary level but their specialisation increases with the grade level. It is also eminent that female teachers tend to dominate at the primary grade level while at the secondary school level most of the teachers are male. Findings like these reinforce many of the criticisms made against the Canadian education system.

Ontario Province and Alberta Province, both provinces that took part in the SITES 2006, are discussed in this section. The Science Teachers' Association of Ontario (1997) shaped two major goals of science education that need to be addressed to provide:

- a basis for further study for the minority of learners
- access to basic science literacy for all.

The renewal of the skills of the classroom teacher is critical to the renewal of science education in Ontario (The Science Teachers' Association of Ontario, 1997). In Ontario the primary goal of science is to understand the natural and human-designed worlds. Canadian science education in general refers to certain processes used by humans for obtaining knowledge about nature, and to an organized body of knowledge about nature obtained by these processes. It is seen as a dynamic and creative activity with a long and interesting history. Many societies have contributed to the development of scientific knowledge and understanding. Against this background the Ontario Provincial education system describe a scientifically and technologically literate person as *one who can read and understand common media reports about science and technology, critically evaluate the information presented, and confidently engage in discussions and decision-making activities regarding issues that involve science and technology* (The Science Teachers' Association of Ontario, 1997). Furthermore, an important component of scientific literacy is an understanding of the nature of science: what science is; what scientists, engineers and technologists do as individuals and as a community; how scientific knowledge is generated and validated; and how science interacts with technology, society, and environment. The Ontario Province is at a crossroad regarding its rapidly changing society. The province receives many immigrants from different countries. During the past decade the demographics of its urban areas, especially, have changed a great deal, making the provision of an appropriate curriculum and assessment for these diverse groups difficult (Earl, 1995).

The Canadian Alberta Program of Studies for Science Education state that science education should *encourage all learners at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavors, and prepare learners to critically address science-related societal, economic, ethical and environmental issues* (Pomahac, Gunn, & Grigg, 2007, p. 2). McEwan (1995b) states that the Alberta reform program is ambitious as the curriculum is designed to help learners to achieve their individual potential and create a positive future for themselves, their families and their communities. The Alberta Education Department has a centralized, high quality curriculum that outlines what learners are expected to learn and be able to do, in all subjects and grades (Government of Alberta, 2009).

Fawcett (1991) discusses the four year study on the problems with teaching of science in Canada. This study was completed by the Science Council in 1984 and suggested ways to solve the problems. The Council study centred on the science curriculum in every province and territory. This research reaffirms the importance of ensuring that every learner possesses a basic understanding of scientific and technological issues. It argues that *for Canada to cope with social changes rooted in highly specialized technologies, its citizens need the best general education possible—an education comprising not only the traditional basics of language and mathematics, but also the new basic of our contemporary culture: science and technology*. Canadians must be ready and able to adapt themselves to new skills and technologies at many different points in their lives.

A special effort must be made to train teachers, particularly at the elementary school level in methods of teaching science. In teachers' colleges and developmental programs, working scientists can be in direct contact with teachers to discuss new scientific ideas and suggest methods to introduce scientific ways into classroom. Many experts believe that this type of contact between scientists and teachers is the key to improving science education in schools (Fawcett, 1991).

Both Ontario and Alberta provinces in Canada reported using ICT for teaching and learning activities in science classrooms during the SITES 2006 (Law & Chow, 2008a). With so many systems in place it is difficult to make a holistic judgment about Canada's education system, but it is clear that the government places a high value on Canadians' educational achievement, similar to the South African education situation. From the above it is apparent that science and technology skills must form part of professional development of teachers.

2.2.1.3 Science education in Hong Kong

Hong Kong, like the rest of the globe, experiences that science and technology have permeated all aspects of modern life. All children experience a need for a rigorous, coherent and engaging science education. Kwok (2009) reports that a core requirement to participate on a personal, professional, social, political and cultural level is scientific literacy. A well developed science curriculum ought to provide a solid base in practical, functional and cultural scientific literacy.

Since December 1998 the Hong Kong Education Bureau set the directions for developing an open, flexible and consistent framework for Curriculum 2000 in order to improve teaching and learning effectively (Curriculum Development Council, 1999). The aim with the curriculum reform is to suggest the general directions for curriculum development in Hong Kong in accord with a lifelong learning vision. Ultimately the outcome should contribute to improving the quality of teaching and learning.

The Hong Kong Education Bureau (2001) defines the governments' position towards science clearly. The Bureau states that science is *the study of phenomena and events around us through systematic observation and experimentation*. Learners' curiosity about the world should be cultivated and scientific thinking enhanced. Through the enquiry process, learners should develop scientific knowledge and skills to help them evaluate the impacts of scientific and technological development. Science education can prepare learners to participate in public discourse in science related issues and enable them to become lifelong learners in science and technology. Reform within the science curriculum is recognised according to the following aims:

- to enhance learners' scientific thinking and strengthen their investigative and problem-solving skills
- to enhance science and technology elements in the primary school curriculum in order to nurture
- to develop learners' curiosity and their inquiring minds

- to better the coordination of fundamental science and technology courses at junior secondary level with a view to promote scientific and technological literacy
- to develop among senior secondary learners a solid foundation in science and technology to empower them to cope with a dynamically changing environment and to make informed judgements in a technological society
- to offer science disciplines as optional courses to prepare senior secondary learners for specialisation in their further studies and to prepare them for their future workplace.

The subject science is one of the electives in the Key Learning Area of Science Education in Hong Kong. The enhanced curriculum aims to empower learners to be inquiring, reflective and critical thinkers, by equipping them with a variety of ways of looking at the world and by emphasizing the importance of evidence in forming conclusions (Hong Kong Education Bureau, 1999). The Hong Kong government also encourages the use of ICT in learning science (Chan & Lui, 1998). It is believed that in a technologically advanced society, like Hong Kong's, people will find knowledge and understanding of scientific concepts useful in their everyday life, and scientific inquiry competency of great value in creative problem solving in life.

To adhere to the challenge of improving the quality of teaching and learning, the Education Bureau in Hong Kong adapts a school-based curriculum approach (Hong Kong Education Bureau, 1999). This approach encourages schools and teachers to become accustomed with the central curriculum and develop their own school-based curriculum guiding learners toward achieving the learning targets. This curriculum is therefore jointly owned by schools and the government. Success in science education can only be achieved with persistent support to science educators through professional development. It is recommended that working scientists serve as mentors for learners and educators in science projects. Public debate and discourse in science and popular science activities are encouraged, as it provides an active science-learning environment for learners and eventually can promote public understanding of science (Hong Kong Education Bureau, 2001).

Science is a universal language that connects people across nations and cultures, consequently the integration of basic competencies in Chinese, as well as English, forms part of the new curriculum (Hong Kong Education Bureau, 2001). Kwok (2009, pp. 1-8) maintains that the science curriculum currently used in Hong Kong has not been adequately updated to reflect the comprehensive growth of scientific knowledge and revolutionary technological advances of today's society. In order to advance these goals, a diverse set of instructional tools need to be implemented. These instructional tools include *interdisciplinary teaching models, hands-on experiments, inquiry-based methods, computer modelling and simulation and collaborative learning models*. These methods could aspire to emulate and prepare the learners for the successful collaborative and competitive environment found in today's academic and industrial science community.

During SITES 2006 Law et al. (2008a), Hong Kong teachers indicated a very high prevalence towards the use of ICT in science classrooms, signifying that the pedagogical adoption of ICT in science is becoming common practice among teachers. From the above literature review it can be concluded that in Hong Kong, like South Africa, the government encourages the use of ICT in teaching and learning of subjects like science. Hong Kong, like South Africa, is subjected to major educational reform. South Africa's current OBE approach strongly resembles the Hong Kong school based science curriculum approach.

2.2.1.4 Science education in Australia

School attendance is compulsory throughout Australia. In most Australian States from 5–6 years of age all children receive eleven years of compulsory education. Australia has a national curriculum framework to ensure high academic standards across the country. All schools in Australia provide subjects in the eight key learning areas: English, Mathematics, Studies of the Society and the Environment, Science, Arts, Languages Other Than English, Technology, and Personal Development, Health and Physical Education (Commonwealth of Australia, 2009a). At secondary school level, choice and diversity are increased as schools are able to offer a wide range of subjects, delivered by highly trained and experienced teachers, and using state-of-the-art technology including the Internet, multimedia equipment and laboratories (Commonwealth of Australia, 2009b). Although Australia was not included in the SITES 2006 (Law, et al., 2008d) the researcher is interested in the approach to science education as it resembles the current South African OBE approach towards science education.

The nature of and approach towards science in Australia can be described as dynamic, forward looking, collaborative activities arising from human curiosity. Science provides distinctive way of thinking about events and phenomena. Scientific knowledge, understanding, theories and explanations are based on observations and evidence gathered during the exploration of phenomena (National Curriculum Board, 2008). The present science curriculum is compiled in such a way that learners, towards the end of the compulsory years of school science should be able to demonstrate:

- an interest in and understanding of the natural world
- the ability to engage in communication of and about science
- skepticism and questioning of the claims made by others
- identification and investigation of questions and drawing together evidence-based conclusions
- the ability to make informed decisions about the environment, as well as their own health and wellbeing.

Historically, the Australian Department of Education (2000) structured their science curriculum goals according to three unambiguous outcomes: to acquire scientific knowledge, to learn the processes or methodologies of the sciences, and to understand the applications of science, especially of the relationships between science and technology-society. Science curricula in Australia have strongly been

influenced by developments in the USA and the UK. By the end of the 1970s, a wide range of curricula was used in Australian schools. This science curriculum was structured in a way that did not cater for a wide range of learners. The National Science Education Standards (National Science Teacher Association, 2010) advised a national curriculum framework that addresses the demands of innovative education and technological change. The Australian national curriculum framework is based on a learner-centred learning philosophy that focuses on measuring learners' performance. Australian Government Department of Education (2000) points out that the diverse backgrounds of the learners become evident in the different ways individuals prefer to work and learn. Learners learn in different ways according to personal preferences and the nature of the task. Background knowledge and the way learners prefer to engage in scientific tasks, determine how much time they need to learn new ideas and skills. Learning is a gradual, incremental process which takes time, and different learners with different experiences may learn at different rates. The implementation of a learner-centred learning approach in Australia does not prescribe a style of teaching or learning, it requires that learners demonstrate that they have mastered the required skills and content.

The Australian science curriculum does not mandate particular technologies. It recognises in the curriculum, the possible support that ICT can provide to aid learners in a better understanding of science (Commonwealth of Australia, 2009a). ICTs available to use in the science curriculum include: internet-based inquiry resources, digital images, computer simulations, probe-ware tools for science investigations and on-line data for scientific analysis. The mentioned ICT tools can help to engage and maintain the interest of learners, provided that the context is relevant and fascinating.

Australia follows a learner-centred learning philosophy very similar to the OBE approach implemented in South Africa. Although Australia never took part in SITES 2006 it is clear that the teachers in Australia are under pressure to explore the possibilities of ICT in Science Education. Learner-centred learning, like OBE, does not prescribe a specific learning style but it expects the teachers to apply ICT whenever possible to prepare the learners for the fast changing societies they will work in.

2.2.2 National views on science education

The nature of science is a rich fusion of the sociology and philosophy of science. Furthermore, it combines research from the cognitive science such as psychology into an affluent description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavours (McComas, 1998). Science education in South Africa is influenced by the nature of science. Since the 1950s the development of appropriate concepts about the nature of science has been an important objective of science education (McCarthy & Sanders, 2007). Brown (2003) explains that science education, like all education in South Africa was teacher-centred before 1994. This approach to education is associated with the mere transmission of knowledge. Teacher control the learning activity and uses their expertise in content knowledge to help learners make associations. The effort to get to know learners and how they process information is secondary. The traditional view entails that knowledge about science is discovered by objective scientists, using an inductive scientific method and that scientific knowledge is a body of facts discovered by scientists, which learners need to learn (McCarthy & Sanders, 2007).

The National Curriculum Statement (NCS) states that with the Natural Science learning area, a teaching and learning milieu is visualised that recognises the diverse, culturally influenced perspectives of South Africa, that should be accommodated by a variety of learning styles. *The national science learning area envisions that all learners should have access to a meaningful science education* (Department of Education, 2009, p. 188). Meaningful science entails that learners learn when they see a purpose for what they are learning that goes beyond the educational system (Meaningful Science Consortium, 2006). The aim is to assist learners to understand not only scientific knowledge, but also the environmental and global issues implicated by this knowledge.

The intent with the introduction of OBE in South Africa is to provide a foundation on which learners can build throughout the rest of their lives (Department of Education, 2009). The NCS states that science education should promote a scientific literacy and focus on the:

- development and use of scientific processing skills in a variety of settings
- development and application of scientific knowledge and understanding
- appreciation of the relationships and responsibilities between science, society and the environment.

Implementation of the OBE approach in South Africa has placed a strain on teachers as the education system winds its way towards the shifting goal posts of the new curriculum (Johnson, Soltz, Hodges, & Botha, 2000). Perhaps science teachers have been under more strain than other teachers, simply because science is generally viewed as a practical subject. With OBE stressing outcomes, science teachers have to weigh up which practical skills they ought to develop in their learners.

There is a need in South Africa to formulate a rigorous national effort towards the promotion of science and technology as a means of improving living standards, by stimulating the learners to develop a passion for science and technology. James, Naidoo and Benson (2008) suggests that an effective way of taking our country forward is to provoke in our young people an enthusiasm for science and technology. South Africa should qualify individuals who can use their skills and entrepreneurial spirit to enable our country to compete internationally. The country needs a new generation of young minds, skilled in and passionate about science and technology, working to put us on the global technological map.

In many cases teachers in South Africa are victims of their own education and they generally teach in the manner in which they were taught. Furthermore, many teachers were neither exposed to nor did they learn large chunks of content knowledge during their schooling (Steers & James, 2004). There is thus the need to influence teachers' perceptions and understanding of science with the aim of changing the way they think about it, so as to increase the global economic and scientific competitiveness of South Africa. An underlying assumption is that if we change teachers' perceptions and understanding of science, this will be conveyed to the learners. However, the question that needs to be asked is: *How do teachers improve their ability to retool teaching, update curricula, integrate new research methodologies into instruction, meet the growing list of the socio-political needs of learners and raise test scores?* James et al. (2008) declares that for the most part the answer is professional development. Universities, teaching colleges and also non-government organisations initiate projects and programs to develop the skills of learners and the teachers in ICT. Howie, Muller and Patterson (2005) explain that the White Paper on e-Education suggest a National System of Innovation that will support and promote the attainment of national objectives by the creative use of the outputs of the science and technology system with regard to new knowledge and new technologies.

Howie et al. (2005) state that through the Universal Services Agency, there is a focus on community information and learning centres around South Africa, centres which will be equipped on a large scale with appropriate mass media and technology. There are currently a number of initiatives in various sectors in South Africa that focus on different aspects of technology in education. Over the years, the Human Science Research Council (HSRC) has been involved in several research projects regarding computer-based education. The HSRC projects include distance learning and a research programme aimed at studying the effective transfer of development information through the application of mass media technology (Howie, et al., 2005). Telkom is also involved in a number of initiatives to provide appropriate networks for computer-based and interactive education projects. The Thousand Schools Project is another Telkom-sponsored initiative to introduce and support ICT in 1 000 schools around the country (Howie, et al., 2005).

Numerous initiatives in private sector companies and international institutions offer educational training and information programmes via the Internet. These expand across all disciplines and levels of education, and tend to be largely in the non-formal sector where there are large amounts of money

involved (Howie, et al., 2005). Industry is also collaborating with organisations in sponsoring some new initiatives such as the Telkom Centres of Excellence and the Soweto Technology Project, to mention merely two such collaborations.

Recently, the South African Department of Trade and Industry, the Information Systems, Electronics, and Telecommunications Technologies (ISETT) Sector Education and Training Authority and the State Information Technology Agency launched a youth internship programme aimed at building skills-capacity in the information technology sector which involves placing interns in private sector companies (Howie, et al., 2005).

Nicol (2002) gives details about policy documents, that state accountability plans for the current job market, all of which points to the fact that continuous school improvement is not optional but compulsory. Science education, like other curricula in South Africa, aims to present a curriculum that will help prepare learners for lifelong learning and provide equal opportunity for all learners.

Science learners' constructivist views of learning in science education suggest that learners can make sense of new situations in terms of their existing understanding (Keogh & Naylor, 1996). Prior knowledge is used by learners to interpret observations and meaning is constructed by individuals in a process of adding to or modifying their existing ideas. Teachers teaching learners in the science classroom environment should determine the learners' ideas about the subject and take these into account in their teaching. Teachers need to provide experiences which challenge the learners' current understanding in order to help them modify their ideas about science. OBE provide the teacher with numerous opportunities to take the learners educational and social needs into consideration. The science teachers should focus on the learner's intellectual level and act as a facilitator to assist the learner to develop creative methods to approach the subject. According to the researcher OBE offer the science teacher a chance to develop teaching and learning strategies that support and challenge the learners creative thinking to reach the outcomes as stated in the curriculum statement.

According to Keogh and Naylor (1996) the constructivist perspectives have had a significant impact on recent research in science education. To a great extent recent research has been concerned with exploring the ideas which learners typically hold in order to inform teaching. Many science teachers are convinced of the value of a constructivist viewpoint and actively promote a constructivist philosophy. As a consequence, it is now commonplace to find that teachers who have been exposed to constructivist ideas, have a commitment to constructivist principles and have made some attempt to modify their practice to take these principles into account.

The changing continuous changing curriculum in South Africa requires implementing of ICTs in schools, anticipating a new approach to improve the educational predicament in this country. The South African Department of Education has been supporting ICT interventions in schools nationally

The goal with the policy was to introduce learners to ICTs in every subject. Science education (grade 8 natural science) teachers should be empowered to teach using ICTs in the grade 8 natural science classroom. The DoE in the Western Cape and Gauteng aim is to reach every educator in the provinces and to empower them with skills and knowledge to integrate technology into their curricula (Khanya, 2005). The Gauteng Online project is involved in the establishment of computer laboratories with 25 work stations, Internet and e-mail access, to be used for curriculum delivery in all Gauteng schools. The main goals of the programme are to contribute towards building the human resources capacity of the province and the country through the provision of quality education (Isaac, 2007).

2.3 ICT IN EDUCATION

ICT is a potentially powerful tool in the expansion of educational opportunities. Through the use ICT the ordinary learning environments can be transformed into learner-centred environments. ICT can have an effect on active learning, collaborative learning, as well as assessment of learning. ICT implies a diverse set of technological tools and other resources used to communicate, and to create, disseminate, store, and manage information (McFarlane & Sakellariou, 2002b). To improve the quality of ICT in education, it is imperative that the government adopt a transverse strategy, which includes the education- and training system. Learning through the use of ICT is arguably the most powerful means of supporting learners to achieve the nationally-stated curriculum goals (Department of Education, 2004b, p. 19). It must, however, be very thoughtfully selected and integrated into educational planning and management. The Department of Education claims that the use of ICT in particular, encourages learning in the following ways: *learner-centred learning, active, exploratory, inquiry-based learning, collaborative work among learners and teachers, and creativity, analytical skills, critical thinking and informed decision-making.*

ICT in education generally refers to learners that familiarise themselves with the operation of computers, related social and ethical issues (Wikipedia-free encyclopedia, 2009). Furthermore, ICT gives the learners and teacher the ability to control, manipulate, and contribute to the information environment. ICT in education does not provide learners with the ability to make choices about the pace and kind of learning material, but they may choose topics; take notes; answer questions; explore virtual landscapes; enter; draw or chart data; run simulated experiments; create and manipulate images; make their own multimedia presentations, communicate with others, and much more (Aldrich, Rogers, & Scaife, 1998).

Sanchez (1991) states that implementation of computers into schools, in order to achieve technology transfer and to support learning, started during the seventies and has progressively entailed special emphasis on computer/digital literacy and technology integration into classrooms. Nationwide school ICT programs or project for school teaching and learning have expanded progressively worldwide

(Ramirez-Romero & Galeana, 2006). Public initiatives have intended to spread the use of computer technology in schools by implementing computer laboratories and embedding actual classrooms with digital technologies to assist and support current classroom learning (Kozma, 2003a).

By the early nineties a Chilean network on computers and education for public schools had emerged called the Enlaces network (Sanchez & Salins, 2008). The Enlaces network, has been considered one of the most systematic, successful and sustainable programs to cope with the special geography and culture of the country, including rural, urban, indigenous, and community education. There were high expectancies that technology could revolutionise education, as well as divergent voices that doubt the real impact of technology on learning. This led to the introduction of a national ICT and education initiative in Chile, designed as part of a series of programs to overcome inequity and quality issues of public education by integrating teachers and learners into the knowledge society.

Sanchez and Salins (2008) clarify that Enlaces provides basic infrastructure tools, ICT connectivity, and teacher training to a huge number of schools. Since its conception, Enlaces has functioned as a network, coordinated by the Ministry of Education composed of 24 public and private universities, some hardware, software and telecommunications companies and other public and private institutions throughout the country. They assumed active roles in advising and implementing technology in schools, training and providing pedagogical support to teachers for technology use and integration into the curriculum, and doing some research and development on educational computing. According to the paper, research on computers and education has posed numerous hypotheses concerning the impact of ICT on learning. National and long term curriculum initiatives, such as Enlaces, offer fundamental opportunities to describe, analyse, explain, and understand the intertwined process of using and integrating digital tools from real and everyday school settings. Enlaces is based on the idea that teachers will be able to transfer the use and application of digital technology to their learners, and that the learners, as digital natives, will utilise these technological tools daily, without considering that this knowledge is not formal and systematic, which goes against the productivity of their academic activities (Sanchez & Salins, 2008).

Enlaces has provided general purpose tools and educational software licences to schools since it was first established. Recently, a new strategy to improve the use of ICT resources in the classroom has been set-up. Universities and other institutions in Chile are working to develop models for ICT integration into specific curriculum subject matters such as science and mathematics. The models include technology, teaching methodology, learning objectives, teaching resources and tools for learner learning assessment (Sanchez & Salins, 2008).

Hayes (2007) exemplifies that politicians, policy makers, school leaders, teachers and parents in Australia are starting to develop more critical understandings of the issues associated with integrating ICT in schools. This may be largely due to the high costs associated with supplying and maintaining these technologies, as well as the slow uptake of ICT by teachers. In New South Wales (NSW), the

introduction of computers into public schools is a major Government priority that has received over 300 million Australian dollars in funding in recent years, with a further 500 million Australian dollars projected over a period from 2003 to 2007. The NSW government's *Computers in Schools Plan* aims to improve learning outcomes for all learners in all key learning areas from kindergarten to year 12. This comprehensive program of support to schools includes provision of regularly updated computer hardware and software, connection of all schools to the Internet, provision of training and development of teachers in the use of computers and the development of curriculum support materials to enhance curriculum in all Key Learning Areas. However, despite this commitment of money and support, *the rate of uptake of ICT and success of school-based practices varies enormously across the state* (Hayes, 2007, pp. 385-395).

Hayes (2007) reported that certain schools were selected after preliminary visits and after discussions with a range of sources, including consultants, teaching and other researchers, who were of the opinion that concerted efforts were being made at each site to integrate ICT. Additionally, to ensure that different types of schools were represented in the study, indicators such as geography location, school type and socio-economic status of the surrounding community were taken into consideration. Consequently, four of the schools received additional equity-based funding, one was located in a rural area and a number of school types were represented (Hayes, 2007). Each school was asked to nominate teachers who were considered to be innovative and confident users of ICT in their classrooms. An in-depth interview was conducted with the nominees, in their classrooms, that included a discussion about what was taking place in the class. We observed and inquire how the lesson fitted within the broader learning program for the class and goals of the school. Many teachers had difficulty in pointing out how integrating ICT impacted on their classroom practices. Most indicated that it had not fundamentally changed the ways in which they teach or the ways they designed learning experiences within the classroom (Hayes, 2007). They tended to integrate ICT in ways that supplemented existing learning designs, often by utilising ICT to replicate comparable tasks completed without ICT. An exception to this was how teachers in the Physical Support Unit at Tall Timbers PS were using ICT to teach children with severe physical disabilities. One computer per child, special peripheral equipment, and specialist software allowed the children to interact with their computers independently of their teacher.

As noted in the *World Education Report* (UNESCO, 2000), education worldwide is facing a significant challenge in preparing learners and teachers for our future knowledge-based society. This is as a result of the unwillingness of teachers to use ICT, as well as ill-equipped school buildings.

According to Atjonen and Li (2006) Hong Kong has twelve higher education institutions which award degrees, eight of which are publicly funded by the government. In contrary to Finland with twenty universities, all state universities. Many universities in Finland and Hong Kong have student-teacher exchange programs, research programs and contracts. Both countries have participated in the same international evaluations. The technological infrastructure is well established and developed in both

areas and offers to promote the use of technology as an important tool in developing context (Atjonen & Li, 2006).

Two main strategic plans have been launched by the Ministry of Education in Finland during the last decade (1995 and 1999). The third and latest information society programs for education, training and research, was published in 2004 which include primary, secondary and tertiary education in the same policy (Atjonen & Li, 2006). The activities fall into three categories; knowledge, content and the operating environment. The program is geared to develop all citizens' information society, knowledge and skills, enable educational institutions to use ICT in a versatile way in their activities, to establish ICT-based procedures in education, training and research, and promote social innovation through the use of ICT.

Recent research by Atjonen and Li (2006) argue that while having no centralised policy on advancing the use of IT in tertiary education, the Education and Manpower Bureau of the Hong Kong Government has launched two important strategic plans: *Information Technology for Learning in a New Era*, which was designed to promote ICT in education in the school sector in 1998 and 2004 respectively. Embarking upon a learner-centred approach, the new ICT in education initiatives were comprised of seven strategic goals namely: empowering learners with ICT, empowering teachers with ICT, enhancing school leadership for the knowledge age, enriching digital resources for learning, improving ICT infrastructure and pioneering pedagogy using ICT, providing continuous research and development, and promoting community-wide support and community building.

Hong Kong, like Finland, invested substantially in improving the technical infrastructure of ICT at schools and universities. At tertiary level, all computers have broadband Internet access (Atjonen & Li, 2006). Recently, universities have been experimenting with the use of Internet in enhancing the performance of the existing network infrastructure. At school level, the statistics derived from the overall study on reviewing and evaluating the progress of the Information Technology in Educational projects 1998-2003 was conducted during 2002 to 2004, and published. The Education and Manpower Bureau indicated, that the student to computer ratios were about 7:4, 4.6 and 2 students per computer in the primary, secondary and special school sectors respectively (Atjonen & Li, 2006). In 2005 all schools reported that they were connected to the Internet, (primary schools, 95.8%, secondary schools, 97.6%, special schools, 93.9%) and that they used broadband.

Studies show that teachers gain positive attitudes towards ICT through government interventions and training programmes (Balanskat, Blamire, & Kefala, 2006). The evaluation of the Norwegian Pilot project between 1999 and 2003 indicated that teachers reflect a more positive attitude towards ICT on impact of the program. In Denmark, ICT is high on the agenda of schools. The issuing of teachers with laptop computers have increased positive attitudes towards using ICT in their classrooms (BECTA, 2003b). UK teachers taking part in an interactive whiteboard (IWB) pilot project were positive about using the technology in their teaching and learning (BECTA, 2003b). They were convinced

that changes in technology improved teaching and learning. However, despite the enthusiasm, it remains unclear if this translates into more effective and purposeful added value in teaching and learning practices. Betcher and Lee (2009) indicated that IWBs made a difference to several aspects of classroom interaction. They maintained that a faster pace (measured by the number of interaction between teachers and learners) prevailed in whiteboard lessons, compared to the non-whiteboard lessons. With regards to pedagogy, they also indicated sustainability where a year later, teachers who had adopted the IWBs as a core part of their teaching toolkit continued to ask better and more open question, and probed learners for further information and more detailed explanations. Betcher and Lee (2009) also establish that teachers gave richer and more evaluative responses during IWB lessons. They also addressed follow-up questions to the whole class rather than to certain individual learners.

IWBs often act as the catalyst for teachers to augment existing practice with more interactive, constructivist approaches (Betcher & Lee, 2009). Betcher et al. (2009) maintain that IWBs assist teachers to become more innovative in the use of teaching resources. Learners appeared to learn more effectively when presented with the wide range of media that IWBs bring to teaching and learning. They also noted that teachers used IWBs in one of three ways: in support of existing didactic approaches, interactive approaches, and enhanced interactive approaches. This last approach integrated the interactive capabilities of the technology most successfully with the conceptual and cognitive development of learners.

Teachers teaching science, mathematics and computer science are the most intensive users of the computer in class. The Eurobarometer Benchmarking Survey describes areas of teachers' ICT use across Europe (Balanskat, et al., 2006). According to Balanskat, Blamire and Kefala (2006), many teachers refer to ICT as a tool. This suggests that they regard ICT as an added element to existing teaching and learning practices, for example, a word processor instead of hand written text, or the Internet or a CD-ROM as a source of information. Balanskat et al. (2006) argue that teachers use ICT to support existing pedagogies. New technologies that provide a good fit with existing practices such as IWBs were the first to be adopted, while others like video conferencing, digital video and virtual learning environments provide evidence of ongoing adoption.

Training for teachers should continue to support innovative pedagogy. Betcher and Lee (2009) make it clear that ICT can enhance teaching practices by introducing new and innovative ways of teaching and learning. Teachers increase their use of ICT in lessons where learners search for information on the Internet, as well as during the use of standard and subject specific applications (Betcher & Lee, 2009). When ICT has been embedded over a longer period of time, its use increased together with the confidence of teachers while using it in the classroom. According to Betcher and Lee (2009, pp. 60-61) the "IT, Medier og Folkeskolen" (*in English*, ICT, Media and Primary and Lower Secondary school) study establish that the greatest impact of ICT use is found in relation to teachers who are experienced users and who, from the start, had already come far with the integration of ICT in their teaching. More positive results have been found, and teachers believe that ICT is a valuable support

in solving pedagogical problems and solving organisational problems. According to Betcher and Lee (2009) similar positive results come from IWBs and the overwhelming majority of teachers participate in the IWBs project in the UK.

According to the BECTA (2002) report teachers who make use of ICT can communicate directly with learners and inspire them to deepen their understanding and knowledge. National expectations for teaching and learning are exemplified through the national curriculum, strategies and associated schemes of work (BECTA, 2002). Through discussion with others and engagement with learners' work, teachers begin to internalise standards as an essential part of their teaching and learning activities. Productivity tools such as word processors, graphics packages, spreadsheets and databases allow learners to work more efficiently, producing well-presented work without spending time on low level activity. The productivity tools can support the development of higher order thinking, and the employment of multimedia helps learners create professional looking work, test out ideas and present them to different audiences, which increase motivation (BECTA, 2002).

Learners show more commitment to tasks and invest more time in developing their understanding of the material being produced (BECTA, 2002). Because learners' work can be shared and exchanged using ICT, it is helpful for schools to create a portfolio of work on the school intranet or website. Effective teaching with ICT involves all learners in the lesson. The use of multimedia allows learners with different learning styles to have access to the content of the lesson and learners can revisit a topic through another medium. Display technologies support whole-class interactive teaching and specialist equipment such as speech recognition systems, overlay keyboards and touch screen technologies can provide learners with particular learning difficulties greater access to the lesson (BECTA, 2002).

ICT offers opportunities for individualised, self-paced instructions with built-in frequent feedback, monitoring and assessment. Electronic content in some computerised learning systems is intended specifically for individual use. The computer can present content to the learner and there are on-screen responses to learners' inputs. These inputs can be logged by a central management system and made available to the teacher. Communications technologies provide a further mechanism for teachers to listen and respond to learners. Communication through such channels can be asynchronous, enabling teachers to respond to learners outside timetabled periods (BECTA, 2002).

Effective teachers model the behaviours they wish to teach, for example, a science teacher may model a science activity using an IWB and they develop the necessary understanding through their own use of ICT (BECTA, 2002). By being confident users of the technology, they act as role models for their learners. Greater familiarity with ICT places the teacher in a more effective position to support learners' use of ICT and extend their own skills. ICT gives learners immediate access to richer source materials, because multimedia can present problems from real life, which draw on the previous learning and experience of learners and link it to their current learning. Using electronic-mail, learners can engage in authentic communications and in modern foreign languages for example, CD-ROM

and interactive video allow learners to interact with original source materials and online experts in new ways that can lead to more reflective work and deeper understanding (BECTA, 2002). Michel et al. (1999) suggest that allowing learners to make video clips can develop their powers of observation and open new perspectives for their understanding of scientific concepts. This is because learners need to think about exactly what should be recorded in order to explain a concept. This type of enquiry-based teaching involves learners in deciding which problems to investigate, searching for alternative solutions, collecting and tabulating data, reporting conclusions, and suggesting new related problems for further investigation (Michel, et al., 1999). The technology also gives teachers the flexibility to demonstrate scientific concepts through a method other than a live demonstration. An example from this study shows, a high school biology teacher produced a CD-ROM of short clips digitised from tapes made by learners during a long-term experiment to grow various plants. The learners later incorporated the clips into a scientific presentation (Michel, et al., 1999). ICT support effective group work, because computer software can help teachers to provide structure, direction and support to learners, and consequently, the management of group work becomes easier. With the computer as a focus, learners can discuss ideas, listen to others and build on each other's experience and knowledge. Significant numbers of case studies show how online exchanges between peers have triggered learning (BECTA, 2002).

ICT is a tool for managing teaching and learning alongside traditional methods. It can help teachers evaluate and monitor learner's progress against benchmark data (BECTA, 2002). ICT can also automate some of the tasks associated with recording and reporting learners' attainment, and through the use of projected performance data, enable target setting and feedback in order to develop practice. Computer simulations can provide useful insights into learners' understanding, and specific assessment software can enable teachers to assess learners (BECTA, 2002).

BECTA (2002) identifies the role of ICT as more effective in lesson planning, for example, new lessons can be created and teachers can access plans developed by others to assist them in their teaching. Lessons with ICT are well structured, with clear introductions and closing plenary (BECTA, 2002). Sometimes the teacher's intervention is needed to direct the student by suggesting strategies for problem solving, or by giving new pieces of information, and the teacher becomes a resource to enrich the learning with ICT (BECTA, 2002). ICT can assist in continuous professional development (CPTD). British Educational Communication Technology Agency (2003) established that CPTD refers to the process by which teachers acquire and develop the skills and knowledge to become effective in the classroom. Teachers are aware that developing their own knowledge, understanding and practice, helps in both their learning and teaching. An opportunity for teachers to take control of their own professional development is through the use of ICT. Through the careful use of purposefully designed websites and CD-ROMs, teachers can absorb new knowledge and understanding at their own pace, plan the integration of their new skills into their teaching, and continually develop as professionals (British Educational Communications Technology Agency, 2003).

Teacher Net (2004) identifies professional development in the use of ICT in teaching and learning as essential if schools want to realise their investment in ICT. Furthermore, teachers should use ICT in the classroom, but also use it to facilitate their own professional development (Teacher Net, 2004). BECTA (2003) has long known that some teachers' competence in ICT is low and this means that many teachers shy away from using ICT to help with their teaching. In a study in 1998 researchers found by giving teachers a laptop, they can continue work they were doing at school such as planning and creating resources, at home (BECTA, 2003c). Government should offer much more to help teachers for their own professional teaching development. For all teachers wanting to use ICT to help with their teaching, the first stop must be the Internet. The Internet has an enormous amount of resources for teachers to use. These resources might develop their teachers' expertise and confidence in teaching a particular subject and gives them the opportunity to try out new ideas and new ways of teaching familiar topics in different subjects (BECTA, 2003c).

Teacher workload has an impact on teacher morale, recruitment and retention (Selwood & Pilkington, 2005). ICT has many potential benefits for teachers, learners and schools, including helping to reduce their workload. According to Selwood and Pilkington (2005) the Transforming School Workforce (TSW) project was launched by the Department for Education and Skills (DfES) in 2002. The project was part of a government initiative to reduce the working hours of teachers and with the use of ICT, enable them to spend more time on activities directly related to teaching. The researchers surveyed and interviewed teachers at 32 schools (primary and secondary schools) and came to tentative conclusions regarding the potential benefits for teachers using ICT. They found that by the end of the one year study, the teachers generally felt more positive about the potential of ICT for helping to reduce their workload (Selwood & Pilkington, 2005). They suggested for example, ICT could help them to monitor the learner attendance, their progress and their performance. Researchers also interviewed the teachers to find out other ways they perceived ICT could help them and identified a number of recurring themes including creating reusable teaching materials (saving preparation time) and sharing teaching materials and lesson plans via Internet. The researchers also found a number of factors that appeared to contribute to the teachers' change in attitude towards the potential value of ICT in schools. A striking change during the project was the increase in teachers' sole access to a computer at school, increased access to a laptop computer at home and also an increase investment in IWB (Selwood & Pilkington, 2005).

2.4 ICT IN SCIENCE EDUCATION

ICT is no longer just about the entry, storage, retrieval and manipulation of text, images, sounds and video in electronic format (Byrne & Sharp, 2002). It is also concerned with the sophisticated ways in which we access and transfer such information from computer to computer, person to person, right around the world and next door. Aspects of the Internet, including the WWW, email and video conferencing, are influencing many aspects of our lives as we begin the 21st century (Byrne & Sharp,

2002). The technology itself will continue to develop and change, but ICTs' real power in education lies in its use as a tool to support and enhance teaching and learning across the curriculum (Byrne & Sharp, 2002).

Claro (2005) declares that in the early 1990s, Chile started implementing an educational reform to upgrade the quality and equity of the Chilean education. The main components of this reform are comprehensive investment and support programs, which combine more resources with new teaching and learning methodologies; specific programs for the poorer schools; a new, more ambitious and contemporary curriculum aimed at developing higher order thinking skills; an extended school day for the whole learner population; and better salaries and working conditions for teachers (Claro, 2005). Enlaces has been the ICT initiative of this reform since 1992 (Hinostroza, Hepp, & Cox, 2003). Enlaces became the official nation-wide initiative for the introduction of ICT into the Chilean Education System. Education has been consistently promoted as the nation's number one priority during the last decade, in an unprecedented effort to overcome poverty and to place Chile as a stable country in the current millennium (Hepp, 1998).

The aim of this educational reform in Chile is to integrate technologies as learning and teaching resources for all learners and teachers in the 10,000 Chilean public schools, as 90% of the total learner population attends public schools in Chile (Claro, 2005). Each of these schools received computers, local networks, educational and productivity software and most of them have free and unlimited Internet access to specially created educational content relevant to the Chilean curriculum.

There is a growing body of evidence relating to the positive impact of ICT on learner attainment and others outcomes in science education (Kozma, 2003c). Learners collaborate with others in their class and search for information. Both teachers and learners use email and productivity tools. Learners' collaborative skills, provide learners the opportunity to conduct science research and solve problems by using the e-mail and productivity tools to search for information (Kozma, 2003a). Learners collaborate with others both inside and outside the class and search for information, create and publish results.

Hepp, Lavel and Ripoli (1996) recognise that ICTs are tools to be used by all participants in the educational process, like learners, teachers, school administrators and parents. The government setting ought not only to equip schools with computers, but also to connect them with other schools and the world through an educational network, thus enabling schools to exchange ideas and experiences regardless of their location. This goal also addresses one of the Chilean Educational Reform's key objectives: increasing equity in educational opportunity for all Chilean students (Hepp, et al., 1996).

The integration of ICT into science education can motivate learners and teachers and improve the quality of the teaching and learning of science (Hennesy, Wishart, Whitelock, Deaney, & Brawn, 2007). This is because ICT can make science education more versatile and goal oriented, inspire

students to be more active in their own education, promote co-operation, study in authentic contexts and creativity in learning (Hennesy, et al., 2007). Over the three-year period of the Finnish sub-project, in Finland, altogether sixteen meetings with teachers from three schools were organised in a CPTD project. Moreover, 21 days of in-service training courses were organised in different cities in Finland. The main aim of the in-service training was to emphasise use of ICT and Microcomputer Based Laboratories (MBLs) in science education. Videos demonstrate effective ICT use in science education from the point of view of the Finnish sub-project perspective (Hennesy, et al., 2007). A special web-page was developed, which helps teachers to integrate MBLs to science education. These developed activities were introduced to Finnish teachers through 21 days of in service training courses, organised in different cities in Finland (Solomon & Tresman, 1999). The main aim of the DP project was to support the co-operation of teachers to share knowledge and experiences with ICT use in science education in Finland, present teaching practices and plan and arrange small teaching experiments in their classrooms and evaluate them (Solomon & Tresman, 1999).

The role of ICT use in science education was classified in the Finnish sub-project. A teacher can use a PowerPoint™ presentation or an IWB when he or she explains a science model. Furthermore, databases, spreadsheets, graphing tools and modelling environments can be used as tools in science education (McFarlane & Sakellariou, 2002b). The main uses of ICT in learning science can be divided into different categories for directly supported learning. Computer-assisted learning (CAL) is any interaction between a learner and a computer system designed to help the learner learn. A learner can, for example, learn with interactive educational software. Computer-assisted research is the use of ICT as an aid in collecting information and data from various sources to support scientific reasoning (McFarlane & Sakellariou, 2002b).

Typically ICT is used as an agent for interaction with the information source, like the Internet or MBLs (Lavonen, Juuti, Aksela, & Meisalo, 2006). The MBLs tool is a combination of the hardware and software that are used for collecting data using sensors connected to a microcomputer through an interface. The collected data can be analysed and displayed in graphic form, in real or delayed time. Electronic mail, newsgroups, chat rooms, blogs, Wikis, and videoconferencing are used for educational purposes in distance learning approaches. For example, a newsgroup can be used for facilitating learners' homework. The whole course can be managed through a learning management system (LMS). MBLs can be used as tools and also in a computer-assisted inquiry project. It can also be used as a tool for data capture, processing and interpretation (Lavonen, Aksela, Juuti, & Meisalo, 2003). Educational multimedia software can be used for single simulation of a process or carrying out virtual experiments. In several situations, not only a computer and software in science teaching and learning, but digital equipment is connected to the computer and used. When a digital recording is made, a microphone, digital camera, webcam, computer-controlled microscope or video camera is connected to a computer. A video or LCD projector is an example of computer projection technology. It is explained that MBLs are a combination of the Interface, sensor and software. Moreover, scan-

ners and printers are used as tools in science education. Mobile technology and portable MBL tools offer totally new possibilities for science education (Lavonen, et al., 2003).

New technologies have changed research in science significantly. Technologies make visible the things that are too small, too big, too fast, too slow, or too complex for human perception (Osborne & Henesey, 2003). Data models based on measurements of digital surveying instruments enable more precise predictions than ever before. Technology is expected to have a similar impact on science learning. To foster science learning processes, technology is implemented for accessing broader resources, scaffolding learning and for communication and collaboration (Osborne & Henesey, 2003).

Access to scientific texts and lectures, news, hypertext and hypermedia materials or scientific data, is a function of technology with high relevance for science learning. One of the big promises of technology, especially the Internet, is that it broadens the range of accessible information and educational resources and helps to make science in the classroom more current and authentic, e.g. through providing access to live news or real data. In addition, learners' awareness of the uncertainties around the construction of scientific knowledge has been raised through the use of digital resources, thus proving them beneficial for developing scientific literacy (Osborne & Henesey, 2003).

The access to various resources through digital media or the Internet makes it possible for instructors to integrate more resources in their lessons, to use existing or even develop their own web-based learning environment (Liu, Hsieh, Cho, & Schallert, 2006). ICT can provide scaffolding through prompts, hints, questions, concept maps, tutorials and intelligent tutorial applications. Different types of supportive measures are designed to help learners understand concepts, monitor their learning processes, organise and structure their tasks and necessary steps, find alternative strategies. Support measures have been found to improve learners' scientific conceptions and to help resolve misconceptions (Kim, et al., 2007).

E-mails, weblogs, discussions boards, chat-rooms and collaborative electronics environments facilitate learners' working together on tasks, sharing their knowledge and expertise, and producing joint outcomes (Osborne & Henesey, 2003). Well-designed collaborative opportunities can foster some aspects of knowledge integration and increase learners' conceptual understanding. Evidence showed that properly scaffolding online discussions involved more complex ideas and justifications on comments than typical class discussions (Linn, 2003). Prolonged engagement in computer-based collaborative activities, embedded in the science curriculum, was found to improve learners' problem-solving and thinking skills (Wegerif, 2002). Currently, a number of projects target the use of ICT to support collaboration and communication in science education. Such a learning environment is the Web-based Inquiry Science Environment (WISE), which offers opportunities for students to examine authentic data and to analyse scientific controversies.

According to Chaplin (2003) most science teachers spend time establishing a set of routines and expectations for work in a science laboratory, getting out equipment and clearing away, lighting a Bunsen burner, gathering round for a demonstration, doing practical work with lenses and mirrors in near darkness, and so on. Using ICT equipment effectively should also involve appropriate routines, known and used by everyone in the science department, for example: learners do not go to work at a computer until directed by the teacher and every learner should know how to access resources and documents in different contexts around the school, the science labs, and the ICT suites (Chaplin, 2003).

A big advantage of using ICT-based materials for many learners is that they can go back to them as often as they wish. Science teachers must make sure that there are science resources available for learners to use independently in the library (Denby & Cambell, 2005). If possible, establish a science presence on the school intranet or website, with links to schemes of work and resources (Denby & Cambell, 2005). Science resources can mean not just commercially produced teaching and reference materials, but also home-grown revision exercises, outlines of schemes of work with lists of, or links to relevant resources. Linking a projector up to your computer, you can increase the impact and every learner in class can see the material. IWBs are also very useful in presenting a science activity or lesson to the class. There are a range of IWBs available commercially that are connected to the computer and projector and allow the image to be controlled from the board itself (Denby & Cambell, 2005). Most boards have specially designed software that allow images on the board to be annotated, saved and permits rapid and very useful movement between current and previous screen images. Some manufacturers have developed notepads that link to the whiteboards so that learners can contribute to what is on the main board from their seat in class.

Millar (2001) describes how the use of spreadsheets can support work on statistics for A-level biology, but spreadsheets can also be used to look at diet and energy values, investigating energy use in the home, or handling experimental data. Staples and Heselden (2001) suggested that ICT can also be used very effectively to support writing in science lessons, whether it involves the use of writing frames, or allows learners to present their own articles about a topic as a potentially more engaging way of doing a revision summary. Strategies to bring ICT support into the science education space have received much more attention. One approach is the use of a class set of laptop or notebook computers within the science area.

In South Africa attention is focused on technology-enhanced learning in the hope that it may offer some solutions to the challenges of education (Howie, et al., 2005). The White Paper on Education and Training focuses on OBE, developing problem-solving skills, and providing a creative environment in which new technologies are harnessed to produce knowledge products. Furthermore, the White Paper states that the DoE aims to integrate technology into these education strategies in order to advance the country's ability to adopt new technologies to facilitate its growth and development (Howie, et al., 2005).

More government support is can be found in the White Paper on Science and Technology, which stresses that access to ICT is crucial to national competitiveness and popular empowerment. The White Paper proposes a National System of Innovation that will support and promote the attainment of national objectives by the creative use of the outputs of the science and technology system with regard to new knowledge and new technologies (Howie, et al., 2005). In pursuit of this idea, the Department of Science and Technologies (DST) believes that the knowledge, technologies, products and processes produced must be converted into increased wealth, by industry and business, as well as into an improved quality of life for all members of society.

Through the Universal Services Agency, there is focus on community information and learning centres around South Africa. These centres will be equipped, on a large scale, with appropriate mass media and technology, some of which have already been established. There are currently a number of initiatives in various sectors in South Africa that focus on different aspects of technology in education (Howie, et al., 2005).

2.5 PEDAGOGICAL USE OF ICT

Research has shown that the appropriate use of ICT can catalyse the paradigmatic shift in both content and pedagogy that is at the heart of education reform in the 21st century. Tinio reflects that if ICT-supported education is designed and implemented properly, it can promote the acquisition of the knowledge and skills that will empower learners for lifelong learning. When used appropriately, ICT, especially computers and Internet technologies, enable new ways of teaching and learning rather than simply allow teachers and learners to do what they done before in a better way. These new ways of teaching and learning are underpinned by constructivist theories of learning and constitute a shift from a teacher-centred pedagogy—in its worst form characterised by memorisation and rote learning to one that is learner-centred (Tinio, 2002b).

ICT is a tool for use across the curriculum or in separate subjects where the emphasis is on the development of ICT-related skills, knowledge, processes and attitudes. It is a tool to enhance learners' learning outcomes with the existing curriculum and existing learning processes (Khvilon & Patru, 2002). As an integral component of the broader curriculum, ICT can reform not only how learners learn, but what they learn as well. All of this indicate that ICT is integral to the reform that alter the organisation and structure of schooling itself (Khvilon & Patru, 2002). The implementation of ICT in science education emphasises integration of relevant skills in the pedagogical use that are linked to different teaching approaches performed across the curriculum.

Constructivist teaching refers to a teaching approach that focuses on psychological and philosophical perspective, contending that individuals form or construct much of what they learn and understand

through individual and social activity (Schunk, Pintrich, & Meece, 2010). The constructivist approach can be applied to assess learners as well as engage them in group work using ICT skills.

Active learning, as a learning approach, creates opportunities for learners to participate in different learning activities, such as whole class instruction, interaction, group or pair activities, and some individual activities. Active learning enables seeking for that, which will turn the unfamiliar into the familiar (Craig, 1996). ICT-developed learning mobilises tools for examination, calculation and analysis of information, thus providing a platform for learner inquiry, analysis and construction of new information. Learners, therefore, learn as they do and, whenever appropriate, work on real-life problems in-depth, making learning less abstract and more relevant to the learner's life situation (Tinio, 2002b). In this way, and in contrast to memorisation-based or rote learning, ICT-enhanced learning promotes increased learner engagement. ICT-enhanced learning is also *just-in-time* learning in which learners can choose what to learn, when they need to learn it (Tinio, 2002b)

Collaborative learning is defined as a relationship among learners that requires positive interdependence (a sense of sink or swim together), individual accountability (each of us has to contribute and learn) and interpersonal skills (Kollar, Fisher, & Hesse, 2006). This approach to learning is also a condition in which two or more individuals learn or attempt to learn something together. More specifically, collaborative learning is based on the model that knowledge can be created within a population where members actively interact by sharing experiences and take on asymmetric roles.

Computer-supported collaborative learning is a relatively new educational paradigm within collaborative learning, which uses technology in a learning environment to help mediate and support group interactions in a collaborative context (Dillenbourg & Tchounikine, 2007).

Creative learning is described as a learner-centred process of discovery in education that challenges preconceptions, deepens conceptual understanding, and engages in meaningful, real world problem solving through the mastery of systems thinking and system dynamic modelling (Gunter, Estes, & Mintz, 2010). ICT-supported learning promotes the manipulation of existing information and the creation of real-world products rather than the regulation of received information (Tinio, 2002a).

Integrative learning refers to a way of learning that entails making connections between classes, fields, academic and co-curricular life, learners can encounter new challenges and new knowledge in a productive manner (Universities, 2002). Integrative learning is a view of liberal education that supports connectedness among life experiences, multidisciplinary formal study, and diverse perspectives. It seeks to foster the abilities of learners in order to integrate their learning across context and over time (Hubber & Hutchings, 2004). ICT-enhanced learning promotes a thematic, integrative approach to teaching and learning. This approach eliminates the artificial separation between the different disciplines and between theory and practice that characterises the traditional classroom approach (Tinio, 2002a).

Subject-specific approach indicates the starting point of ICT in one's own subject area. By this method teachers not only expose learners to new, innovative ways of learning, but also provide them with a practical understanding of what learning and teaching with ICT looks and feels like (Paily, 2006). In this way, ICT is not an add on, but an integral tool that is accessed by teachers and learners across a wide range of the curricula (Paily, 2006).

All the above teaching and learning approaches boil down to the pedagogical use of ICT in the science education environment. The result of integrations of the approaches mentioned above direct the teacher towards ways of incorporating ICT in a pedagogical way. The ICT-supported learning approach and ICT pedagogy approach are but a few of the possible approaches.

ICT-supported learning encourages interaction and cooperation among learners, teachers, and experts, regardless of where they are (Tinio, 2002a). Apart from modelling real-world interactions, ICT-supported learning provides learners with the opportunity to work with people from different cultures, thereby helping to enhance learners' teamwork and communicative skills. It models learning done throughout the learner's lifetime by expanding the learning space to include not just peers, but also mentors and experts from different fields (Tinio, 2002a).

The *ICT pedagogy approach* specifies implementation of overall perspectives used to plan and apply one or more instructional approaches for example: case-based learning, inquiry-based learning, project-based learning, resource-based learning and game-based learning (Learning Science Technology, 2003). The ICT pedagogical approach emphasises the integrating of ICT skills in respective subjects, drawing on the principle of constructivism, pre-service teachers design lessons and activities that centre on the use of ICT tools that will foster the attainment of learning outcomes (Paily, 2006). This approach is useful to the extent that the skills enhance ICT literacy skills and the pedagogy allows learners to further develop and maintain these skills in the context of designing classroom-based resources (Paily, 2006). Learners who have been subjected to this type of training have reported significant changes in their understanding of effective implementation strategies, as well as their self-efficacy as to their ICT competencies.

The assessment associated with the above teaching and learning approaches is an important driver in education, and if not managed properly, can become a barrier to innovation. Once ICT is embedded in teaching and learning processes, learners will want to be assured that assessment does test the level of acquisition of skills and competencies acquired through e-learning (Department of Education, 2004a). The administration of assessment is a labour-intensive exercise. The use of ICT in assessment has the potential to increase the efficiency of assessment and to streamline and safeguard data-transfer processes. It is, therefore, imperative that online and ICT-based formative and summative assessment methods are developed (Department of Education, 2004a).

Under the changing scenario, there is a need to redefine the role of the teacher (Paily, 2006). The National Council of Educators (NCTE) Jaipur, based on a thorough job analysis, presented three areas in which a teacher needs to acquire mastery (Paily, 2006). The teacher involved in the changing education system should incorporate ICT in the curriculum for the successful integration of ICT in teacher education, the teacher, in addition to taking up the responsibilities mentioned in these areas, must shoulder the additional, survival responsibilities outlined below: Encourage technology integration among the trainees, colleagues, teachers and parents; be involved in planning and implementing ICT CPTD. Technologies such as e-mail, forum, communities, blogging with participating schools, and parents can assist in the planning, designing and demonstrating the use of multimedia applications for instructional use through multimedia projects (Paily, 2006).

The most extensive uses of ICT in education have been in science at both primary and secondary levels. This can be seen through different types of ICT environments such as simulations and modeling (BECTA, 2003a). ICT provides opportunities for learners to explore simulations of these processes in the classroom, where previously they would have needed to travel to a science centre or museum. A body of researchers have investigated the extent to which ICT-based simulations can substitute for advanced experiments or experiences in a museum or science centre (BECTA, 2003a). For example, Baxter and Preece (2000) found that the education of 48 learners in years 5 and 6 (9- and 10-year olds), when they taught with the aid of computer planetaria, was equally effective as teaching with dome planetaria. Learners worked in pairs at a computer, using *Planetaria* software.

The evidence from experimental studies shows that various aspects of achievement can be improved by integrating simulations into topics that learners find conceptually difficult (BECTA, 2003a). The activities set by the teacher which involve simulations are often problem solving and enquiry tasks, in which learners interact with each other as well as with the teacher. Although these studies rarely consider pedagogy in detail, they do suggest that the collaboration between learners was an outcome that was encouraged, but not specifically designed by the teachers and that the collaboration is one of the factors that leads to improved attainment (BECTA, 2003a).

Computer simulations of experiments are often used in short episodes in existing curricula. Huppert and Hutchings (1998) conducted an experimental study of the effect of computer simulations on grade 10 learners' ability to apply their knowledge to the growth curve of micro-organisms. The use of simulations allowed the learners to carry out investigations more quickly and focus on analysing the results and hypothesising (Huppert, et al., 1998). The structure of the course helped to create a collaborative learning atmosphere, with learners comparing results and exchanging ideas. These aspects resulted in gains in cognitive learning (Huppert, et al., 1998).

Learners who build their own models by identifying relevant factors and variables and hypothesising relationships, is another important aspect of ICT in science at both primary and secondary levels. Most of the research in this area focuses on learning and attaining, but large projects, such as the

London Mental Models project, have also studied the role of the teacher in the classroom when learners are building scientific models (BECTA, 2003a). This study and others have shown that although learners could investigate existing models and hypothesise relationships, it was more difficult for them to build their own model without the guidance of a teacher. They tended to build very basic models, and could not decide on strategies for further work, without being told about the goals which they were trying to achieve (BECTA, 2003a).

The use of technology as a learning tool is expanding as a global mechanism for enabling access to information and communication. It is not surprising, therefore, that there has been a slow but steady increase in the use of ICT in science lessons. However, the implication of ICT in science is only now being fully explored. According to Byrne and Sharp (2002) the most recent statistical survey of the use of ICT in schools in the UK found that 50% of schools were already making substantial use of ICT in science. Drawing together statistics from a range of sources, including Ofsted inspections and Key Stage 2 National Test results, the BECTA has found that schools who have good ICT resources and are using them in the teaching of science are achieving higher standards (Byrne & Sharp, 2002).

Whether teachers are in training or already qualified, it is crucial that they are aware of the importance of learners experiencing ICT in a worthwhile and meaningful manner within the context of the science being taught, and to consider how ICT will support that learning. Except for using ICT as an aid to learning, teachers are increasingly making use of it as a medium to assist their teaching. IWBs and large screens linked to a computer for whole-class teaching are becoming more common in schools (Byrne & Sharp, 2002). Word processing, graphics packages and data handling are all used regularly to prepare teaching materials and assist in such activities as assessment and report writing. Since ICT can overcome physical and geographic barriers and facilitates communication, it has the potential to eliminate the artificial boundaries between schools and the outside world, and to promote an environment that emphasises collaboration rather than competition (Haddad & Jurich, 2001). Videos and computer animations enable learners to witness a volcano eruption, which aids in learning about pressure and rock formation.

More than any other technology, the Internet opens new opportunities for collaborative work. From group discussions to full collaborative research projects, the Internet has the potential to connect classrooms, research centres and learners to actual scientists (Haddad & Jurich, 2001). According to Haddad and Jurich (2001) some schools are using videotaped sessions to prepare new teachers to enter the classrooms without relying solely on mentors. Videos can also be used to analyse teaching styles and assist educational systems in amending their approaches to teaching. A research project related to the Third International Mathematics and Science Study (TIMSS) videotaped mathematics and science teachers in their classes where they were busy teaching in Japan, Germany and the United States of America (USA) (Haddad & Jurich, 2001). The study analysed variations in teaching styles and lesson content among the three countries looking for correlations between those dimensions and learners' performance.

ICT can be used as tools for training and support of teachers, regardless of their geographical dispersion. Scripted lessons in conjunction with educational programs via radio and television ensure that all learners receive quality, updated information while imparting to inexperienced and generalist teachers the appropriate content knowledge and new pedagogical strategies (Haddad & Jurich, 2001).

The use of technology for teachers has at least three major advantages, namely it reduces travel costs, avoids disrupting classroom routines and familiarises the teachers with technology. The Internet has a myriad of websites to help teachers develop or improve lesson plans exchange ideas, obtain information, and find free animation and simulations to enliven their lessons. Haddad and Jurich (2001) state in their studies that most Internet-based collaborative learning projects include support and training and conference proceedings are published regularly on the WWW. Chat rooms or forums may become a laboratory for new ideas. For instance, teachers in Soweto, South Africa, used their online connections with schools in Birmingham, United Kingdom, to create a support network and promote discussions on curriculum reform and school management practices. Contrary to the notion that technology is replacing the teacher, ICT have expanded the quantity and quality of resources available to make teaching less of an endeavour (Haddad & Jurich, 2001).

More important still, researchers indicate that the introduction of ICT for educational purposes has the potential to bring positive changes to teaching practices. In a survey of more than 2000 teachers and school principals across the USA, the teachers stated that technology helped them to become more effective. Both the teachers and administrators agreed that ICT had reinforced instruction and functioned as a motivator for the learners who were more prone to ask questions and participate in the lessons (Haddad & Jurich, 2001). Using ICT in science, teachers generally agree that ICT makes them more effective in their teaching of science education in schools, more organised in their work and better able to meet the carrying needs of the learners (Haddad & Jurich, 2001). A further positive sign, that teachers indicated, is that they would like to integrate more computer applications into their teaching. According to Haddad and Jurich (2001) it appears that teachers' perceptions towards ICT are encouraging, as most of them showed positive perceptions. It is believed that teachers can see the value of the ICT in enhancing teaching and learning, and they are positive towards integration of technologies into classroom instructions.

Science teachers gave examples of their use of computers on lessons that included accessing information on the Internet to answer learners' questions, such as when were the first plants discovered (Cowie, Harlow, & Jones, 2006). On some websites, science teachers had access to educational games in certain learning areas, such as human evolution or the study of light. They then downloaded and had their learners compete with one another. They also used the computer with information from the Internet to enhance learners' understanding of a complex technique and to demonstrate concepts that were difficult to illustrate in the lab (Cowie, et al., 2006). Information from the

Internet was used to facilitate classroom discussions, for example on online current weather and satellite maps, pictures of various bacteria and fungi, biological models and examples of big cat hybrids, how they occur and their physical characteristics. This was typical examples of how science teachers had used the Internet in science lessons. Classroom presentations have been used by science teachers to show chemical reactions which could not be demonstrated in the lab and to present difficult models such as the structure of an atom. According to Cowie *et al.* (2006) a science teacher had used a computer and a data projector to show pictures from NASA in a space craft and humans in space. Presentations were also used by science teachers to introduce a topic or to explore a website with the class and science learners had made presentations of their own work to present to the class.

Parkinson (2002) states that certain teaching styles have become embedded in the way science is taught in the UK, and the introduction of computers will have a distinct effect on the style of teaching used and the classroom interactions that take place. He further states that new entrants to the teaching profession will have been educated in an environment where the use of ICT is a fundamental aspect of the day to day life of a practising scientist and are likely to see science without computers as strange (Parkinson, 2002). It may be the case that these new teachers will be the driving force for change. Not only do they have first-hand knowledge of relevant computer use in the development of science, but frequently are also experts in a wide variety of computer applications.

Recent research carried out on behalf of BECTA's indicates that the use of ICT improves learners' performance in science (Parkinson, 2002). For individuals to pick up required knowledge at various stages of their working life in order to deal with situations in a rapidly changing world and a flexible job market, current educational thinking is based on a scenario of lifelong learning. Using computers in science lessons can help to promote a modern image of science and give a sense of the importance of ICT at all levels of learning about the subject. Robinson (1994) suggests that the use of the Internet helps to raise learners' awareness and understanding of science and technology in the real world. Such improvements will only be achieved through careful planning and the formulation of precise objectives matched to appropriate technology (McFarlane & Sakellariou, 2002a).

Parkinson (2002) explores what ICT can offer science teachers in terms of providing learning experiences for learners. Notwithstanding that the use of ICT in science is a part of the statutory National Curriculum, he argues that it should form a natural component of a teachers' repertoire of techniques. In traditional lessons, learners learn from the teacher, other pupils and the resources available. In a science lesson involving the use of ICT, there is the possibility that learners can learn directly from the computer and by means of situations that arise because of computer use (Parkinson, 2002).

Computers create situations that encourage learners to interact with the teacher, and other learners. Computers afford the possibility of constructing such conversations in a coherent fashion. The ever-present screen provides learners with a means for co-ordinating and structuring what they are talking about (Roth, Woszczyna, & Smith, 1996). The term used to describe the potential for action and the

capacity of an environment or object to enable learners to achieve their goals is affordances. The affordances of a particular environment include the opportunities presented to the learner by the technology in support of the task, social support for learning provided by the teacher or other learners in class, and the contextual support in which the activity occurs (Roth, et al., 1996). Computers can contribute towards the scaffolding of learning alongside the teacher. The teacher can set up situations that prompt learners to think and discuss things with fellow learners and their teacher, and from time to time it may be the computer that supplies the additional information that moves the learning along. Wild and Braid (1996) note that working with computers can increase learners' participation in discussion, and provides them with an environment where they feel confident in using exploratory language to arrive at decisions.

In some instances the affordances of the technology reduce the total cognitive load on the learner by taking care of the mechanical or routine tasks. For example, the computer may carry out a number of tedious calculations, or it may plot a graph, leaving time for the learner to concentrate on the interpretation of the data (Parkinson, 2002). In these situations, as in all other teaching situations, the teacher needs to make decisions about how much information and help to give to learners and when to leave them to their own devices. Most of the research on collaborative group work using ICT has been carried out in schools (Hoyles, Healy, & Pozzi, 1994). However, there are a number of important outcomes that are of relevance to learn science through the use of ICT in secondary schools, such as the nature and quality of any computer-based activity is almost defined by the software. The procedures and outcomes of the activity are shaped by the interaction between teachers and learners.

Research has highlighted the value of learners' collaboration. Indeed, there is evidence that working in small groups at the computer is more beneficial to learning than individual use (Underwood & Underwood, 1990). Group work not only facilitates the sharing of ideas, it provides opportunities for learners to explain and have ideas validated as they help each other (Sandholtz, 2001). Such implicit acknowledgement of learners' expertise and the encouragement of mutual help can have a profound positive effect on the motivation and achievement of learners (Sandholtz, Ringstaff, & Dwyer, 1997).

It has further been observed that when teachers overtly learn alongside and from expert learners, the process of integrating the use of ICT into the classroom setting gathers pace (Hruskocy, Cennamo, Ertmer, & Johnson, 2000). Loveless *et al.* (2001) have suggested that constructing knowledge from information requires more than the ability to use a variety of ICT techniques, but also embraces an ability to question, access, interpret, aim and analyse information. This, in essence, is the concept of IT capability and the teacher should be in a strong position to take a lead in helping learners to develop this broader skill (Loveless, et al., 2001).

Further affirmation of familiar teaching skills comes from the frequent references in teachers' reports to making links with previous work, setting targets, giving instructions, deciding when to intervene,

giving the right sort and amount of help, prompting discussions, asking questions to probe understanding and sharing ideas (Rogers & Finlayson, 2004). It is also evident that ICT provided opportunities for enhancing such skills. Further aspects of teachers' pedagogical skills are decisions about lesson formats and classroom arrangements. Choices they make about whole—class activity, group work, or the use of the computer suite by individuals, and so on, have a profound effect on the manner of engagement of learners (Rogers & Finlayson, 2004). Teachers were creative in optimising hands-on experience for learners through asking them to help with teacher demonstrations, organising them to work through a circus of different activities, or by organising a split class rota. Each organisational format has implications for the interaction between learners and teachers and learners with each other (Rogers & Finlayson, 2004).

2.6 INTERNATIONAL SIGNIFICANCE OF ICT POLICY

International policies and programs can be an important tool in the realisation of ICT in education and that is the focus in this part of the chapter, which concludes with recommendations that countries can use when formulating their educational ICT plans (Kozma, 2003a). As we have entered the 21st century, there has been considerable international attention given to the role that ICT play in economic, social, and educational change (Kozma, 2003a). This role has been most pronounced in the world's developed countries where technology has permeated businesses, schools, and homes and changed the way people work, learn, and play. The impact that ICT has had to date in the developed world, and the potential for further dramatic changes, is reflected in a range of multinational policy documents (Kozma, 2003a). For example, the leaders of the world's eight major industrialised democracies have noted that ICT has become an engine of growth for the global economy and has the potential to contribute significantly to sustainable economic development, to enhance public welfare, to strengthen democracy, to increase transparency in governance, to nourish cultural diversity, and to foster international peace and stability (Kozma, 2003a).

According to Kozma (2003a) the group emphasises should develop human resources and capable response to comply with the information demand and the lifelong learning are imperative.. The OECD also emphasises the economic importance and impact of ICT in developed countries and points out the need for these countries to develop a workforce with the skills to use ICT to increase productivity, as well as the need for young people to develop ICT skills in preparation for adult life (Kozma, 2003a). However, it is not only the leaders of developed nations that stress the importance of ICT. The UN and the World Bank both advocate the use of ICT to support the development of the world's poorest countries. The World Bank emphasises the potential that ICT has to improve efficient delivery of resources to the poor, to bring markets within reach of rural communities, to improve government services, and to transfer knowledge needed to meet the Millennium Development Goals (2003a). The African Heads of States concur on the potential for ICT to promote trade, improve health care, enhance good governance, and make education more available. ICT can increase access to education

through distance learning, enable a knowledge network for learners, train teachers, and broaden the availability of quality education materials (Kozma, 2003a).

International ICT policies can serve several important functions (Kozma, 2003a). Strategic policies can provide a rationale, a set of goals and a vision for how education systems might change with the introduction of ICT and how learners, teachers, parents and the general population might benefit from the use of ICT in schools. These strategic policies can motivate change and coordinate disparate efforts so as to advance the nation's overall educational goals. Companion operational policies can set up programs and provide resources that enable these changes (Kozma, 2003a). An analysis of national ICT policy statement identifies alternative, somewhat-related rationales that are used to justify the investment of funds on educational ICT. These high-level statements can be thought of as strategic policies. Some strategic policies promote the use of educational ICT to support economic growth or promote social development. Some policies focus more specifically on the impact of ICT on the education system, either to advance education reform or support education management (Kozma, 2003a). An example is Singapore, where education policy has always been strongly linked to the development of human capital (Kozma, 2003a).

The most recent economic develop plan in Singapore challenges businesses and workers to move beyond productivity gains resulting from the pervasive use of technology to the development of a knowledge economy, which relies on the development of new businesses based on research, innovation, and knowledge creation. In coordination with this economic plan, the Education Ministry instituted a number of reforms under the title of *Learning to think, Thinking to learn: Towards thinking schools, Learning Nation*. The country second ICT Master Plan, launched in 2002 and updated in 2006, CPTD and school culture to provide learners with and prepare them to participate in the country's knowledge economy (Kozma, 2003a). Within the European Union, Finland illustrates a national policy that focuses on the social impact of ICT. In its economic, social, and educational policies the Government of Finland places a very high importance on collaboration and knowledge sharing. The Finnish Information Society Program envisions a society in which knowledge and expertise form part of the culture and also the key factor in production. The country's education policy is coordinated with this vision. As part of this Information Society Program, the Ministry of Education in Finland developed the Information Strategy for Research and Education (Kozma, 2003a). The goals of this emphasise the need to develop information society skills among all learners, the building of open education and research networks, and the development of educational information products and services. The social impact of ICT is also, perhaps especially, a concern among less-developed countries. Chile, for example, has used its educational ICT policy to address the social inequities in the country (Kozma, 2003a).

In the early 1990's the education policy in Chile addressed inequities caused by years of neglect and privatisation under military rule. These policies focused initially on education improvements and ultimately on reform which extended the school day and the required period of matriculation, improved

teacher quality and bettered resources, particularly for the poorest performing schools (Kozma, 2003a). A central part of this policy was the widespread introduction of ICT, the training of teachers in their use, and the development of an educational portal on the WWW. Particular attention was paid to ICT access for rural schools, most of which are attended by the nation's significant indigenous population, who have been traditionally underserved by the education system. Rural schools account for a third of the Chile's schools, yet they are attended by only 10% of the country's students, often in one-room school houses, many without telephone access and some without electricity (Kozma, 2003a). As of 2004, 80% of the nation's schools are equipped with digital resources and 55% have Internet access, as a result of the policy. More specifically, nearly 2000 (or more than 60%) of the rural schools have broadband Internet access and more than 90% of the rural communities have Internet access through community info-centres.

ICT-related pedagogical changes treat learners as active agents who are engaged in collaborative projects that solve complex, real world like problems or in sustained investigations and interactions that generate new ideas by building on extending the ideas of others (Kozma, 2003a). The pedagogical role of teachers is to structure and support these practices by providing resources and prompting learners to take up these practices. Assessment reformed emphasises the need for continuous assessment that is integrated into regular, ongoing instructional activity and involves new assessment methods that include performance tasks and portfolio assessments. International studies have reported the use of these technology-based reforms in schools and classrooms in many countries around the world (Kozma, 2003a). These ICT-based curricular and pedagogical approaches are beginning to appear in national educational around the world. For example, Australian schools and teachers are integrating ICT to support experiential, constructivist learning in schools and across learning sites, engage learners in personalised, collaborative, connected and interactive learning, and broaden and use new pedagogies and assessment approaches.

2.7 WHITE PAPER ON e-EDUCATION

South African Education ICT policy states, *Learning through the use of ICT is arguably one of the most powerful means of supporting learners to achieve the nationally-stated curriculum goals* (Department of Education, 2004a, p. 13). The White Paper on e-Education states that *Every South African manager, teacher and learner in the general and further education and training bands will be ICT capable (that is, use ICTs confidently and creatively to help develop the skills and knowledge they need as lifelong learners to achieve personal goals and to be full participants in the global community) by 2013* (Department of Education, 2004a, p. 17). The achievement of the e-Education goal will require the development of schools that are learning organisations consisting of a community of both teachers and learners. In such schools, teachers and learners will be able to think what is worth knowing about education and new technologies along three dimensions, namely operational, cultural, and critical (Department of Education, 2004a).

The aim of the policy is not just to build technical skills, but also to use ICT to extend and enrich educational experiences across the curriculum. The objective is to build digital and information literacy so that all learners become confident and competent in using technology to contribute to an innovative and developing South African society (Department of Education, 2004a). In particular, the use of ICT for learning encourages learner-centred learning, active exploratory, inquiry-based learning, collaborative work among learners and teachers and creativity, analytical skills, critical thinking and informed decision-making.

The e-Education policy provides a strategic framework for national co-ordination with the Presidential National Commission on Information Society and Development, the Provincial Education Department, other government departments, business and industry, non-profit organisations, higher education institutions general and further education and training institutions, and local communities to implement e-Education (Department of Education, 2004a).

e-Learning is about learning and teaching philosophies and methodologies within the context of outcomes-based education, using ICT in the learning environment. Enriching the learning environment through the use of ICT is a continuum, a process that takes learners and teachers through *learning about ICT* (exploring what can be done with ICT), *learning with ICT* (using ICT to supplement normal processes or resources), and *learning through the use of ICT* (using ICT to support new ways of teaching and learning) (Department of Education, 2004a, pp. 20-25).

e-Learning will require teachers and learners to reflect upon and improve their approaches and strategies to teaching and learning. The use of efficient e-learning methodologies has the potential to enhance the quality and value of assessment (Department of Education, 2004a).

2.8 POLICY RECOMMENDATIONS

The strategic and operational policy elements provided above can serve as a framework for the analysis and comparison of national policies (Kozma, 2005). But there are particular substantive recommendations that can help policymakers use this framework to craft particularly effective educational ICT policies. National ICT policies will have the greatest impact if they are aligned with other strategic and operational policies. There are three possible alignments: strategic operational alignment, horizontal alignment, and vertical alignment (Kozma, 2005). Alignment between strategic and operational policies ensures that ICT programs and projects are directly tied to the nation's goals and rationale. For example, strategic policies that emphasise economic development should be matched by operational programs that use ICT to develop of new workforce skills, not just purchase new equipment, and strategic policies that emphasise pedagogical reform should be aligned with ICT training that provides teachers with new pedagogical skills, not just new technology skills (Kozma, 2005).

Horizontal alignment ensures that ICT policies are consonant with other policies within the education system. For example, changes in ICT policies can both contribute to and benefit from corresponding changes in curriculum, pedagogy, assessment, and teacher training and it behoves ICT policymakers within the ministry of education to coordinate their policymaking efforts with those in other departments. More generally, policymaking efforts in the education ministry can benefit from coordination with those in the ministry of economic planning, telecommunications, labour and rural development (Kozma, 2005). Often, policy coordination of this sort requires the guidance of the highest level policymaker, the minister of education in the first instance and the prime minister in the second instance. Some countries constitute cross-ministry councils to guide and coordinate related policies with shared goals. Vertical alignment refers to the coordination of policies up and down structural layers. That is, national policies should guide and be coordinated with those at the state, provincial, or local level. This will ensure that resources allocated at the national level are appropriately applied at the state and local levels to have the maximum impact on schools and classrooms (Kozma, 2005).

In some countries, educational policies may have the sole prerogative of the central government. In these countries, ICT policy may be formulated as a discrete policy statement within the ministry of education, such as that in Singapore or the United States (Kozma, 2005). In other countries, it may be integrated into the overall national educational policy, such as Malaysia and Chile, or it may even be embedded in the national telecommunication policy, such as in Egypt where the ministry of communication and information technology lead the nation's ICT-based Egypt education initiative, in collaboration with the ministries of education and higher education (Kozma, 2005). In South Africa, the Technology Enhanced Learning Initiative (TELI) planning document presented a model of the upgrade paths implied in the developmental integration of technologies into the learning and teaching environment. In addition to outlining four possible stages in the use of technologies, which culminate in the implementation of ICT facilities, the document also specifies the broad technical and parameters for any schools planning for educational technology acquisition. The TELI document aimed to provide guidelines for educational institutions (Howie, et al., 2005). According to Howie et al. (2005), it is quite clear that in the intervening years, the importance of ICT in national economies and in national education systems has increased within the global context. In South Africa, as elsewhere in the world, it is no longer sufficient for government education departments to guide ICT policy and to rely on local initiatives. In the 21st century it is essential for national education departments to initiate education-related ICT-policies (Howie, et al., 2005).

2.9 CONTRIBUTION OF ICT TOWARDS SUCCESS IN SCIENCE EDUCATION

The contribution of ICT towards success in science education is made complicated by the many variables which influence the outcome in science lessons. A significant variable is the diverse readiness of learners in classrooms, in terms of their ICT skills (British Educational Communications Technology

Agency, 2003). Software design is also clearly a very important factor towards success. The evaluation of software for learning cannot be satisfactorily approached without reference to situational factors which are directly influenced by decisions of teachers as they define lessons objectives and interact with learners. Squire and Mc Dougall (1996) argue that the success of software also depends upon the match between the software author's implicit pedagogy and that of the teacher. Evaluation is further complicated by the fact that ICT often confers advantages which change learning parameters and render tasks with ICT, which cannot be directly compared with conventional practice (Hummond, 1994). It appears to be part of the nature of ICT to cause qualitative change to the learning context to which it is applied. Since all the teachers involved in our study drew from a common pool of software applications (embracing Internet use, multimedia, data logging, spreadsheets, simulations and presentational tools) carefully chosen by the training provider, the effect of software is much less significant in our data set than differences arising from individual teachers in different schools (Rogers & Finlayson, 2004).

The teacher is a key variable which we regard as central to our discussion. The use of ICT cannot succeed on its own merits, but needs the actions of a teacher (Kennewell, 2001). Numerous studies have pointed to the importance of the teacher's role in integrating ICT into classroom teaching, the setting of parameters for learning, the definition and management of appropriate learning objectives, supporting learners with procedural strategies and establishing the norms and culture of the classroom (Pedretti, Smith-Meyer, & Woodrow, 1999). Rogers and Finlayson (2004) maintain that relying on the self-evaluations of teachers, 83% of their lessons with ICT were rated as having successfully fulfilled their teaching objectives. Clearly, teachers were persuaded of success in terms of the value to their subject teaching rather than the development of ICT skills for their own sake.

Advantages of ICT use were frequently quoted as gains of quality and efficiency, for example the speed of access to information, accuracy of data obtained electronically from experiments, speed of calculation of numerical data and the clarity and speed of graphical representation (Rogers & Finlayson, 2004). More importantly, such examples are valuable signals of the recognition by teachers of potential benefits to learning. Examples like this also illustrate a change in emphasis, reported by many teachers, from the collection of information towards its analysis, facilitating an investigative approach in which learners take a large measure of responsibility for designing activities and asking questions about the results. Wild (1996) observed in earlier research, in practical science lessons, that the use of ICT and an investigative mode of working were mutually beneficial. Investigative methods of working imply a constructivist teaching approach and research has established a strong compatibility between this and ICT tasks. A major study by Sandholtz in the USA, the Apple Classroom of Tomorrow project, demonstrated how ICT transformed classrooms to become more student centred in teaching approach. Smaller-scale studies in the UK have also indicated high levels of interaction and engagement fostered in ICT tasks (Sandholtz, et al., 1997).

2.10 SUMMARY

This chapter investigated the uses of ICT in science education by means of a literature study. Due to the reality that science has a lot of difficult theoretical and abstract concepts, some of the learners need visual material to learn, which underlines the importance of ICTs in education. From the literature it is clear that there are diverse ways in which different countries approach the use of ICTs in science education. ICTs in Norway, Canada and Hong Kong are reviewed due to the fact that they reported the use of ICT in the teaching and learning activities for grade 8 learners. Learner-centred philosophy in Australia is explored and the influence of ICTs on the approach is defined. The significance of the use of ICTs in education and the effect of the development of policy is explained. The implication of the teacher as the key variable to direct learners on a route to know how to access resources and documents in different contexts is of importance for inclusion of ICTs in science education. An overview of SITES 2006 modules is presented and discussed in chapter three.

CHAPTER 3

OVERVIEW OF THE SITES MODULES

CHAPTER 3

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3.1 INTRODUCTION

In the previous chapter broadly examined from a literature perspective of the use of ICT in science education. Chapter three aims to describe the previous SITES Modules, SITES Module 1 and SITES Module 2. A discussion on the research design and methodology of the SITES group of studies was necessary.

3.2 BACKGROUND

IT has become an integral part of many aspects in our everyday life and its use to support learning and teaching is becoming more common place in formal and informal education. ICT assumes a strong and constant presence in nearly all daily human activities (Gomes, 2005). This increasing presence is accompanied by changing expectations of the role of IT in schools, particularly in classroom practice (Law, Pelgrum, & Plomp, 2008c).

Educational policy documents in many countries have placed emphases on promoting the use of ICT in teaching and learning, often in conjunction with curriculum reform initiatives that aim to enhance the development of 21st century skills such as collaborative inquiry and collaboration (Law, et al., 2008a). While SITES is a series of comparative studies on ICT-use in education, all three modules maintained a strong focus on pedagogy and pedagogical innovation for two main reasons. The three completed SITES modules are interested in identifying (1) whether there is evidence that the policy rhetoric about the need for pedagogical change to prepare learners for the knowledge economy, has made on pedagogical practice in classrooms around the world, and (2) if so, whether ICT-use is contributing to such changes (Law, et al., 2008a).

The rapid and escalating growth of technology advancement and profound changes in many aspects of human activities has created vast challenge for education. This is often referred to as indicative of the world moving into the knowledge age. Such changes have stimulated much discussion about the role and processes of education as well as the role of information and communication technology in teaching and learning in the new era (Pelgrum & Law, 2008). Questions have been raised about the effectiveness and impact of technological applications. The International Association for the Second Information Technology in Educational Achievement (IEA) contributed significantly to addressing this with two studies on computers in education in 1989 and 1992 (Plomp, Anderson, & Kontogiannopoulou-Polydorides, 1996).

There have also been many policy documents on themes published by international/regional organisations such as the European Commission, 1995, European Roundtable of Industrialist (ERT, 1997, OECD, 1999; UNESCO, 2003; World bank, 1998) as well as numerous master plans on education reform and ICT in education launched by various governments since the mid-1990s (Pelgrum & Law, 2008). Examples of the plans are the Educational Testing Services, 2002; EMB, 1998, 2004; Finnish Ministry of Education 1999; Education Networks Australia, 2000. Many of these policies' initiatives brought along a variety of strategic implementation priorities which differ from country to country, depending on the specific social-economic and political contexts involved. Such educational strategies may involve, amongst others, changes in curriculum and/or assessment at the system level, provisions for ICT infrastructure, teacher professional development or technical and pedagogical support for teachers (Pelgrum & Law, 2008).

The IEA decided in the late 1990s to start the Second Information Technology in Education Studies (SITES), an international comparative research program studying the use of ICT in education. SITES consist of three independent modules: Module 1, the indicators; Module 2, the innovative practice and Module 3, the survey module. The first module of SITES, a large quantitative study carried out between 1997 and 1999, was an international cross-section survey of principals and technology coordinators in schools of 26 countries. Module 1 focused on ICT resources and the extent to which schools have adopted and implemented pedagogical practices essential to education in the information society (Pelgrum & Law, 2008). The second module of SITES was an international qualitative study of innovative pedagogical ICT practices conducted between 2000 and 2002 in 28 countries according to a selection of mutual criteria that identified 174 innovative classrooms. The third module of SITES in 2006 collected data from 22 countries. Three questionnaires targeted mathematics and science teachers, principals and technology coordinators to determine teachers' pedagogical practices and the use of ICT in teaching and learning. The central theme of SITES is to foster our understanding of how ICT is affecting the way learning and teaching take place in schools. It was started in 1997 with a school-survey called Module-1 (M1). This was followed by Module-2 (M2) which was a comparative study of case studies of innovative pedagogical practices supported by ICT (Pelgrum & Law, 2008). SITES M1 and SITES M2 are discussed below.

3.3 SITES MODULE 1: INDICATORS MODULE

The second Information Technology in Education Study: Module 1 (SITESM1) was an international comparative study designed to help countries to estimate their current positions with regard to using ICT in education, relative to other countries (Pelgrum & Law, 2008, pp. 1-10). The study established baselines against which developments could be judged in subsequent years. Moreover, the comparative data were intended to assist national policy-makers reflect upon improvements that may be considered for the near future. The study was designed as a survey of principals and technology co-

ordinators from a representative sample of schools in each of the participating countries. A total of 26 systems from Europe, North America and Asia participated. Schools were sampled at one or more of three levels in the education system: primary, lower secondary and upper secondary education. The data collection for the study took place between November 1998 and February 1999. The International Coordination Centre of the study was located at the University of Twente in the Netherlands and Dr. Willem J. Pelgrum directed the research.

As reported in Pelgrum and Anderson (1999) module 1 produced findings on the extent to which ICT is used in education and whether education systems have implemented objectives and pedagogical approaches that are considered important for education in a knowledge society. Findings of SITES M-1 showed that educational systems differed a lot in this respect, but that in a few educational systems more than a half of the schools had begun to use ICT to change toward a more learner-centred pedagogical approach with the aim of making learners more active in and responsible for their own learning (Plomp & Voogt, 2009).

The following four questions were addressed by the study:

- To what extent does the school management offer a supportive climate for the use of ICT in the school?
- What ICT infrastructure (equipment, software, access to the Internet) is available to the school?
- What staff development and support services exist with regard to ICT?
- To what extent have schools adopted objectives and practices that reflect a focus on autonomous learning strategies?

This study examines the student-computer ratio across countries pertaining to the ICT infrastructure in schools. The ratio indicates the relation of students per computer in the schools that participated. A ratio of 20, for instance, means that if all students want to use the equipment at the same time, 20 students would have to share one computer. The computer-learner ratio for lower secondary schools ranged from approximately 9 to 1 in Canada and 12 to 1 in Denmark and Singapore to 133 to 1 in Lithuania and 210 to 1 in Cyprus (Pelgrum & Law, 2008). Of the 24 countries, 13 responded at the lower secondary level and had a ratio of 30 students per computer or less. The other 11 countries indicated higher ratios. Nonetheless, it is clear that this ratio has come down significantly over the past several years. Similar collection of data in 1995 as part of the TIMSS report indicated that Norway dropped from a ratio of approximately 55 students per computer to 9 in the Module 1 study, while Thailand dropped from 206 to 62. Substantial declines in this ratio occurred in every country that participated in both studies. SITES M1 also examined the extent to which schools had access to the Internet for instructional purposes. Again, there were significant differences between countries. During 1998-1999, Singapore and Iceland had shown that a 100% of the lower secondary schools had access, while in Canada this figure was 98% and in Finland 96%. Contradicting this, only 11% of

schools in Cyprus and only 4% of the Russian lower secondary schools had access to the Internet during 1998-1999 (Pelgrum & Law, 2008).

Despite the general increase in the availability of computers and their connection to the Internet, the problem most often mentioned by respondents was the inadequate number of computers. Other infrastructure-related problems often mentioned by respondents include insufficient peripherals, a lack of software, and an insufficient number of computers that could simultaneously access the WWW. However, the second most often mentioned problem was teachers' insufficient knowledge and skills regarding ICT (Pelgrum & Law, 2008). While the majority of schools reported having a policy goal of training all teachers in the use of ICT, in most countries this goal was achieved only in a minority of schools. The majority of technology coordinators, that is, those persons who answered the technical questionnaire, responded that they were adequately prepared with regard to general applications, such as word processing, data base and spreadsheet software, while a much lower percentage indicated that they adequately prepared in the pedagogical aspects of ICT (Pelgrum & Law, 2008).

Many schools around the world indicated that emerging pedagogical practices were present in their schools. However, as with other indicators, there were also large differences between countries in terms of their pedagogical practices. For example, on a scale of 0-100, Norway scored the highest with 71, and Denmark and Hungary scored 69 on emerging pedagogical practices in their lower secondary schools. Hong Kong scored 36 and Japan scored 29, the lowest (Pelgrum & Law, 2008). Regarding traditional practices, Thailand scored 75 and Luxembourg scored 72, while Norway scored 43. Beyond this, principals were asked the extent to which ICT had contributed to the realisation of the various emerging pedagogical practices in their schools. In Denmark, 62% of the lower secondary principals responded affirmatively, this figure was 58% in Israel and 56% in Canada, Hungary, and Slovenia. The figure was much lower in Hong Kong (40%), the French Belgium community (37%), and Japan (31%). In summary, SITES M1 established that many school principals considered ICT to be important in their schools and many had developed local policies regarding its use (Pelgrum & Law, 2008).

Computers in schools demand a significant investment. In many countries, the ratio was below 30 students per computer and this figure had been falling significantly since 1995. A large investment had also been made to connect schools to the Internet. These results correspond to findings from other similar studies. Module M1 data indicated that this investment had started to pay off in many countries, at least in some schools, as teachers began to use ICT to change their pedagogical approach to be more student-centred. The relationship between ICT use and innovative pedagogical practices in classrooms was further explored in-depth in SITES M2.

3.4 SITES MODULE 2: INNOVATIVE PRACTICES

The SITES M2 study aimed to determine the features and characteristics of the most innovative cases of ICT use in classrooms, which were considered to be indicative of the direction in which future classroom practices would be like in countries around the world. In each of the 28 educational systems that participated in the study, national panels identified a number of innovative classrooms using a set of common selection criteria adapted for the national context. This resulted, altogether, in 174 case studies of innovative pedagogical practices using ICT. National research teams used a common set of case study methods to collect data on the pedagogical practices of teachers and learners, the role that ICT played in these practices and the contextual factors that supported and influenced them. The International Coordinating Committee (ICC) conducted a cross-case analysis using qualitative and quantitative methods. Implications were drawn for both improved policy and classroom practice (Pelgrum & Law, 2008). The results of this study provided teachers all over the world with outstanding examples of how technology can change classroom teaching and provide policy makers with guidelines that they can have on their educational systems. Some key findings from this study include:

- In the 174 cases, technology was supporting significant changes in classroom teaching and learning. These paint a very different picture than the traditional classrooms where the teacher lectures in front of the classroom and students take notes or complete worksheets. They show important similarities in how technology is being used in many countries around the world.
- In these selected cases, students were actively engaged in what is sometimes called constructivist activities, such as searching for information, designing products, publishing or presenting the results of their work. Students often collaborated with each other on these projects and occasionally they collaborated with others outside the classroom, such as students in other countries. Productivity tools, such as word processors and presentation software, were used in a majority of the cases, as were World Wide Web resources, e-mail, and multimedia software. These tools and resources were used to create products and presentations, support communication, and search for information.
- A large majority of case reports said that teachers created structure for students by organising student activities and teachers advised students and monitored or assessed student performance, as they were engaged in the innovation. A majority of the cases reported that teachers collaborated with other teachers as part of their innovation. And in a few of the cases, teachers collaborated with people outside the class, such as professors, scientists, or business people.
- Certain patterns of practice were more likely to be associated with significant positive outcomes. For example, in cases where technology supported students to collaborate with each other, to conduct research and analyse data, they were far more likely to report that students acquired new ICT, problem-solving, and collaboration skills than other practice patterns.

- A large number of cases occurred in the science learning area. Languages accounted for another large group, both mother tongue and foreign languages. A smaller group of cases were in the social science or creative arts. Many of these ICT-based innovations involved multidisciplinary projects. In only 29% of the cases was the innovation limited to a single subject area. Only a small minority of the cases involved the study of computer literacy, computer science, or *informatics* as a subject area.
- This technology supported innovations had a limited impact on the curriculum. Only 18% of the 174 cases reported a change in curriculum goals or content that was supported by technology.
- While 75% of the innovation had been used for at least a year, only 41% provided evidence that the innovation had been disseminated to the classrooms or schools. In the schools where they had been both continued and disseminated, continuation depended on the energy and commitment of teachers, students' support, the perceived value for the innovation, the availability of teacher professional development opportunities, and administrator support.
- Innovations were more likely to continue if there was support from others in the school and from external sources, innovation champions, funding, and supportive policies and plans. Particularly important was the connection with national technology plans that provided resources that often enabled the innovation to succeed.
- Policies, both local and national, were important to the success of many of the 174 innovations.
- This study provides teachers all over the world with outstanding examples of how technology can change classroom teaching and provide policy makers with guidelines that they can use to increase the impact that the technology can have on their educational systems.

3.5 CONCEPTUAL FRAMEWORK

Findings from SITES-M1 and M2, and recent national surveys and other research outcomes were used to elaborate the conceptual framework and the research questions for the study. The study took the view that pedagogical practices which employ ICT, are part of the overall pedagogical practices of the teacher (Plomp & Voogt, 2009). For teachers, the reasons for and the ways of using ICT in the classroom are underpinned by their overall pedagogical vision and competence. Also, pedagogical practices are not determined solely by the characteristics of the teachers, such as their academic qualifications and ICT-competence, but also by school and system-level factors. While it is expected that learners' learning outcomes are influenced by the pedagogical use they experience, the perceived outcomes also impact on subsequent pedagogical decisions of the teacher (Plomp & Voogt, 2009). This is because teacher, school, and system-level factors often have to change or be changed to accommodate the expected or actual impact of pedagogical practices on learners.

Indicators for each of the concepts in the framework were developed and questionnaires for school principals, school ICT-coordinators, mathematics and science teachers were designed (Plomp & Voogt, 2009). The target grade of the study was the grade that presents eight years of schooling, counting from the first year of ISCED Level 1 (Organisation for Economic Co-operation and Development, 1999) in which, most countries, is grade 8. Data collection for SITES 2006 took place in Southern Hemisphere countries in 2005 and in 2006 in the Northern Hemisphere countries. Eighteen of 22 educational systems participating in the study only collected data online (Plomp & Voogt, 2009).

From Figure 1 it is clear that during the formation of the conceptual framework of SITES 2006 it was revealed that "learning resources and ICT infrastructure and the assessment practices may be associated with different categories of pedagogical practices, and the same pedagogical practices may use more than one feature within each of these supplementary concepts" (Law & Pelgrum, 2005).

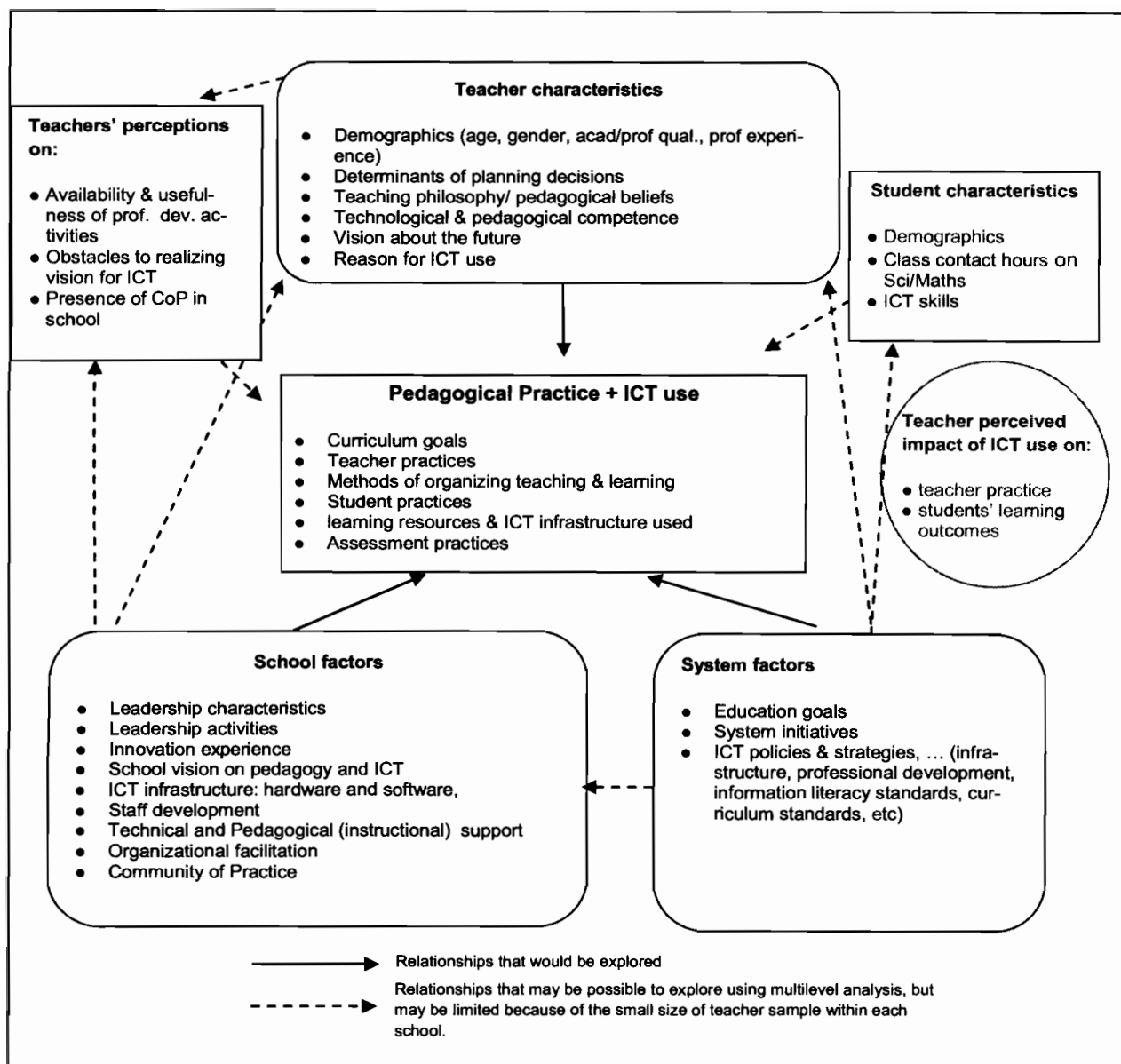


Figure 3.1: SITES 2006 Conceptual Framework

3.6 RESEARCH QUESTIONS

SITES 2006 addressed three major research questions, of which two are related to investigations on the primary process of teaching and learning and a third is related to the contextual factors that could be conditional and explanatory with regard to variations in the primary processes found across schools and countries (SITES 2006, 2008a):

- **Research question 1:**

What are the pedagogical practices adopted in schools and how is ICT used in them?

This question finds out the key pedagogical approaches adopted by teachers, generally in terms of the main characteristics of the teaching and learning process as well as the importance of employing ICT in realising the different classroom processes and pedagogical approaches.

- **Research question 2:**

What and how is ICT used in specific situations where ICT has been used relatively extensively within the pedagogical practice?

This question aims to better understand teachers' own past experiences where ICT has been used extensively to support learning and teaching. In this question, teachers are asked to report in much greater detail, the specific curriculum goals (including content) targeted by the specific tools they have used and the contributions such use has made to learners' learning. Data collected from this question will provide a more holistic picture of how ICT is actually being used in specific contexts as well as a means of triangulating with the findings from RQ1.

- **Research question 3:**

What are the teacher, school, community and systems factors that are associated with different pedagogical approaches and ICT use, and can an explanatory model be identified?

There are factors identified in SITES-Module 2 and other research as conditional for innovative pedagogy and ICT use in teaching/learning practices. This question explores how such factors may be related to different characteristics of pedagogical practices and ICT use and whether there are systematic differences across countries in relation to the explanatory models identified.

3.7 SITES 2006 SAMPLING

The sample of schools in SITES-M2 was drawn with a probability proportional to size (PPS) in order to allow for generalisation of statistics to the population of learners. SITES used a sampling design for the schools which entailed randomly sampling from the population of schools in order to allow for statistical generalisation to the whole populations of schools. Compensating for this difference required new calculations to be done for the SITES-M2 statistics. These used a sampling weight that corrected for the over representation on large schools, so that the resulting sampling statistics could be generalised to the population of learners. It should also be noted that in SITES-M1, the samples were focused on all schools. Hence, with regard to this aspect, the samples are comparable if both in 1998 and 2006 all targeted schools were using ICT. The data in SITES 2006 was hierarchically structured. The sampling was conducted through a two-step process which entailed that schools were firstly random sampled from each participating system (Law, et al., 2008a, p. 3). Then the two samples of mathematics teachers and science teachers were randomly selected from the teachers teaching these two subjects at grade 8, in the sampled schools, to complete the teacher questionnaire. Principals and technology coordinators from the sampled schools were then analysed to provide statistics at the school level. Hence, the data collected from SITES 2006 is hierarchically structured, with

teacher data (level-1) nested within schools (level-2) and school data nested within educational systems (level-3) (Law, et al., 2008a). As such, a multilevel analysis is a more appropriate and stronger method for exploring the questions described in the earlier section.

At the individual teacher level, there are two groups of characteristics that are most likely to have an influence on the perceived impact of ICT-use on learners' inquiry skills based on findings reported in the first international report (Law, et al., 2008a). The first group is the (self-reported) ICT competence of the teacher, both pedagogical and general ICT competence (Law & Chow, 2008b). The other group is lifelong learning pedagogical orientation of the teachers as found to correlate significantly with perceived learner learning outcomes at the system level. The findings from SITES-M2 indicate that vision of the school leadership as well as technical and pedagogical support from the school are important factors contributing to the sustainability and scalability of pedagogical innovations (Owston, 2003).

3.8 SITES 2006 FIELD TRAIL

In 2005, the field trail of the IEA Second Information Technology in Education Study (SITES) 2006 was conducted. SITES 2006 is the first international study in the field of education where the mode of data collection was optionally web based. One of the purposes of the field trial study was to examine whether the two modes provide comparable results and whether the online data collection can be implemented on the international level in the main study.

In order to examine mode effect in SITES 2006, field trial data was used. In the field trial, 18 countries participated, each with a sample of 25 primary schools. For each of the participating countries which conducted mixed mode study, SE was computed for participation rate, and countries where the difference in participation was statistically significant were excluded from any further analyses. For the analyses, data from nine countries, which conducted mixed mode study, were used (Catalonia, Denmark, Finland, Hong Kong, Italy Singapore, Slovakia, Slovenia and Taiwan). To allow comparison between the modes, a split sample design was implemented for the SITES 2006 field test, that systematically assigned half of the selected schools to the online mode, the other half to paper and pencil questionnaires. Since the sample of schools was relatively small (25 randomly selected primary schools per country), only teacher questionnaires were used for the in-depth reliability analyses on average four teachers, teaching mathematics and science in grade 8, per school participated in the study (number of teachers sampled depended on the frequency of using a computer for educational purposes).

Participants included in the database complied with the set of rules in terms of the random selection of schools, in terms of the random assignment of mode to the schools and in terms of response rate requirements to calculate unbiased statistics. As the data comes from the field trial, one should be

aware of certain limitations. The database consists of several stratified country samples of which field trial samples are not really probability samples, although they are proportional to explicit stratum distribution. The database used for the analyses consisted of 934 mathematics and science teachers from 9 countries, 49.7% completed a paper based questionnaire and 50.3% completed web based questionnaire.

3.9 AIMS OF THE SITES 2006 STUDY

SITES 2006 builds on these earlier findings and aims to seek an understanding of the extent and ways in which ICT is integrated in classroom practices at the system-level in countries around the world and to identify factors that contribute most to effective integration of ICT into learning and teaching. This was achieved by completing a survey of teachers, principals and ICT coordinators.

A first major issue that is being addressed is that of changes of objects of education and educational practice, as well as any evidence supporting these changes. From statistical indicators as well as policy analyses that were conducted during SITES-M1, it appeared that in many countries policy actions were undertaken to initiate ICT supported pedagogical reforms in schools, but the implementations of ICT in the teaching-learning processes was not widespread. In SITES-M2 more than 170 qualitative case studies were conducted to study in-depth examples of ICT supported pedagogical practices in order to investigate the characteristics of these innovations (Kozma, 2003b). From the SITES results as well as extensive additional policy document analyses, one may conclude that in quite a number of educational systems throughout the world, a need is felt for integrating ICT in education in order to implement pedagogical changes related to changes in our societies (Plomp, Anderson, Law, & Quale, 2003).

Major aims of SITES 2006 were to provide international benchmarks of the changes of pedagogical practices within the information society, the extent to which ICT is used in education and how the use of ICT is associated with changing pedagogical practices. Another aim of the study is building upon the large number of case studies of innovative pedagogical practices supported by ICT, to investigate which factors are associated with the use of ICT and the nature of pedagogical practices found in schools and among teachers (Plomp, et al., 2003).

SITES 2006 has been designed as a survey of schools and teachers to examine the kinds of pedagogical practices adopted in different countries and the use of ICT in them. The study administered three questionnaires (principals, technology coordinators and maths and science teachers) to a sample of about 400 schools and 4 teachers per school (Pelgrum & Law, 2008). A noteworthy feature of SITES 2006 is that most data were collected via an Online Data Collection (ODC) that was specially developed for this study, which contains many features that are needed in international comparative assessments. The study aimed at producing an international comparison of various indicators, ICT in

education policy recommendations and an in depth analysis of the way in which ICT is impacting teaching and learning processes (Pelgrum & Law, 2008).

The study focused on the role of ICT in teaching and learning in mathematics and science classrooms. It examined the extent to which pedagogical practices were considered to be conducive to the development of 21st century skills. 21st Century skills were defined as the capacity to engage in life-long learning (understood as self-directed and collaborative inquiry) and as connectedness (communication and collaboration with experts and peers inside and outside the school), as already stated above, these skills are considered important for the knowledge society (Law, et al., 2008d). SITES 2006 also examined how teachers and learners used ICT and whether ICT use contributed differentially to learning activities geared towards the development of 21st century skills. In addition, analyses were conducted to identify conditions at the system, school and teacher level associated with different pedagogical practices and different ways of ICT use in teaching and learning (Law, et al., 2008d).

3.10 SITES SCALE INDICATORS

In quantitative studies, scale indicators are often preferred to indicators derived from single-item responses, because they provide improved stability and reliability for important constructions. Confirmatory Factor Analysis (CFA) is widely recognised as a rigorous statistical technique used to construct measurement models for confirming or disproving hypothesised underlying latent variable structure (Byrne, 1998).

This methodology was adopted in the pre-pilot and field trial phases involving the development of the key indicators in the teacher questionnaire, because it provides a better estimate of scale quality, which is important in the instrument design stage. The quality indicators from the CFA for the field trial teacher questionnaire data are reported in the following section. For the main study data, Cronbachs' Alpha reliability scores were reported for scale indicators in both the teacher and school questionnaires in order to reflect the quality of the indicators reported in the international report.

The first step in constructing a CFA model is to determine the specific link between the construct and its latent factor, normally exploratory factor analysis is conducted on data collected from the items pertaining to the construct to identify the likely number of latent factors and their constituent items (Joreskog & Sorbom, 1998). Based on findings from exploratory factor analysis, CFA can be conducted to check on the robustness of the factor model. The ability of fit statistics to evaluate the robustness of a CFA model commonly include the following: Root Mean Square Error of Approximation (RMSEA), developed by Steiger (1990), comparative fix index developed by Bentler (1990). A model with RMSEA Lower than 0.1 and both a NNFI and a CFI larger than 0.9 is generally taken as statistically validated (Diamontopoulus & Siguaw, 2000). For each latent factor, the factor loading of its component items should be checked to see if there is (are) any dominating item(s). If there is no

dominating item(s) the indicator scores of a latent factor can be taken as the meaning of its respective component items. If there is (are) dominating item(s) the indicators score is the factor score.

CFA is a more demanding method and requires more time and resources to implement. Scale Indicators are often constructed based on prior theoretical or empirical studies without being validated through CFA. Under such circumstances, reliability is taken as a measure of scale quality. IEA's technical Standards for IEA Studies recommends annotating and interpreting with caution any reliability below 0.7 (Martin, Rust, & Adams, 1999). In order to avoid making the questionnaire too long, some of the scales ended up with only three items, which makes it difficult to achieve such a high reliability. Some commentators argue that a Cronbachs' Alpha value above 0.5 is satisfactory. In SITES 2006 reliability of 0.5 or above was adopted as a marginally acceptable quality measure for a scale indicator.

The CFA method was adopted in the analysis of the pilot test and field trial data for the construction of a number of scale indicators in the teacher questionnaire. It is important to point out that the validity of scale indicators as psychometric constructs can differ across countries/systems due to socio-cultural, linguistic and other contextual differences. Hence, it is desirable to check the quality of the scale indicators for each system to ensure that these indicators can be used for international comparison. Because of the small sample size of the field trial data for each participating system, the CFA was conducted on the entire international data set. In finalising the indicators for use in the international report of the SITES 2006 main study, Cronbachs' Alpha reliability scores for each of the indicators were computed for each of the participating systems to ensure that the scale indicators were valid at the system level and could thus be used for comparative purposes.

3.11 COUNTRIES PARTICIPATING IN SITES 2006

A total of 22 countries participated in SITES 2006. The following countries were involved: Albert Province (Canada), Spain, Chile, Chinese Taipei, Denmark, Estonia, Finland, France, Hong Kong, Israel, Italy, Japan, Lithuania, Moscow, Norway, Ontario Province (Canada) Russian Federation Singapore, Slovak Republic, Slovenia, South Africa and Thailand (Pelgrum & Law, 2008).

In 2004, Alberta Province, Canada published its Learning and Technology Policy Framework. While it does not refer to 21st century skills, it emphasises learning in the knowledge economy and lifelong learning. It does not promote constructivism, but it emphasises individualised learning, learning communities, and optimal learning environments. Alberta's policy on ICT skills is to infuse ICT in learning all subjects (Anderson & Plomp, 2008).

Integration of ICT in the teaching, learning and evaluation processes is a priority for the school system of Catalonia, Spain. The Department of Education has established that schools have to foster peda-

gological strategies aimed at developing communication skills and building shared knowledge. It is mandated that across school subjects, secondary education learners have to develop information processing and management skills, applying today's wide-ranging palette of digital applications and devices to text creations, to support oral and distance communication and to work with numbers and figures. The use of ICT should include visual-arts production and musical expression and interaction with the physical environment (Anderson & Plomp, 2008).

ICT skills are part of the secondary curriculum and the Ministry of Education in Chile is starting a pilot project for providing ICT skills and related course materials based on the International Centre for Distance Learning standards. There are several references to 21st century skills in a set of transversal aims in the national curriculum (Anderson & Plomp, 2008).

The newly implemented Nine-year Joint Curriculum in Chinese Taipei (integrating elementary and junior high curriculum) claims to cultivate 21st century citizens, but the 21st century skills are not formally defined. The curriculum emphasises that all learning subjects should integrate ICT into their instructions. It aims to develop learners' skills in collecting, analysing, and utilising information, as well as problem-solving, collaborating, active and lifelong learning (Anderson & Plomp, 2008).

Since the late 1990's the Danish Ministry of Education has published a couple of action plans for the integration of ICT in the educational systems specifying both the need for increasing learner skills in ICT and the need for integrating new pedagogic opportunities into learning. While it does not mention 21st century skills, it emphasises learning goals and activities very consistent with that movement. *In addition to the purchase of computers, the action plans focus on better access to the Internet, e-mail and virtual network, increased use of ICT in relation to test and examinations, and increased integration of ICT in pre and in-service training of teachers* (Anderson & Plomp, 2008, pp. 36-66).

Estonian schools are using the national curriculum enacted as a government decree in 2002 and subject to the amendments in 2008 or 2009. In the curriculum effective from 2002, four cross-curriculum topics have been indicated. ICT and media education were among them. ICT is understood as one of the main instruments to enhance work efficiency and social mobility through learners' ICT literacy. To implement the program the Tiger Leap Foundation (TLF) was established in 1997. The intention behind this decision was to separate ICT activities from the general functioning of the Ministry of Education, to allow more dynamics and openness in decision making and to guarantee target financing for ICT needs (Anderson & Plomp, 2008).

Finnish strategy, as found in diverse policy, aimed to develop ICT in education as part of building a Finnish information society. This has meant efforts in creating possibilities for ICT to meet the diverse needs of people at different ages. The latest strategy paper *The National Knowledge Society Strategy 2007-2015* emphasises that a culture of learning and working together has to be created along with close collaboration networks that include decision-makers, developers, implementers and users.

ICT-skills-related strategic intents for year 2015 are that ICT will be inseparably linked to the daily life of citizens and organisations, and that individuals and work communities will be able to renew and continue to develop knowledge and learning which are the foundation of Finland's competitiveness and well-being (Anderson & Plomp, 2008).

In 2002 the Prime Minister of France presented a new set of goals for a policy on ICT use at different levels of education. The 2004-2006 Action plan calls for France to be in the top tier of educational systems using ICT in education. In 2006 the IT and Internet proficiency certificate was established, which specified the ICT skills development required at all levels of the educational system. The emphasis is upon subject-specific ICT learning activities (Anderson & Plomp, 2008).

In Hong Kong, one policy goal is to empower learners with IT. Learners will acquire the necessary skills, knowledge and attitudes for lifelong learning and creative problem solving in the information age. Learners are to use IT for information retrieval, knowledge enquiry, communication, collaboration, and as an analytical and personal development tool. The 2004 document, *Information Technology in Education - Way Forward*, calls for moving to a learning-centred approach. It argues that this and other Internet project-based learning is a paradigm shift to be achieved in five years (Anderson & Plomp, 2008).

The fourth and current stage of the Israeli *National Computerization Program* focuses on 21st century skills, and emphasises ICT as a lever for system-wide change and *ICT as a Way of Life*. This stage includes broad implementation of ICT literacy and information skills in learning processes, facilitation of novel concepts and teaching-learning processes in knowledge-saturated learning environments and spreading ICT-culture typical of the Digital age. Current goals emphasise the broadening of online activities and the implementing thereof in all teaching-learning processes, implementing standards in information studies, developing a bank of learning objects, fostering collaborative learning and advancing the use of ICT by populations with special needs (Anderson & Plomp, 2008).

With recognition of the necessity of the national strategy forward of an ICT revolution, the e-Japan Strategy was developed in 2001. Its aim was to create a *knowledge-emergent society* that fosters diverse creativity through the exchange of knowledge among citizens and has listed education at the top as the vision of the ideal ICT society. This vision entails that all will be able to receive the most advanced level of education they require, regardless of geographical, physical, economic and other constraints (Anderson & Plomp, 2008).

In pedagogy there has been a shift from teaching to learning. Teacher in service training programs in Lithuania now stress topics about collaborative learning, active learning, etc., which presumably have an impact on classroom teaching. The assessment systems has not yet adjusted to this shift, so there is some conflict between new learning goals and national standards for assessment (Anderson & Plomp, 2008).

The situation in Moscow City reflects the general situation in the country. At the same time it is much more advanced in the consistency of the regional policy as well as in financing. So, the use of ICT in learning is supported by adequate hardware, software and connectivity. The regulatory aspect of ICT introduction into general schools is covered by the concept of the ICT-school. An example of the Moscow approach is the distant general school for children that cannot visit schools because of their physical conditions (Anderson & Plomp, 2008).

The multi-year *Programme for Digital Literacy* (2004-2008) aims to smooth out the digital divide (and consequently the social divide) through promoting a vision of digital skills for all. More specifically, the program, which is the Government of Norway's main effort on ICT in education, addresses the entire education sector. Digital literacy consists of basic ICT-skills, equivalent to reading, writing and numeracy, as well as more advanced skills, ensuring creative and critical use of digital tools and media including tasks such as locating and controlling information from different digital sources. ICT will also play a major role in the field of assessment in Norway (Anderson & Plomp, 2008).

In Ontario, Canada, there is an optional grade 9 course in Information and Communication Technology and business, and for grade 10 there is a course in Communications Technology (Anderson & Plomp, 2008). The Soviet Union started its country-wide course of Computer Science and Technology a long time ago and for the last two years of high school there existed two versions two versions: with or without computer support. Today, learning ICT is assumed in primary school, in grade 8-9 (secondary school) and in different profiles of high school. The national standards of 2004 outline learning with ICT in most school subjects. It covers general applications and basic professional and subject-oriented applications. The practical implementation of these standards is evolving slowly. The major progress was made over the last three years in the framework of the *e-Learning Support Project*. Today ICT schooling, in general, belongs to dimensions of the National Priority Projects, for example, in 2007 all schools in Russia should have 128K connectivity (Anderson & Plomp, 2008).

In 1997, Singapore launched the Master plan for IT in Education (MPITE) as a blue print for the integration of Information technology in the education system to meet the challenges of the 21st century. The key objective was to use IT to help equip the young with learning skills, creative thinking skills and communication skills. This was a key strategy for producing a workforce of excellence for the future. The Master plan 2 for IT in Education with similar goals started in 2003 (Anderson & Plomp, 2008).

In the Slovak Republic, a policy of school reform *Millennium* was published in the year 2000. It was supported by the government in 2001. Some of the reforms have already been undertaken (a new law of financing schools), while many steps still remain (e.g., New School Law for Primary and Secondary Education). In the field of ICT in education, the policy is to support the e-Europe+ policy (Anderson & Plomp, 2008).

Slovenia is developing the *Strategy of development of information society in Republic of Slovenia* based on the strategic frameworks of 2010. Part of the strategy is the *National strategy of e-learning 2006-2010*. The goal of the strategy is to develop an efficient and ICT-supported national system of educational at all grade levels. With ICT, learning processes and content are changing: learning becomes more efficient and attractive; and learning and teaching are enabled, as are virtual classrooms. These plans emphasise 21st century skills including more self-evaluation and development of research skills (Anderson & Plomp, 2008).

The white paper on e-Education in South Africa says that the ICT revolution has had an impact on curriculum development and delivery and continues to pose new challenges for education and training systems around the world, which can be summarised into three broad areas, namely: participation in the information society; the impact of ICT on access and cost effectiveness of quality in education and the integration of ICT into the learning and teaching process (Anderson & Plomp, 2008).

Limited ICT infrastructure prohibits the development of many ICT skills in Thailand. Learning and teaching science and mathematics link with project-based learning though the uses of ICT tools, such as the Internet. Anderson and Plomp (2009) explains that the National Education Act B.E. 2542 (1999) clearly identified the General Provisions for the development of the 21st century skills driven by technologies for education. Also the 9th National Economic and Social Development Plan (2007-2011), on the development of the quality of life of the Thai people in the knowledge-based Learning Society, based on sufficiency economy philosophy, reflected the issues more prominently with the results of TIMSS, PISA (Computer-based assessment of science), SITES M1 and M2 studies. First Language, English, Mathematics, and Science are the focal areas of improvement. Thinking skills, learning processes, and technology uses are considered as the vehicles for improving learners' achievement and life skills (Anderson & Plomp, 2008).

3.12 SUMMARY

This chapter started by presenting all of the concepts that is used in SITES 2006. The theoretical framework was discussed. The current status of the use of ICT in South Africa is clarified. Chapter four deals with the research methodology as employed in this study.

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

4.1. INTRODUCTION

An outline of the SD research design and methodology is provided in this chapter. This teacher questionnaire used to gather data for the SITES 2006 is explained and the population is discussed. Variables for the SDA were identified; the study population for the SDA as well as the ethical considerations are clarified. Chapter four is conclude up with a summary.

4.2. RESEARCH DESIGN AND METHODOLOGY

4.2.1 Research design

Research design is a plan or blueprint of how one intends to conduct research (Babbie & Mouton, 2001; De Vos, 1998). Furthermore, De Vos (1998) refines this definition by specifying that this plan, or blueprint offer the framework in accordance with which data are to be collected to investigate the research hypothesis or question in the most economical manner. Denzin and Lincoln (2000) define a research design as a flexible set of guidelines that connect theoretical paradigms firstly to strategies of inquiry, and secondly to methods of collecting empirical material. A research design is therefore a sequential process in accordance with which the research will be conducted in order to contribute towards the attainment of the desired objective. Research design is defined as an act of designing a study in the broader sense, it refers to all processes involved; sampling, procedures for data collection as well as data analysis (De Vos, Strydom, Fouche, & Delport, 2005).

4.2.2 Methodology

The methodology is the general approach the researcher takes in carrying out the research project, to some extent, this approach dictates the particular tools the researcher selects (Leedy & Ormrod, 2005). Babbie and Mouton (2006, p. 75) state the research methodology focuses on *the individual (not linear) steps in the research process and the most objective (unbiased) procedures to be explored*. Bless and Higson-Smith (2000) define quantitative research as a research conducted using a range of methods, which makes use of measurements to record and investigate aspects of social reality. According to Mark (1996) a quantitative research approach is the study of phenomena using numerical means. In these approaches, there is an emphasis on counting, describing, and using

standard statistics, such as means and standard deviations. When we want to verify whether a cause produces an effect, we are likely to use quantitative methods. Numbers are important at all levels of measurement in research. Numbers should be based on significant conceptualizations. Quantitative research in the present-day social science is important because it signifies attempts to become aware of relationships and explanations of a range of occurrences. Leedy and Ormrod (2005, p. 94) define quantitative research as *generally, used to answer questions about relationships of explaining, predicting and controlling phenomena*. This approach is sometimes called the traditional, experimental, or positivist approach. The researcher's view, therefore quantitative research is a research approach that makes use of number and figures.

SITES 2006 was a large scale international quantitative study that compared the ICT pedagogical practices of schools in 22 countries and educational systems (Law, et al., 2008d). SITES 2006 followed a survey research design which administered three questionnaires, i.e. (i) a questionnaire for science and mathematics teachers, (ii) a questionnaire for principals, and (iii) a questionnaire for technical coordinators. The International Association for the Evaluation of Educational Achievement (IEA) centre in Hamburg, Germany, randomly selected 504 South African schools according to stratified sampling at which data were collected. This study followed a SDA methodology of the South African dataset of grade 8 science teachers who completed the teacher's questionnaire during the SITES 2006. No new data was collected for this study. The researcher respected and maintained the integrity of the data and also gave acknowledgement to SITES 2006 for the use of the datasets available in the public domain. SDA can be defined as addressing research questions through analysis of existing data originally collected for another purpose (Glaser, 1963). SDA is the re-analysis of data for the purpose of answering the original research questions with better statistical techniques, or answering new research questions with old data (Glass, 1976). Although SDA can include an entire spectrum of empirical inquiries, it also uses data generated through systematic reviews, through document analysis as well as the results from large scale datasets. SD can be numeric or non-numeric (Smith, 2006). According to Smith (2008), SDA include population censuses, government surveys, other large-scale surveys, cohort and longitudinal studies, regular or continuous surveys, and administrative records. As pointed out before, SITES 2006 was a large-scale survey, therefore a SDA is appropriated to investigate themes and correlations not addressed or reported in the original SITES 2006 reports.

4.3 RESEARCH TOOL: SITES 2006 SCIENCE TEACHER QUESTIONNAIRE

A quantitative research tool was used to collect the SDA. A questionnaire, according to De Vos, et al. (2005, p. 166) is defined as *a set of questions on a form which is completed by the respondent in respect of a research project*. A questionnaire will probably contain the same number of statements as questions (Babbie & Mouton, 2001). SITES 2006 aimed to provide an overall picture of the status of pedagogical practice and ICT-use in the participating countries and systems. Therefore, survey

methodology was considered appropriate. The main data collection was done using a questionnaire: a teacher questionnaire (Science). The Science teacher questionnaire comprises the following parts: Part I: Information about the target class; Part ii Curriculum goals; Part iii Teacher practice; Part iv Student practices; Part v Learning resources and technology infrastructure; Part vi Impact of ICT use; Part vii Information about you and your school and Part viii Specific pedagogical practice that uses ICT. The Science teacher questionnaire asks for information from teachers about education and policy matters related to pedagogical practices and computers. In addition, a national context questionnaire was distributed to the study's national research coordinators (NRCs) in order to gather relevant contextual information at the system level from country or systems in the study.

Table 4.1 Components of teacher questionnaire

Components	Questions	Scales
Part I: Information about the target class	7	Demographic Information
Part II: Curriculum goals	1	Items 8A-M
Part III: Teacher practice	7	Items 9A-M; Items 14A-L; Items 15A-H
Part IV: Student practice	1	Items 16A-L
Part V: Learning resources and Tools	1	Items 17A-K
Part VI: Impact of ICT use	3	Items 19A-L; Items 20A-O
Part VII: Information about you and your school	16	Items 21A-P;
Part VIII: Specific pedagogical practice that uses ICT	5	Items 39A-K; 40

From the indicated four main indicators (§ 4.6.2) different variables that can contribute to the aims of this study were identified and comparisons were made to international countries and education systems where appropriate to illustrate similarities or differences.

4.4. VARIABLES FOR THE SDA

A variable is any quality or characteristic in research investigation that has two or more possible values (Leedy & Ormrod, 2010). The variables used in SITES 2006 data were categorical of nature, i.e. it has a categorical response. In order to address the first research question: *What are the pedagogical uses of ICT in Grade Eight Natural Science in South African Schools?*; the categorical variables of ICT use, as pertained by the items of the SITES 2006 teachers questionnaire, were used. Factor analyses were used to identify clusters (themes) of ICT impact and contribution. These clusters were correlated with each other, as well as with other variables from the teachers' questionnaire in order to address the second research question: *How does the pedagogical use of ICT in Grade Eight Natural Science contributes towards science education in South African schools?*

4.5. Study population for the SDA

According to Mark (1996, p. 105) a population is *the collection of all individuals, families, groups or organizations, communities and events that will participate in the study*. Strydom and Venter (2002, p. 199) refers to the population as the *sampling frame, the totality of persons, events, organizations units, case records or other sampling units* with which the research problem is concerned. Bless and Higson-Smith (2000, p. 85) refer to population as *the set of elements that the research focuses on and to which they obtained results should be generalized*.

A key element of the quality of any international comparative study is the selection of quality samples. Only properly selected and representative samples can yield unbiased, accurate, and internationally comparable survey estimates. SITES 2006 collected data at two levels:

- The school level, through a school principal questionnaire, and an ICT coordinator questionnaire.
- The classroom level, through a teacher questionnaire.

Student achievement surveys such as the Progress in International Reading Literacy Study (PIRLS) and the Trends in International Mathematics and Science Study (TIMSS) also collect information at the school level and at the teacher level, but mainly or exclusively for explaining the variability of student performance. In other words, such surveys are primarily interested in the student population, which means the teacher population cannot be modelled directly. The SITES 2006 data and results are reported at school level and teacher level. Therefore, it defines two target populations: the school population, and the teacher population. The questionnaires were submitted to grade 8 science teachers of approximately 504 South African schools as part of a stratified and randomly selected sample during October 2006.

The South African data from the questionnaire for science teachers formed the basis of the dataset for this study. However, where appropriate, data from other participating countries, as well as data from the questionnaire for other science teachers was used.

4.6 ETHICAL ASPECTS

According to Burns and Grove (2005) the conduct of research requires not only expertise and diligence but also honesty and integrity. The questionnaires and dataset of the SITES 2006 was released for use in the public domain. Therefore, this study will acknowledge the source of data, and will respect the integrity of the dataset. No indicative information is available on the schools that participated in the main study, and no participants can be identified through the data.

4.7 STATISTICAL ANALYSIS

Statistical Consultation Services of the North-West University processed the SD of the SITES 2006. The results of the SDA research were processed using the Statistical Package for the Social Sciences (SPSS) (SPSS Inc, 2007). Different variables that contributed towards the aims of this study were identified. Firstly, descriptive statistics (means and percentage frequencies) were calculated to answer the first research question: *What are the pedagogical uses of ICT in Grade Eight Natural Science in South African Schools?*

Descriptive statistics refers to statistics that are used to describe. When using descriptive statistics, every member of a group or population is measured. Descriptive statistics are ways of summarizing large sets of quantitative (numerical) information. Descriptive statistics is defined as a method used to Borg and Gull (1983). According to (Ngidi, 2005) descriptive data serves as a method or way for organizing, tabulating, depicting and describing summarizing and reducing to a comprehensible form if an otherwise unwieldy mass of data. This statistics is interpreted to give an overview on ICT pedagogical practices in South African grade 8 science classrooms.

The SDA of specific variables within the indicator fields, as indicated in the questionnaire may add useful insights to the Grade 8 teachers' practices and to the pedagogical use of ICT in science classrooms. The four main indicator fields included in the teacher questionnaires are:

- Target class information, e.g. students' ICT competencies
- Core indicators, e.g. ICT-using teacher-practices
- Supplementary indicators, e.g. ICT and learning resources used
- Explanatory indicators, e.g. teachers' self-reported ICT competencies.

De Vos et al. (2005) describe cumulative frequencies and percentage distribution as method generally used for quantitative data. This data only would make sense for categorical data if they are ordered in some way. Graphical presentations can also be used to comprehend the essential features of the cumulative frequency and percentage distribution.

In order to answer the second research question:

How does the pedagogical use of ICT in Grade Eight Natural Science contributes towards science education in South African schools?, factor analysis was used to identify clusters (themes) of ICT impact and contribution, which in turn, were correlated with each other, as well as with other variables from the teachers' questionnaire. Due to the categorical nature of the variables, two-way frequency tables and Spearman's effect sizes (Wegner, 1993) were calculate to determine practically significant correlations (effect sizes) between the variables and clusters of variables (Steyn, 2002).

4.8 SUMMARY

In order to provide a conceptual view of the SITES 2006 research process, this chapter described the research problems, research questions, data collection method and collection system. Chapter five will address the research findings and discuss the findings.

CHAPTER 5

RESEARCH FINDINGS AND DISCUSSION OF FINDINGS

CHAPTER 5

RESEARCH FINDINGS AND DISCUSSION OF FINDINGS

5.1 INTRODUCTION

The preceding chapters form a background to chapter five. The focus of chapter five is to determine the teachers' use of ICT in South African schools and to investigate if the pedagogical use of ICT can contribute towards science education in grade 8 natural science classes.

5.2 RATIONALE AND AIM

A science teacher is a qualified academic who teaches science, at schools, to learners. To motivate learners in their field of discipline, a science teacher should be aware of pedagogical practices. To improve and encourage the study of science in South African schools there should be capable science teachers. Learners bring valuable experience into the classroom. The teacher's role is to initiate discussions and reflections, in which learners' prior knowledge is acknowledged, and then valued. Teachers also need to challenge learners with new ways of making sense of natural science (Department of Education, 2003a). A qualified and competent science teacher can create a lifelong learner who is confident and independent, with a respect for the environment and the ability to participate in society as a critical and active citizen (Department of Education, 2003a).

The Department of Education (2004a) science is considered to be among the requirements for creating wealth, and improving the quality of life. In South Africa, obstacles are widely articulated, for example, by McDonald and Rogan (1988) who found impoverished communities that could not contribute towards curriculum development, poor school resources and inadequate teacher training in the Eastern Cape Province of South Africa. The low pass rate in science at grade 12 level and occasional reports on the low international ranking of science education are believed to be among the problem indicators in science education in South Africa (Muwanga-Zake, 1998).

The purpose of this study is to attain the research aim, and to better understand the conceptual framework, and for this purpose the contemporary availability of the pedagogical use of ICT in science could prove to be a valuable tool in creating a motivated and interested learner in the science class.

5.3 RESEARCH DESIGN AND METHODOLOGY

SITES 2006 was a large scale international quantitative study that compared the ICT pedagogical practices of schools in 22 countries and educational systems (Law, et al., 2008d). SITES 2006 followed a survey research design, which administered three questionnaires, i.e. a questionnaire for science- and mathematics teachers, a questionnaire for principals and a questionnaire for technical coordinators.

5.3.1 Advantages and disadvantages of self-reported data

There are a few disadvantages when using a self re-ported survey, data or questionnaires. Researcher experienced most of the time that the respondent give exaggerated answers, the respondent may be too embarrassed to reveal private details. Another disadvantage of self re-ported surveys is various biases may affect the results, like social desirability bias. Some of the self re-ported answers will be more negative, if the person attitude is bad. It is also possible for results to be biased by a lack of respondents (Wikipedia, 2002a). The person may not be able to give an accurate response due to cognitive biases, poor memory etc.

Advantages of self-reported data, surveys or questionnaires are ample as one is able to study large samples of people easily. The surveys are also able to examine a large number of variables. Another advantage of self reported questionnaires can ask participants to reveal behaviour and feelings which have been experienced in real situations. Self re-ported surveys are uncomplicated to administer in many cases, and no complicated technology is required. When using a self reported survey the researcher gets the respondents views directly (Wikipedia, 2002a).

This study follows a SDA methodology of the South African dataset of grade 8 science teachers who completed the teachers' questionnaire during the SITES 2006. No new data were collected. The researcher respects and maintains the integrity of the data and also acknowledges that SITES 2006 provided the publicly available datasets. SDA can be defined as the study of specific problems, through the analysis of existing data, which were originally collected for another purpose (Glaser, 1963), with the aim of addressing a research question distinct from that interpretation and conclusions (Hewson, 2006). SDA is the re-analysis of data for the purpose of answering the original research questions with better statistical techniques, or answering new research questions with old data (Glass, 1976). Although SDA can include an entire spectrum of empirical inquiries, it also uses data generated through systematic reviews, through document analysis as well as the results from large scale datasets. SD can be numeric or non-numeric (Smith, 2006). According to Smith (2008), SDA can be done on the following data: population census, government surveys, other large-scale surveys, cohort and other longitudinal studies, other regular or continuous surveys, and administrative records. As pointed out before, SITES 2006 was a large-scale survey, therefore a SDA is appropriated to investigate themes and correlations that were not addressed and reported in the original SITES 2006.

In order to answer the question, as presented in chapter one, regarding the pedagogical use of ICT in grade 8 natural science and how this can contribute towards science education in South African schools, findings will be discussed by using different analyses. Results concerning the pedagogical use and contribution of ICT in grade 8 natural science in South African schools will be examined by using descriptive analysis of the SD, factor analysis of the main correlation variables and correlations to find the relationships between the variables.

5.4 RESULTS: DEMOGRAPHICS

In this section, respondents were asked to report on the number of male or female learners in the target class, the mixed gender of the target class, the curriculum track followed, the number of absentees on a typical school day, the number of learners who speak their native language during instruction and hours of scheduled class time teachers spend on science lessons per week. The South African demographical information of the grade 8 natural science learners in the target classes are presented in Table 5.1.

Table 5.1: Demographical information about the learners in the target classes

Number of Learners in target class	Male and Female 602				
Gender mix of target class	Boys 4	Girls 13	Both 575		
Curriculum track	Academic 551	Vocational 10	No tracking 20		
Absentees in target classes on a typical school day	≤5% 443	5-10% 126	11-20% 26	≥ 20% 9	
Native speakers of language of instruction	≥ 90% 191	76-90% 46	50-75% 55	≤ 50% 287	
Hours of scheduled class time spent on Science lessons per week	≤ 2 hrs 31	2-4 hrs 301	5-6 hrs 166	7-8 hrs 58	≥ 8 hrs 43

The 602 participants that form part of this research project were 4 target classes of male learners. Thirteen of the target classes were only female learners, while 575 of the target classes are presented by female and male learners. The curriculum track in the target class was 551 academic 10 vocational and 20 no tracking. The majority of 443 absentees in the target class on a typical school day were less than 5%, and a total of 126 absentees in the target class were between 76-90%. Nine learners were more than 20% absent in the target class. Less than 50% of the target class (n=287) are native speakers of the language of instruction. Less than 50% (n=287) are receiving their instruction in their native language. A majority of 31 teachers responded that they spend less than 2 hours on science lessons per week. More than 8 hours were spent by 43 teachers per week on science lessons for the target class.

5.5 RESULTS: DESCRIPTIVE DATA ANALYSIS

South Africa faces considerable challenges regarding the integration of ICT into schools (Blignaut, Els, & Howie, 2009). In response to the aim to determine the pedagogical use of ICT in grade 8 natural science in SA schools, descriptive data analysis of the study (§ 5.5.1) establishes a better understanding of how natural science teachers use ICT in the target classes. Descriptive statistics in § 5.5.2 are used to help address the second research aim, i.e. to determine how the pedagogical use of ICT in grade 8 natural science contributes towards science education in South African schools. Descriptive data analysis is used to answer the research aims through interpretation of the available data (Leedy & Omrod, 2010). Fraenkel and Wallen (2008) describe descriptive statistics as the data analysis that enables the researcher to describe data with numerical indices.

5.5.1 Pedagogical uses of ICT in grade 8 natural science

ICT can be integrated into education to deliver old classroom practices for the achievement of long existent goals, or it can be used in practices that bring about new learning goals and new modes of learning that will define and shape the future of schooling. In analysing the cases, SITES 2006 identified 6 types of pedagogical practices. The pedagogical practices found in the 130 case studies can be categorised into six types: project work, scientific investigations, media production, virtual schools/online courses, task-based learning and expository teaching (SITES 2006, 2008a).

5.5.1.1 *Proportion of learners that are competent in ICT*

Today's classroom teachers must be prepared to provide technology-supported learning opportunities for learners. Being prepared to use technology and knowing how that technology can support learning must become integral skills in every teacher's professional repertoire (GAID, 2000). Teachers must be prepared to empower learners with the advantages technology can bring. Schools and classrooms, both real and virtual, must have teachers who are equipped with technology resources and skills and who can effectively teach the necessary subject matter content while incorporating technology concepts and skills (GAID, 2000).

Research has shown that the appropriate use of ICTs can catalyse the paradigmatic shift in both content and pedagogy that is at the heart of education reform in the 21st century. If designed and implemented properly, ICT-supported education can promote the acquisition of the knowledge and skills that will empower learners for lifelong learning. When used appropriately, ICTs, especially computers and Internet technologies, enable ways of teaching and learning rather than simply allowing teachers and learners to do what they have done before in a better way. These new ways of teaching and learning are underpinned by constructivist theories of learning and constitute a shift from a teacher-centred pedagogy in its worst form, characterised by memorisation and rote learning, to one that is learner-centred (Browne, 2000). Osterwalder (2004) states that the requirement to understand and

use the above mentioned applications necessitate improved ability from the teacher as well as the learner.

Table 5.2: Proportion of learners that has competence in ICT according to the teacher participants

OPERATION SKILLS	Nearly None %	Few students %	Majority Students %	Nearly all %	Do not Know %
A Word-processing	42.5	22.3	11.5	6.6	17.1
B Database Software	52.9	16.6	5.7	2.3	22.5
C Spreadsheet	54.3	17.4	3.8	2.3	22.2
D Presentation Software	55.7	17.0	3.0	2.1	22.3
E Applications of Multi Media	52.5	18.3	5.0	2.9	21.2
F e-Mail	57.0	15.7	3.5	3.6	20.2
G Internet	55.3	17.1	4.1	4.5	19.0
H Graphic Calculator	53.4	15.4	4.8	4.1	22.3
I Data-logging Tools	58.7	12.4	1.6	1.0	26.3

The frequencies in Table 5.2 represent question seven of the SITES 2006 teacher questionnaire (Addendum 5.1). The above background guides the researcher to investigate the proportion of learners that has competence in ICT according to the teacher participants. The purpose of question A to I was to determine what the learners' competencies are, as interpreted by the teachers in the target classes. All of the 602 science teachers answered the questions related to the competencies of the grade 8 natural science learners.

It is evident from Table 5.2 that the sample of grade 8 science learners' computer competencies is overall of a poor standard. The target classes presented a large number of learners that are not competent in word-processing (64.8%), database software (69.5%), spreadsheets (71.7%), or presentation software (72.7%). The science teacher respondents (n=579) also indicated that

- 70.8% of the learners in the target classes are not able to apply multi-media
- 72.7% cannot correspond via e-mail
- 72.4% of the science learners cannot perform internet searches
- 68.8% are not able to use a graphic calculator
- 71.1% cannot make use of different data-logging tools.

5.5.1.2 Teachers' indication that they use ICT for specific activities in the target classes

ICT is a powerful tool for future teaching and learning, but teachers are not prepared to apply the ICT into their future teaching and learning practices. Despite the increased availability and support for ICT integration, only a few teachers integrate ICT into their teaching activities (Guoyuan, Martin, van-Braak, & Tondeur, 2010). ICTs are a potentially powerful tool for extending educational opportunities, both formal and non-formal, to previously underserved constituencies, scattered and rural populations, groups traditionally excluded from education due to cultural or social reasons as ethnic minorities, girls and women, persons with disabilities and the elderly, as well as all others who, for financial reasons, or because of time constraints are unable to enrol on campus (Browne, 2000).

ICT can be a powerful learning and teaching tool across all subject areas. The interactivity of a computer can allow learners to become actively involved in a lesson. ICT provides many opportunities to easily use a variety of pedagogies. As a tool, ICT can support didactic or facilitative approaches, collaboration and interaction across time and distance. The capacity of ICT to deliver information or to communicate with a mass of learners in quite individual ways opens up the possibility of tailoring pedagogy to the needs of a learner in time and place without the limitation imposed by peer groups (Browne, 2000). Haydn and Barton (2007) affirm that even in the United Kingdom no intervention, policies or any investments support teachers to embed the use of ICT activities in the teaching and learning situation.

Table 5.3 reflects the results obtained from the questionnaire that relates to the use of ICT in teaching activities by science teachers in the target classes (Addendum 5.1). The respondents were asked to present their opinion with reference to the use of ICT during the science teaching activities in question 14 (b) of the SITES 2006 teacher questionnaire.

Table 5.3: ICT use in teaching activities by science teacher

STATEMENT		% Yes	% No
A	Present information/demonstrations and/or give class instructions	16.35	83.65
B	Provide remedial or enrichment instruction to individual students and/or small groups of students	12.66	87.34
C	Help/advise students in exploratory and inquiry activities	15.58	84.42
D	Organise, observe or monitor student-led whole-class discussions, demonstrations, presentations	12.47	87.53
E	Assess students' learning through tests/quizzes	15.59	84.41
F	Provide feedback to individuals and/or small groups of students	12.39	87.61
G	Use classroom management to ensure an orderly, attentive classroom	11.72	88.28
H	Organise, monitor and support teambuilding and collaboration among students	10.09	89.91
I	Organise and/or mediate communication between students and experts/external mentors	11.80	88.20
J	Liaise with collaborators (within or outside school) for student collaborative Activities	11.84	88.16
K	Provide counselling to individual students	9.40	90.60
L	Collaborate with parents/guardians/caretakers in supporting/monitoring students' learning and/or in providing counselling	10.90	89.10

The results of this section of the questionnaire are overall indicative of poor use of ICT in science teaching activities by teachers. It can be concluded from Table 5.3 that a large number of teachers do not present information/demonstrations and/or give class instructions by using ICT tools (86.65%), help/advise students in exploratory and inquiry activities (84.42%) and assess students' learning through tests/quizzes (84.41%). It is obvious from Table 5.3 that the majority of teachers indicated that they do not make use of ICT in teaching activities in the targeted classes (83.65% to 90.60%). Although a majority of teachers responded that they do not make use of ICT in natural science teaching activities, a few teachers indicated that they do make use of ICT in their teaching activities in science, and it can make a difference in the learners' education.

5.5.1.3 Science teachers who indicated that they use ICT to carry out assessments

Educational assessment is the process of documenting, usually in measurable terms, knowledge, skills, attitudes and beliefs. Assessment can focus on the learner, the learning community (class, workshops, or other organised groups of learners) the institution or the educational system as a whole (Wikipedia, 2002b).

Assessment is a continuous, planned process of identifying, gathering and interpreting information about the performance of learners. It involves four steps: generating and collecting evidence of achievement, evaluating this evidence against outcomes, recording the findings of this evaluation and using this information to understand and thereby assist the learners' development and improve the process of learning and teaching (Department of Education, 2009).

Assessment in education has been vital since the initial approach to formal education. Well developed criteria for the successful use of assessment procedures and easy-to-use techniques are necessary to support the teacher in carrying out assessments. Table 5.4 explains the ICT use of teachers during the targeted classes as indicated in question 15 (b) of the SITES 2006 teacher questionnaire (Addendum 5.1).

Table 5.4: ICT used to carry out assessments according to science teacher respondents

STATEMENT		Yes %	No %
A	Written test/examination	23.15	76.85
B	Written task/exercise	23.42	76.58
C	Individual oral presentation	15.86	84.14
D	Group presentation (oral /written)	18.01	81.99
E	Project report and/or (multimedia) product	21.08	78.92
F	Students' peer evaluations	14.45	85.55
G	Portfolio/learning log	18.36	81.64
H	Assessment of group performance on collaborative tasks	15.62	84.38

It is noticeable from Table 5.4 that grade 8 science teachers do not frequently use ICT as a method to carry out assessments in natural science teaching and learning environments. A minority of the teachers indicated that they use ICT during written tests or examinations (23.25%), written tasks or exercises (23.42%) and project reports and/or (multimedia) products (21.08%).

The remaining questions indicate that:

- 84.14 % of the teachers indicated that they apply individual oral presentation for assessment in the targeted classes
- 81.99% of teachers do not make use of oral or written group presentations
- 85.55% teachers are of the opinion that they do not use relevant peer evaluations for assessment

- 81.64% of grade 8 natural science teachers do not carry out portfolios or learning logs to assess.
- 84.38% estimate that they do not assess by means of group performance on collaborative tasks.

5.5.1.4 Science teachers who indicated that the learners use ICT to perform activities

ICTs such as videos, television and multimedia computer software that combine text, sound, and colourful moving images can be used to provide challenging and authentic content that will engage the learner in the learning process (Browne, 2000). Interactive radio likewise makes use of sound effects, songs, dramatisations, comic skits, and other performance conventions to compel the learners to listen and become involved in the lessons being delivered. More so than any other type of ICT, networked computers with Internet connectivity can increase learner motivation as it combines the media richness and interactivity of other ICTs with the opportunity to connect with real people and to participate in real world events (Browne, 2000).

Table 5.5: ICT used in teaching activities by learners according to science teacher respondents

	STATEMENT	Yes %	No %
A	Students working on the same learning materials at the same pace and/or sequence	12.87	87.13
B	Students learning and/or working during lessons at their own pace	10.44	89.56
C	Complete worksheets, exercises	14.37	85.63
D	Give presentations	14.35	85.65
E	Determine own content goals for learning (e.g. theme/topic for project)	9.78	90.22
F	Explain and discuss own ideas with teacher and peers	10.52	89.48
G	Collaborate with peers from other schools within and/or outside the country	8.33	91.67
H	Answer tests or respond to evaluations	12.76	87.24
I	Self and/or peer evaluation	9.84	90.16
J	Reflect on own learning experience review (e.g., writing a learning log) and adjust own learning strategy	7.76	92.24
K	Communicate with outside parties (e.g., with experts)	10.00	90.00
L	Contribute to the community through their own learning activities (e.g., by conducting an environmental protection project)	9.11	90.89

The use of ICT at pedagogical level can provide the teacher with valuable insights into the relationship between themselves, learners and the learning environment. The teaching activities used by learners during teaching activities are reflected in Table 5.5 (Addendum 5.1). The highest percentage of respondents (14.37%) indicated that learners use ICT to complete worksheets, while 14.35% make use of presentations by using ICT. Learners (87.13%) do not share the same learning materials between them to work at their own pace and/or sequence. Only 10.44% of learners utilise ICT for learning and/or working during lessons at their own pace, 10.52% make use of ICT to explain and discuss their own ideas with teachers and peers and 12.76% apply it to answer tests or respond to evaluations.

The majority of learners do not perform learning activities associated with ICT:

- 90.22% do not determine their own content goals for learning (e.g. theme/topic for project)

- 91.67% form no teamwork with peers from other schools within and/or outside the country
- 90.16% do not generate self and/or peer evaluation
- 92.24% do not create their own learning experience review (e.g., writing a learning log) and adjust own learning strategy
- 90% establish no conversation with outside parties (e.g., with experts)
- 90.89% add to the community through their own learning activities (e.g., by conducting an environmental protection project).

5.5.1.5 Science teachers indicated that they incorporate ICT in their classes

Today's classroom teachers must be prepared to provide technology-supported learning opportunities for their learners. Being prepared to use technology and knowing how that technology can support student learning, must become integral skills in every teachers' professional repertoire (GAID, 2000).

Teachers should be prepared to empower learners with the advantages technology can bring. Schools and classrooms, both real and virtual, must have teachers who are equipped with technology resources and skills and who can effectively teach the necessary subject matter content while incorporating technology concepts and skills (GAID, 2000).

Real-world connections, primary source material, and sophisticated data-gathering and analysis tools are only a few of the resources that enable teachers to provide unimaginable opportunities for conceptual understanding. Table 5.6 presents question 17 of the SITES 2006 teacher questionnaire (Addendum 5.1)

Table 5.6: ICT incorporation of learning resources and tools in target class according to teacher respondents

STATEMENTS		Never	Sometimes	Often	Nearly always
A	Equipment and hands-on materials (e.g., laboratory equipment, musical instruments, art materials, overhead projectors, slide projectors, electronic calculators)	29.58	36.66	20.25	13.51
B	Tutorial/exercise software	67.71	16.89	12.13	3.27
C	General office suite (e.g., word-processing, database, spreadsheet, presentation software)	78.65	14.28	4.86	2.21
D	Multimedia production tools (e.g., media capture and editing equipment, drawing programs, web-page/multimedia production tools)	80.59	15.58	2.80	1.04
E	Data-logging tools	87.60	8.27	3.13	1.00
F	Simulations/modelling software/digital learning Games	86.03	10.52	2.99	0.46
G	Communication software (e.g., e-mail, chat, discussion forum)	83.81	11.42	3.83	0.94
H	Digital resources (e.g., portal, dictionaries, encyclopaedia)	58.10	29.12	9.76	3.02
I	Mobile devices (e.g., Personal Digital Assistant (PDA), cell phone)	72.46	19.99	6.01	1.53
J	Smart board/interactive whiteboard	79.06	11.75	5.84	3.35
K	Learning management system (e.g., web-based learning environments)	84.08	12.06	3.00	0.86

In Table 5.6 the overall picture shows that the majority of teachers never incorporate ICT into their teaching practice. The highest percentage of teachers (36.66%) indicated that they sometimes make use of equipment and hands-on materials (e.g., laboratory equipment). The minority teachers with a percentage of 13.51% indicated that they nearly always make use of equipment and hands-on materials in their target class:

- 87.60% never make use of data logging tools
- 2.99% often make use simulations/modelling software learning games
- 83.81% of teachers responded that they never used communication software
- 29.12% often make use of digital resources (e.g., portal, dictionaries, and encyclopaedia)
- 3.35% nearly always makes use of smart board or interactive whiteboards.

5.5.1.6 General use of ICT and Pedagogical use

ICT forms part of our daily lives. Each time a cashier scans a barcode in a shop, a customer uses an automatic teller machine (ATM) to do her/his banking, or when we query an account at a local council office or clothing shop, a computer is involved (Cohen, 2003). This is also the case when we use e-mail to exchange written messages and photographs with friends and family in distant places or we search for information, order books and buy airtime tickets on the world wide web (Cohen, 2003).

Silverstone and Haddon (1996) stress the importance of everyday life experience in the adoption and the use of ICTs. The context of everyday life defines the needs and the wants of people. It provides the catalyst, but also the barriers for the decision to adopt. People want to organise their daily activities, they need to communicate with their social networks, and they have their specific hobbies and time consumers that should be addressed. Beyond that, they are part of a changing world with changing demands on the way we work, educate our children, run our households and meet people (Silverstone & Haddon, 1996).

The teachers' own pedagogical beliefs and values play an important part in shaping technology-mediated learning opportunities (Cox, Webb, & Abbott, 2003). Teachers need extensive knowledge of ICT to be able to understand how to incorporate the use of ICT into their lessons. They may need to develop new pedagogies to achieve this (Cox, et al., 2003). Pedagogical practices of teachers using ICT can range from only small enhancement of practices using what are essentially traditionally methods to more fundamental changes in their approach to teaching (Cox, et al., 2003). Table 5.7 represents question 21 of the questionnaire as indicated in Addendum 5.1.

Table 5.7: Percentage frequencies: general and pedagogical use of ICT in schools

		Not at all	A little	Somewhat	A lot
1	GENERAL USE OF ICT				
A	I can produce a letter using a word-processing program.	23.63	20.59	16.05	39.72
B	I can e-mail a file (e.g., the notes of a meeting) to a colleague.	42.80	15.33	13.46	28.42
C	I can take photos and present them on the computer.	50.00	14.35	12.35	23.30
D	I can file electronic documents in folders and sub-folders on the computer.	39.28	13.13	13.89	33.70
E	I can use a spreadsheet program for budgeting or student administration.	41.60	16.49	13.92	27.98
F	I can share knowledge and experiences with others in a discussion forum/user group on the Internet.	52.42	15.31	13.14	19.13
G	I can produce presentations with simple animation functions.	50.96	16.30	14.15	18.59
2	PEDAGOGICAL USE OF ICT				
H	I can use the Internet for online purchases and payments.	55.64	15.68	10.25	18.43
I	I can prepare lessons that involve the use of ICT by students.	53.46	18.32	13.65	14.58
J	I know which teaching/learning situations are suitable for ICT use.	47.83	19.98	18.23	13.95
K	I can find useful curriculum resources on the Internet.	47.03	15.44	14.32	23.21
L	I can use ICT for monitoring students' progress and evaluating learning outcomes.	47.03	15.44	14.32	23.21
M	I can use ICT to give effective presentations/ explanations.	51.49	16.17	15.29	17.05
N	I can use ICT for collaboration with others.	51.73	18.29	15.47	14.51
O	I can install educational software on my computer.	53.58	14.09	14.25	18.09
P	I can use the Internet (e.g., select suitable websites, user groups/discussion forums) to support student learning.	50.96	16.90	12.42	19.73

Table 5.6 gives an indication that the teacher's general use of ICT is incompetent. Teachers also indicated their pedagogical use of ICT in the target classes; the use in grade 8 natural science class less seems to be inadequacy. The highest percentage is 52.42% of teachers who show that they cannot share knowledge and experiences with others in a discussion forum/user group on the Internet. 33.70% indicated that they can file electronic documents in folders and subfolders on the computer:

- 50.96% cannot produce presentation with simple animation functions
- 53.46% indicated that they cannot prepare lessons that involve the use of ICT by learners
- 47.03% responded that they cannot use the computer to find useful curriculum resources
- on the Internet
- only 18.09% of the teachers indicated that they can install educational software on a computer

- 51.73% cannot use ICT to collaborate with others.

5.5.2 ICT contribution towards science education in South African schools

ICT is changing education by providing teachers with tools to use in all spheres of their profession. The Western Cape is a leading province in this regard and projects implementing ICTs in schools are spreading rapidly with the hope to alleviate the educational crisis in this country. Recognising the potential benefits of ICT-enhanced education, the South African Department of Education has been driving ICT interventions in schools nationally. The Western Cape Education Department (WCED) has taken the initiative by involving itself with many such projects to implement ICT in schools (Dougmore, 2004). It is the goal of the WCED that by the end of 2005, all schools will be equipped with a computer lab, satellite dish and television and video cassette recorder (VCR) set (Dougmore, 2004). The WCED is involved with many projects to implement ICTs in schools, one of the foremost of these projects currently running is the Khan project. The initiative is a pilot project geared towards implementing technology in under-resourced schools for curriculum development and delivery. By 2012, this project aims to have reached every educator in the Western Cape, and empowered them with skills and knowledge to integrate technology into their curricula (Khanya, 2005).

Gauteng Online is the leading technology access programme in schools in the Gauteng Province, South Africa. It is a programme of the Gauteng Provincial government through the Department of Education (Isaac, 2007). The programme's access model involves establishing a computer laboratory with 25 work stations, Internet and e-mail access, to be used for curriculum delivery in all Gauteng schools. The main goals of the programme are to contribute towards building the human resources capacity of the province and the country through the provision of quality education (Isaac, 2007).

5.5.2.1 Science teachers who indicated the impact of ICT use on their teaching and learning activities

Part VI of the Science teacher questionnaire of SITES 2006 consists of two sections: The first section starts with question 18 to determine if the teacher uses ICT in the teaching and learning activities of the target class. The teacher must respond by marking Yes or No. If the teacher indicated that they do use ICT in the teaching and learning activities they can continue with question 19 (To what extent do you agree that the use of ICT has had the following impacts on you) in regard with the impact on the teacher.

In Table 5.8 it is offered that the number of teachers who indicated yes for question 18 on the first question of the teacher questionnaire is $n=67$. Five hundred and two teachers in South Africa completed the questionnaire. It is cumbersome as only 67 of the teachers use ICT in their teaching activities. The Table 5.8 refers to questions 18 and 19 of the questionnaire (Addendum 5.1).

Table 5.8: Impact of ICT use on science teachers indicated that they use ICT for teaching and learning activities.

IMPACT ON TEACHER	Not at All	Little	Some what	A Lot
ICT skills improved	23.9	19.4	17.9	38.8
Incorporation of new teaching methods	25.4	20.6	23.8	30.2
Provision of individual feedback to students	29.0	22.6	19.4	29.0
Incorporation of new ways of organising student learning	23.3	28.3	28.3	30.0
Makes the monitoring of student learning progress more easy	24.6	24.6	11.5	39.3
Provides better access to more diverse/higher quality resources	25.0	21.7	21.7	31.7
More collaboration with colleagues within school	22.0	20.3	22.0	35.6
More collaboration with peers and experts outside school	29.3	25.9	13.8	31.0
Completion of administration tasks more easily	24.1	12.1	12.1	51.7
Workload has increased	32.2	23.7	13.6	30.5
Increase work pressure	35.6	20.3	15.3	28.8
Less effective as a teacher	71.2	16.9	0.00	11.9

Table 5.8 reflects the impact of ICT on the teaching and learning activities of the teacher when they use ICT. More than a third of the teachers (38.8%) indicated that ICT had an impact on their teaching and learning activities in the target classes. ICT impacted a lot (30%) on the implementation of new ways to organise student learning. A minority (11.9%) of the teachers pointed out that the impact of ICT resulted in their efficiency as a teacher:

- 39.3% of teachers experience the impact of ICT as positive towards monitoring student learning progress
- 35.6% experience more collaboration with colleagues within school
- 51.7% are of the opinion that the impact of ICT is positive with regards to the completion of administration tasks.

5.5.2.2. Computer competencies of science learner's operation skills according to science teacher respondents

Computer competency means to perform simple tasks with a computer, such as e-mail research creating and editing documents, spreadsheets and maybe a slide show (Power Point) (Answers, 2000). According to Governments around the world, developing and sustaining technological skills and competencies are seen to be a key part of a learners' ability to engage with 21st century schooling (Selwyn & Hussen, 2010).

The ability to make good use of ICT is seen as an essential "life skill" for individuals as they grow up into an information society. School systems around the world now face an imperative to provide learners with the necessary technological skills to survive and hopefully thrive as citizens in the information society (Selwyn & Hussen, 2010). Question 20 as represented in Table 5.8, reveals the extent of the impact of ICT on the ICT competencies of the learners (Addendum 5.1).

Table 5.9: The extent to which the use of ICT impacted on the ICT competencies of the learners

IMPACT ON LEARNER			DECREASE		NO IMPACT	INCREASE	
			A lot	A little		A little	A Lot
A	Subject matter knowledge	n	7	10	52	63	43
		%	3.7	5.34	30.98	37.64	22.34
B	Learning motivation	n	6	7	57	60	45
		%	3.21	3.94	32.63	34.35	25.86
C	Information-handling skills	n	7	7	55	62	44
		%	3.48	4.17	32.36	34.64	25.26
D	Problem-solving skills	n	6	7	60	61	39
		%	3.22	4.53	34.63	34.24	23.38
E	Self-directed learning skills	n	6	7	66	62	34
		%	3.21	3.65	36.54	37.33	19.27
F	Collaborative skills	n	6	5	65	63	33
		%	3.25	2.32	37.44	36.27	20.72
G	Communication skills	n	8	3	60	59	43
		%	4.20	1.11	34.23	35.14	25.32
H	ICT skills	n	9	7	58	76	26
		%	4.93	3.56	34.14	42.13	15.24
I	Ability to learn at their own pace	n	8	6	9	65	37
		%	4.53	2.64	33.59	37.71	21.52
J	Self esteem	n	7	2	58	56	47
		%	3.90	1.28	32.84	34.49	27.48
K	Achievement gap among students	n	8	7	62	58	36
		%	4.08	3.36	34.76	35.82	20.96
L	Time spent on learning	n	10	8	57	64	33
		%	5.45	4.37	33.07	37.17	19.94
M	School attendance	n	9	6	68	51	39
		%	5.32	3.33	38.26	29.61	23.46
N	Assessment results	n	6	4	60	69	34
		%	3.27	2.51	33.31	38.87	22.05
O	Digital divide (i.e. inequity between students from different socioeconomic backgrounds)	n	13	8	70	59	22
		%	7.42	5.47	40.12	33.09	12.89

The majority of learners' competencies either increased a little or no impact was experienced, as indicated in Table 5.9. It is clear that approximately a third of the learners experienced a little impact while the other third experienced no impact at all, concerning the extent to which the use of ICTs impacted on their ICT competencies. Learners with the abilities to work at their own pace, handle information, communicate, engage in collaborative problem solving as well as self-directed experienced an increase in learning, as a result of ICT use in the pedagogical practice. According to many teachers, learners' learning motivation and self esteem also increased due to ICT use.

5.5.2.3 Use of ICT in pedagogical practice to change teaching

Pedagogy is a word that encompasses all teaching strategies. Thus, pedagogical strategies are basically educational strategies used to help learners learn. It can also be defined as theory that is put into practice (Yahoo, 2005). Herts-Lazarowits (1995) indicates that pedagogical practice involves a special attentiveness to the experience of the learners, therefore, educators need to act from a deeper understanding of the cultural and historical context of current educational policies and teaching practices. Another pedagogical practice in teaching is cooperative learning. Traditionally, when

teachers implemented whole-class instruction, the results showed that they spent more time directing, questioning and disciplining learners and that their language tended to be more authoritarian and impersonal. However, when they implemented cooperative learning, their discourse was more helpful, more supportive and encouraging of learners' endeavours and their language was more friendly and personal (Herts-Lazarowits, 1995).

The ICT pedagogical approach emphasises the integrating of ICT skills in respective subjects, drawing on the principle of constructivism, pre-service teachers design lessons and activities that centre on the use of ICT tools that will foster the attainment of learning outcomes. This approach is useful to the extent that the skills enhance ICT literacy skills and the pedagogy allows the learner to further develop and maintain these skills in the context of designing classroom-based resources. Teachers who have undergone this type of training have reported significant changes in their understanding associated with effective strategies, as well as their self efficacy in their ICT competencies.

Table 5.10: Use of ICT on pedagogical practice to change your teaching of the target class

PEDAGOGICAL PRACTICE		Decreased	No difference	Increased
A	Quality of coaching learners	7.24	27.52	65.24
B	Time available to help individual students	11.03	37.77	51.20
C	Time needed to solve technical problems	13.26	37.18	49.55
D	Time needed for preparation	17.20	30.62	52.18
E	Quality of instructions given to learners	8.82	28.43	62.75
F	Time needed for classroom management	14.28	35.91	49.82
G	Quality of classroom discussions	8.13	32.30	59.57
H	Collaboration between learners	8.54	33.35	58.10
I	Communications to the outside world	8.84	38.40	52.76
J	Availability of new, learning content	7.00	32.11	60.89
K	Variety of learning resources/materials	7.67	32.31	60.02
L	Variety of learning activities	7.67	32.31	60.02
M	Adaptation of individual needs of learners	7.66	35.46	56.88
N	Amount of effort needed to motivate learners	9.74	34.37	55.89
O	Insight into the progress of learner performance	7.52	34.66	57.82
P	Self-confidence	7.69	28.28	64.03

Table 5.10 gives us an indication that the teacher's use of ICT, on pedagogical practice, has changed the teaching of the target class:

- quality of coaching learners increase (65.24%)
- time available to help individual learners has also increased (51.20%)
- time needed for preparation increased (52.18%)
- quality instructions given to learners' increased (62.75%)
- collaboration between learners increased (58.10%)
- communications to the outside world also increased (52.76%)
- variety of learning activities and a variety learning resources/materials increased (60.02%)
- self-confidence of the learner increased (64.03%)
- availability of new, learning content for the learner increased (60.89%)
- quality of classroom discussions increased (59.57%).

The greater majority of the science teachers reported that ICT in the pedagogical practice has led to an increase in the variety of the learning activities, the quality of coaching learners, the quality of classroom discussion and collaboration between learners. A large majority of the science teachers also observed that ICT had contributed to an increase in available content and an increase in the variety of available learning resources. Time needed for classroom management, solving technical problems and for coaching individual learners had increased for only a minority of the science teachers.

5.6 FINDINGS: FACTOR ANALYSIS

In this statement some of the questions pertain to the grade 8 teachers' practices and some pertain to the pedagogical use of ICT in science classrooms. A factor analysis was conducted on the dataset. Leedy and Omrod (2004, p. 282) describe factor analysis as *the examination of data to identify clusters or highly interrelated variables that reflect specific themes (or factors)*. A number of variables is present and can be clustered into specific groups. Variables used in SITES 2006 data are categorical of nature, i.e. it has a categorical response. In order to help address the second research aim and answer the second research question: *How does the pedagogical use of ICT in grade 8 natural science contribute towards science education in South African schools?*; the categorical variables of ICT impact, as presented by the items of the SITES 2006 teachers questionnaire, were calculated to be used in § 5.7 for the correlation study. The statistical analysis was carried out with the help of the SPSS-program (SPSS, 2003).

5.6.1 Factor analysis of teacher questionnaire Items 19A-L (Positive and negative ICT impact)

The principal component factor analysis indicated a two factor loading for Teacher Questionnaire Items 19 A-L (Kaiser-Meyer-Olkin Measure of Sample Adequacy; 0.882). The factor analysis revealed two factors, i.e. items 19A-I and 19J-L (Table 5.11). The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was used and provided a sample adequacy of 0.882 indicating sufficient data for a factor analysis. Kaiser-Meyer-Olkin Measure varies between 0 and 1, and values closer to 1 are better. A value of 0.6 is a suggested minimum.

Table 5.11: Positive and negative ICT impact on teachers

IMPACT ON TEACHER	Factor 1	Factor 2
ICT skills improved	.711	
Incorporation of new teaching methods	.902	
Provision of individual feedback to students	.753	
Incorporation of new ways of organising student learning	.874	
Makes the monitoring of the student learning progress easier	.961	
Provides better access to more diverse/higher quality resources	.902	
More collaboration with colleagues within school	.879	
More collaboration with peers and experts outside school	.879	
Completion of administration tasks more easily	.935	
Workload has increased		.917
Increased work pressure		.870
Less effective as a teacher		.750

Items 19A-I seem to measure positive ICT impact, while 19J-L seem to measure negative ICT impact, therefore the two factor loading. These two factors were used in § 5.7 for correlation investigation to help address the second research aim.

5.6.2 Factor analysis of teacher questionnaire Items 20 (General learner skills developed via ICT)

A factor analysis found a one factor loading (Table 5.12) for Teacher Questionnaire Items 20A-K.

Table 5.12: General learner skills developed via ICT

TEACHER QUESTIONNAIRE ITEMS 20 A-K	Factor 1
Item 20 A Subject matter knowledge	.888
Item 20 B Learning motivation	.914
Item 20 C Information-handling skills	.910
Item 20 D Problem-solving skills	.937
Item 20 E Self-directed learning skills	.939
Item 20 F Collaborative skills	.976
Item 20 G Communication skills	.918
Item 20 H ICT skills	.910
Item 20 I Learn at their own pace ICT skills	.921
Item 20 J Self esteem	.936
Item 20 K Achievement gap among students	.909
School attendance	.927
Study skills	.909
Time spent on learning	.898
Digital divide	.511

This factor seems to measure general learner skills developed by means of ICTs. This factor was used in § 5.7 for the correlation investigation to help address the second research aim.

5.6.3 Factor analysis of teacher questionnaire Items 21 I-P (Teachers' confident pedagogical use of ICT).

The principal component factor analysis indicated a one factor loading (Table 5.13) for teacher questionnaire items 21 I-P (Kaiser-Meyer-Olkin Measure of Sample Adequacy= 0.897).

Table 5.13: Teachers' confident pedagogical use of ICT

TEACHER QUESTIONNAIRE ITEM 21 I-P	Factor 1
Can prepare lessons that involve the use of ICTs by students	.888
Know which teaching/learning situations are suitable for ICT use	.899
Can find useful curriculum resources on the Internet	.893
Can use ICT for monitoring students' progress and evaluating learning outcomes	.911
Can use ICT to give effective presentations/explanations	.920
Can use ICT for collaboration with others	.932
Can install educational software on my computer	.874
Can use the Internet (e.g., select suitable websites, user groups/discussion forums) to support student learning	.937

This factor seems to measure teacher's confident pedagogical use of ICT. This factor was used in § 5.7 for the correlation investigation to help address the second research aim.

5.6.4. Factor analysis of teacher questionnaire items 40

Table 5.14 Teachers' pedagogical practice contribute to their teaching

PEDAGOGICAL PRACTICE	Factor 1	Factor 2	Factor 3
A Quality of coaching learners			-.896
B Time available to help individual students			-.762
C Time needed to solve technical problems	.799		
D Time needed for preparation	.492		
E Quality of instructions given to learners		.376	-.781
F Time needed for classroom management	.490	-.346	-.466
G Quality of classroom discussions			-.814
H Collaboration between learners			-.951
I Communications to the outside world	.335		-.521
J Availability of new learning content		.646	-.349
K Variety of learning resources/materials		.783	
L Variety of learning activities	.357	.746	
M Adaptation of individual needs of learners	.982		
N Amount of effort needed to motivate learners	.872		
O Insight into the progress of learner performance	.880		
P Self-confidence	.809		

This factor seems to measure teacher's pedagogical practices. This factor was used in § 5.7 for the correlation investigation to help address the second research aim.

The factor analysis provided the researcher with variability amongst the variables in terms of factors. The interdependencies are used in the next section to indicate the correlations (relationships) between the variables in order to determine how pedagogical use of ICT in grade 8 natural science can contribute towards science education in South Africa.

5.7 FINDINGS: CORRELATIONS

To address the second research aim and answer the second research question: *How does the pedagogical use of ICT in grade 8 natural science contribute towards science education in South African*

schools?; a factor analysis (§ 5.6) was used to identify categorical constructs (variables) of ICT impact and contribution, as pertained by the items of the SITES 2006 teachers questionnaire. The researcher also identified individual constructs (variables) of ICT impact and contribution from the questionnaire. These constructs were used for a correlation investigation. A correlation is a statistical technique that is used to measure and describe a relationship between two variables. There is no attempt to control or manipulate the variables.

Cohen (1988) defined the standard for assessing the size of correlations. He called the size of the effect of one variable on another variable the effect size. According to Cohen, a correlation of 0.5 is considered a large effect size (preferably ≥ 0.8), 0.3 a medium effect size, and 0.1 a small effect size. Another method to calculate meaningful correlations between variables is by using a Spearman's Rho Correlation (usually shortened to Spearman correlation)—a non-parametric measure of agreement between two ordinal measures (Spearman, 1904). In this study, Spearman's effect sizes were calculated to identify meaningful correlations between the constructs (variables). In most studies, Spearman's effect size is interpreted according to the same criteria as proposed by Cohen, i.e. $R \geq 0.5$ is considered a large effect which is indicative of a practically significant correlation between two variables. However, according to Cohen (1988), preferably an effect size ≥ 0.8 is indicative of a large practically significant correlation. In this investigation a large number of correlations (effect sizes) were calculated that are ≥ 0.7 . Therefore, for the purpose of this investigation, an effect size $0.5 \leq R \leq 0.7$ is considered a medium effect which tends towards a practically significant correlation, an effect size $R \geq 0.8$ is considered a large effect which indicates a practically significant correlation and an effect size $R \leq 0.4$ is considered a small effect which is only statistically significant. Table 5.15 (see page 112) shows the Spearman correlations that were found between the selected constructs. Only medium and large effects are discussed after the table.

Table 5.15
Spearman correlations

	Positive ICT Impact on Teachers (19A-I)	Negative ICT Impact on Teacher (19J-L)	General Learner Skills Developed (20B-K)	F40_teacher pedagogical practice	F40_learner pedagogical practice	F40_resource pedagogical practice	Subject matter knowledge (20A)	ICT Skills (20H)	Learning motivation (20B)	Learn at own pace (20I)	Communication skills (20G)	Info handling skills (20C)	Collaboration skills (20F)	Self directive learning skills (20E)	Problem solving skills (20D)	Narrow Achievement Gap (20K)	Self esteem (20J)	Teachers' Confident Pedagogical Use of ICT (21I-P)
Positive ICT Impact on Teachers (19A-I)	1.000	.524**	.560**	.229	.196	-.023	.253	.312	.365	.362	.358	.334	.426*	.474**	.437*	.274	.364	.516**
Negative ICT Impact on Teachers (19J-L)	.524**	1.000	.375**	-.306	-.219	-.058	-.088	-.021	-.004	-.041	-.085	-.085	-.130	-.215	-.256	.003	-.077	.191
General Learner Skills Developed (20B-K)	.560**	.375**	1.000	.308	.439*	.197	.279	.173	.230	.260	.293	.217	.282	.308	.243	.339	.361	.361**
F40_teacher pedagogical practice	.229	-.306	.308	1.000	.757**	.535**	.370	.114	.059	.232	.324	.334	.299	.348	.417*	.325	.388*	.143
F40_learner pedagogical practice	.196	-.219	.439*	.757**	1.000	.568**	.381	.170	.252	.436*	.503**	.413	.399	.370	.452**	.537**	.562**	.013
F40_resource pedagogical practice	-.023	-.058	.197	.535**	.568**	1.000	.262	.184	.099	.045	.072	.112	.000	.102	.157	.190	.243	.314
Subject matter knowledge (20A)	.253	-.088	.279	.370	.381	.262	1.000	.876**	.697**	.647**	.656**	.751**	.768**	.841**	.768**	.758**	.678**	.200
ICT Skills (20H)	.312	-.021	.173	.114	.170	.184	.876**	1.000	.710**	.661**	.501**	.653**	.658**	.720**	.658**	.632**	.564**	.419*
Learning motivation (20B)	.365	-.004	.230	.059	.252	.099	.697**	.710**	1.000	.831**	.767**	.652**	.769**	.716**	.654**	.734**	.667**	.354
Learn at own pace (20I)	.362	-.041	.260	.232	.436*	.045	.647**	.661**	.831**	1.000	.933**	.843**	.831**	.660**	.716**	.669**	.720**	.134
Communication skills (20G)	.358	-.085	.293	.324	.503**	.072	.656**	.501**	.767**	.933**	1.000	.888**	.878**	.714**	.767**	.727**	.774**	.000
Info handling skills (20C)	.334	-.085	.217	.334	.413	.112	.751**	.653**	.652**	.843**	.888**	1.000	.890**	.725**	.771**	.644**	.683**	.042
Collaboration skills (20F)	.426*	-.130	.282	.299	.399*	.000	.768**	.658**	.769**	.831**	.878**	.890**	1.000	.831**	.769**	.734**	.667**	.149
Self directive learning skills (20E)	.474**	-.215	.308	.348	.370	.102	.841**	.720**	.716**	.660**	.714**	.725**	.831**	1.000	.945**	.782**	.833**	.292
Problem solving skills (20D)	.437*	-.256	.243	.417*	.452**	.157	.768**	.658**	.654**	.716**	.767**	.771**	.769**	.945**	1.000	.734**	.895**	.202
Narrow Achievement Gap (20K)	.274	.003	.339	.325	.537**	.190	.758**	.632**	.734**	.669**	.727**	.644**	.734**	.782**	.734**	1.000	.833**	.114
Self esteem (20J)	.364	-.077	.361	.388*	.562**	.243	.678**	.564**	.667**	.720**	.774**	.683**	.667**	.833**	.895**	.833**	1.000	.146
Teachers Confident Pedagogical Use of ICT (21I-P)	.516**	.191	.361**	.143	.013	.314	.200	.419*	.354	.134	.000	.042	.149	.292	.202	.114	.146	1.000

* medium effect which tends towards a practically significant correlation

**large effect which indicates a practically significant correlation

As indicated in Table 5.15, a medium effect, which tends towards a practically significant correlation ($R= 0.542$) was found between the positive impact (items 19 A-I combined) and negative impact (items 19 J-I combined) on teachers, which indicate that the more teachers make use of ICTs (positive impact) the more their workload and work pressure decreases and they become more effective as teachers. From the review of literature it can be concluded that workload has a negative impact on teacher morale, recruitment and retention. Teachers experience ICT possibilities positive with reference to the reduction of their workload. ICTs are beneficial to teachers, learners and schools as it reduces the mentioned workload (§ 2.3).

A medium effect ($R=0,560$), which tends towards a practically significant correlation, was found between general learner skills development (item 20 B-K) and positive impact on teachers (Item 19 A-I), which indicates that the more learners develop general skills through the use of ICT, the more positive the ICT impact is on teachers. The integration of ICT into science education motivates learners to develop their ICT skills. This inspires the teacher to improve the quality of teaching and learning of science by means of versatility of ICTs (§ 2.4).

As indicated in Table 5.15 a large effect, which indicates a practically significant correlation ($R=0,876$), was found between subject matter knowledge (item 20 A) and ICT skills (item 20 H). This means the higher the teachers ICT skills are, the higher will their subject matter knowledge be. Haddad et al.(2001) agree that teachers with higher ICT skills know their subject better (§ 2.3).

A medium effect ($R=0,697$), which tends towards a practically significant correlation, was found between learning motivation (item 20 B) and subject matter knowledge (item 20 A) which indicates that the higher the teachers subject matter knowledge become, the more motivated the learners. Teachers are aware that the development of their own knowledge and understanding of the subject knowledge increases the motivation level of the science learner (§ 2.3). The learner attendance and their interest in the subject increased enormously.

A medium effect, which tends towards a practically significant correlation ($R=0.710$), was found between learning motivation (item 20 B) and ICT skills (item 20 H). This indicates that the learning motivation of the learner will increase through ICT skills. ICT has the potential to augment learning in school. Effective teaching with ICT involves all learners in the lessons and learning through the use of ICT is arguably the most powerful means of supporting learners to achieve the curriculum goals (§ 2.4).

Between learning motivation (item 20 B) and learning at own pace (item 20 I) a large effect was found, which indicates a practically significant correlation ($R=0.831$). The motivation to learn by the learners will encourage them to learn at their own pace. ICT has an effect on active learning (§ 2.5). Learners learn *by doing* and, if possible, work on real-life problems in depth, making learning less abstract and more relevant to real life situations.

gical practices. Teachers who engage with ICT as part of their teaching practice in new and original ways, inspire learners to be part of their own learning practices evolving from the new experiences (§ 2.3).

A medium effect, which tends towards a practically significant correlation ($R=0.535$), was discovered between teacher pedagogical practices (item F 40) and resource pedagogical practices (item F 40), which indicates that the pedagogical resources of teaching has a positive effect on teachers' pedagogical practices. Teachers who e.g. make use of IWB as a pedagogical resource, support different learning approaches that maintain existing pedagogical practices. ICT should be regarded as add-on to the existing learning practices (§ 2.3).

The medium effect was found that tends towards a practically significant correlation ($R=0.568$) between learners pedagogically practices (item F 20) and resource pedagogical practices (item F 20), which it is noticeable that resource pedagogical practices have a positive impact on the learners' pedagogical practices.

A large ($R=0.843$) effect, which indicates a practically significant correlation between information handling skills (item 20 C) and learning at own pace (item 20 I) was discovered. From this we can clearly see that learners with good information handling skills can learn at their own pace in class. A successful learner must also be adopting information findings, evaluating, and applying new content understanding with great flexibility (§ 2.5). Learners must be equipped with skills and perspectives designed to help them anticipate change and plan accordingly. This will equip them to thrive in a world characterized by rapid change.

Subject matter knowledge (item 20 A) and self directive learning skills (item 20 E) reveal another large effect, with a practically significant correlation ($R=0.841$), which indicates that teachers with subject matter knowledge has a positive impact on learners with self directive learning skills.

A large effect ($R=0.945$), which indicates a practically significant correlation was found between self directive learning skills (item 20 E) and problem solving skills (item 20 D). This shows that learners with self directive skills also have good problem solving skills.

A practically significant correlation ($R=0.895$) shows a large effect, between self-esteem (item 20 J) and problem solving skills (item 20 D) was discovered and this possibly means that learners with self-esteem has good problem solving skills. Perceptions of children about their competence and self esteem effect their attitude towards problem solving (Lochman & Lampron, 1986).

Large effect ($R=0.782$) which indicates a practically significant correlation was found between narrow achievement gap (item 20 K) and self directive learning skills (item 20 E), which indicates that self directive learners have a narrow achievement gap.

A practically significant correlation was discovered, which shows a large effect ($R=0.833$) between self directed learning (item 20 E) and self esteem (item 20 J). From this we can derive that learners with self directed learning skills have good self-esteem. Learners with good self-esteem will be ready to face many challenges in the outside world. The self-esteem of a learner usually refers to opinion or worth of the self. Pilay (2006) explains that it is useful for learners to attempt to develop ICT skills that enable them to think critically, analyze information, communicate, collaborate, and solve problems, and realize the essential role technology plays in realizing these learning skills in today's knowledge-based society (§ 2.3).

A large effect ($R=0.933$), possibly indicates a practically significant correlation was found between learn at own pace (item 20 I) and communication skills (item 20 G). Good communication skills tender learners with abilities to express themselves in a clear and understandable way. They take on responsibilities for their own teaching and learning, which means they usually have the ability to do things on his/her own pace and this gives the learner more confidence to communicate with others (§ 2.5).

A practically significant correlation was discovered between communication skills (item 20 F) and collaboration skills (item 20 G) indicating a large effect indicates ($R=0.878$). Learners with the ability to communicate with others also have the ability to collaborate with others. Learners who collaborate with others learn more and there is a good cooperation between them in class. Pedretti et al.(1998) specify that learners in classrooms of a collaborative nature help others them to learn better, particularly by clarifying understandings and supporting deeper learning (§ 2.6).

Between narrow achievement gap (item 20 K) and self esteem (item 20 J) a large effect indicates a practically significant correlation was found ($R=0.833$). Learners who show a narrow achievement gap in class always has a good self esteem. Learners with a high self-esteem usually mirror a competitive spirit that guides them to challenge themselves and their peers (§ 2.5).

A large effect ($R=0.890$) indicates a practically significant correlation between collaboration skills (item 20.F) and info handling skills (item 20 C). Collaboration among learners in class is a good way of learning. Collaborating not only facilitates the sharing of ideas, it also provides opportunities for learners to explain and have ideas validated as they help each other. Group work usually have a positive effect on the learners' achievement (Hoyles, et al., 1994).

A medium effect ($R=0.678$) was found between self-esteem (item 20 J) and subject knowledge matter (item 20 H) which tends towards a practically significant correlation. Learners in class with a good self esteem always have good subject knowledge (§ 2.5).

A practically significant correlation ($R=0.564$) between self esteem (item 20 J) and ICT skills (item 20 H) show a medium effect that tends towards a practically significant correlation. Learners with good self-esteem have the ability to develop skills much quicker than learners with little or no self-esteem (Kim, et al., 2007).

As indicated in Table 5.15, a medium effect, which tends towards a practically significant correlation ($R= 0.516$) was found between the teachers confident use of pedagogical use of ICT (item 21 I-P) and the positive impact on teachers (items 19 A-I), which indicate that the more confident the teachers are with regard to the use of ICTs the more positive the impact on them. This means that when teachers are positive they have the ability to control, manipulate and contribute to the information environment (§ 2.3).

Another large effect which indicates a practically significant correlation ($R=0.751$) between info handling skills (item 20 C) and subject matter knowledge (item 20 A) was found. It is possible that learners with good subject matter knowledge will have good info handling skills. Learners can choose any topics, take notes, explore virtual landscapes, enter draw, creates and manipulates images or make their own multimedia presentations and run simulated experiments (§ 2.3).

Between communication skill (item 20 G) and learners' pedagogical practice (item F 40) a correlation that tends towards a practically significant was found ($R=0.503$). Good communication skills have always a positive impact on learners' pedagogical practices. Learners with such skills can communicate with other learners in other countries around the world to seek information and gain new knowledge (§ 2.4).

Another large effect, which indicate a practically significant correlation ($R=0.768$) between problem solving (item 20 D) and subject matter knowledge (item 20 A) was revealed in Table 5.14. This can indicate that an increase in the learners' subject knowledge can lead to better problem solving. Learners who knows their subject matter very well are able to solve problems (§ 2.3).

Another practical significance was discovered, which shows a large effect ($R=0.758$) between subject matter knowledge (item 20 A) and narrow achievement gap (item 20 K). From this we can derive that one of the ways to narrow the achievement gap is to increase the level of the learners' subject matter knowledge. Learners with a wide range of knowledge tends do well in class and able to achieve good results (§ 2.3).

A medium effect, which tends towards a practical significance correlation ($R = 0.667$) was noticed between self esteem (item 20 J) and learning motivation (item 20 B), which indicates that learners with a high-quality self esteem has learning motivation to excel in science education. Self esteem and learning motivation is a condition in which two or more individuals learn on attempt to learn something together. The creation of knowledge within a population lead to learners actively interact by sharing experience and take asymmetric roles (§ 2.3).

A medium effect, was found between learners pedagogical practice (item F40) and narrow achievement gap (20 K), that tends towards a practically significant correlation ($R=0.537$). It is noticeable that learners pedagogical practices have a positive impact on the narrowing the achievement gap. The narrow achievement gap, usually indicates a positive change of good results (§ 2.3).

A large effect, which indicates a practically significant correlation ($R=0.716$), between problem solving skills (item 20 D) and learn at own pace (item 20 I) was found. It is possibly that learners who learn at their own pace will possibly have good problem solving skills. Such learners has the ability to learn to solve real life problems in real life situation (§ 2.3).

Another large effect ($R=0.734$), which indicates a practically significant correlation between narrow achievement gap (Item 20 K) and learning motivation (Item 20 B) was discovered. The level of learner's motivation to learn can narrow the achievement gap that exists between the subject knowledge and the learners' performance in natural science education. Through learning motivation, learners achieve much more in class and mostly their results is always good (§ 2.3).

From Table 5.15 it can be derive that a medium effect of practically significant correlation ($R=0.500$), between problem solving skills (item 20 D) and learner pedagogical practices (item F 40) was discovered. Learners can solve their own problems and has a positive impact on their pedagogical practices (Learning Science Technology, 2003).

Another large effect which indicates a practically significant correlation ($R=0.771$) between info handling skills (item 20 C) and problem solving skills (item 20 D) was found. It is possible that learners with well developed info handling skills may have good problem solving skills. Learners with such skills like problem solving skills become good citizen in life (§ 2.3).

Between collaborative skills (item 20 F) and subject matter knowledge (item 20 A) a large effect ($R=0.768$) that tends towards a practically significant correlation was found. It can be derived that learners with high subject matter knowledge can make use of collaborative skills. Learners who work collaborative in class can learn quickly and build up their knowledge in their subjects. Collaborative learning can foster knowledge integration and increase learners' conceptual understanding. WWW is a well developed tool to support and scaffold group processes and cognition, for example virtual workspaces for collaborative learning (McLoughlin, 2002).

Another practically significance correlation ($R=0.562$), was discovered which indicate a medium effect between self esteem (item 20 J) and learners pedagogical practices (item F 40). Learners with a good self esteem have always a positive impact on their pedagogical practices. Such learners perform well at school (§ 2.4).

A medium effect, was found between communications skills (item 20 G) and subject matter knowledge (item 20 A), that tends towards a practically significant correlation ($R=0.656$). Learners' subject matter knowledge will increase if they use their communication skills to communicate more via the internet with their peers around the world to seek for information (§ 2.4)

A practically significant correlation was discovered, which shows a medium effect ($R=0.660$) between self directed learning (item 20 E) and learning at own pace (item 20 I). Learners with self-directed learning skills have the ability to learn at their own pace. Learning at their own pace will give learners the opportunity to learn more (§ 2.3).

As indicated in Table 5.15, a large effect, which tends towards a practically significant correlation ($R=0.734$) was found between narrow achievement gap (item 20 K) and the learning motivation of the learners (item 20 B) in the grade 8 natural science classes. Learners with a motivation of learning achieve better results in class and narrow the achievement gap. Such learners has good learning skills (§2.3).

Another large effect indicates ($R=0.720$), a practically significant correlation was discovered between, self esteem (item 20 J) and learn at own pace (item 20 I). It is possible that learners with a high self esteem can learn at own pace. Learners with a good self esteem can face many challenges in real life and know how to learn something on their own (§ 2.3).

As indicated in Table 5.15, a large effect, which disclose a practically significant correlation ($R=0.725$), between self directed learning skills (item 20 E) and information handling skills (item 20 C) on learners, which indicate that the more the learners' apply self directive learning skills, the better their info handling skills. Learners with such abilities can achieve so much in real life. They know how to write, read and speak properly (§ 2.3).

Another medium effect, which tends towards a practically significant correlation ($R=0.658$), between collaborative skills (item 20 F) and ICT skills (Item 20 H) was found. It is possible that learners with good ICT skills will have better collaborative skills than those without ICT skills. ICT skills can overcome physical and geographic barriers and facilitates communication and has the potential to eliminate artificial boundaries between schools and the outside world (§ 2.4).

As indicated in Table 5.15, a large effect, which reveal a practically significant correlation ($R=0.714$), was found between self directive learning skills (item 20 E) and the communication skills of learners (item 20 G) in the grade 8 natural science classes. Good communication skills of the learners will help them in real life to speak to people and write to people in a proper way (§ 2.3).

A large effect ($R=0.727$), which indicates a practically significant correlation was found between narrow achievement gap (item 20 K) and communication skills (item 20 G), which indicates that high le-

easily communicate with learners around the world via the Internet. The use of the internet helps to raise learners awareness and understanding of science and technology in the real world (§ 2.3).

Another medium effect, which tends towards a practically significant correlation ($R=0.667$) between learning motivation (Item 20 B) and self esteem (Item 20 J) was found. It is possible that learners with a well developed self esteem can have a high level of learning motivation. Through learning motivation learners can promote co-operation, study in authentic context and be creative in learning (§ 2.4).

Another practical significance was discovered, which shows a large effect ($R=0.769$) between problem solving skills (item 20 D) and collaborative skills (item 20 F). From this we can derive that learners with high collaborative skills will display high levels of problem solving skills. Learners with collaborative skills are learners with confidence and they solve any problem they face in life.

Table 5.15 shows a tendency towards a practically significant correlation ($R=0.653$), between information handling skills (item 20 C) and ICT skills (item 20 H). Using the computer in science lessons can help to promote a modern image of science and give a sense of the importance of ICT at all levels of learning about the subject (§ 2.4).

A practically significant correlation ($R=0.831$), was discovered which shows a large effect between self directive learning skills (item 20 E) and collaborative skills (item 20 F). From this we can derive that learners with self directive learning skills have better collaborative skills. Learners with self directive learning skills are more versatile and goal oriented and more active in their own education.

A medium effect was found between learning at own pace (item 20 I) and subject matter knowledge (item 20 A), which tends towards a practical significant correlation ($R=0.647$). It is noticeable that subject matter knowledge can affect the learners' pace of learning. Learners who know their subject matter very well has the opportunity to learn at their own pace and are more likely to complete their task (§ 2.4).

Another medium effect, which indicates a tendency toward practically significant correlation ($R=0.654$) between problem solving skills (Item 20 D) and learning motivation (Item 20 B) was found. It is possible that learners with good problem solving skills will have the benefit of better learning motivation. Motivated learners have also the ability to improve their results and their achievements. Highly motivated learners have the confidence to solve their own problems.

A practically significant correlation ($R=0.644$), was discovered which shows a medium effect between narrow achievement gap (item 20 K), and information handling (item 20 C). From this we can derive that learners with well developed info handling skills will reflect narrowing of the achievement gap referring to grade 8 natural science. Learners with good information handling skills are better performers in school and they achieve results that reflect their effort (§ 2.3).

A large effect ($R=0.890$) indicates a practically significant correlation between collaboration skills (item 20.F) and information handling skills (item 20 C). The learner with well developed information handling skills, easily work in groups with their peers.

A medium effect ($R=0.678$) was found between self-esteem (item 20 J) and subject knowledge matter (item 20 H) which tends towards a practically significant correlation. Learners in class with a good self esteem have good subject knowledge.

Another medium effect was discovered which tends towards a practically significant correlation ($R=0.564$) between self esteem (item 20 J) and ICT skills (item 20 H). Learners with good self-esteem have the ability to develop skills much quicker than learners with little or no self-esteem (§ 2.5).

The above correlations were used to attempt to determine the contribution of ICT use in grade 8 natural science classes. The correlations described the degree between the different concepts to provide the researcher with results that reflect the contribution of pedagogical ICT use in science education. Integrating ICT in the curriculum has great potential for learners and teachers to increase their ICT skills and at the same instant narrow the achievement gap.

4.6 SUMMARY

This chapter started with the descriptive analysis of the data regarding the pedagogical use of science education. Factor analysis was used to identify variables of ICT impact and contribution, as pertained by the items of the teachers' questionnaire. Furthermore, Spearman correlations originate between the selected constructs. The focus of the study is the South African science teachers' use of ICT in pedagogical practices and pedagogical orientations. Chapter six comprises a proposed framework for the pedagogical use of ICT in grade 8 natural science and recommendations as an outcome of the study

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The aim with this study was to investigate ICT as a teaching and learning tool within the pedagogical framework of grade 8 natural science. This chapters' main focus is captured in a short summary to generate a conclusion for each one. The conclusions attained from the research findings (chapter 5) are presented in accordance eminent conclusions and the research aims. Evidently recommendations will follow before the chapter is brought to a close.

6.2 OUTLINE OF STUDY

An overview of the study is render if the researcher determined the teachers' use of ICT in South African schools and investigated if the pedagogical use of ICT can contribute toward science education in grade 8 natural science classes.

6.3 REVIEW OF LITERATURE

Chapter one as introduction to the study explained the necessity for pedagogical use of ICT in the natural science classroom. Knowledge, practical replication of experiments and reflection are central to the teaching and learning process in science. Teachers and learners should be encouraged towards the application of ICT's within a pedagogical environment. The problem statement, purpose and aim of the study, research design and methodology, contribution and outline of the study were captured to describe the value of ICT-supported learning and ICT pedagogical use.

Conclusion:

The problem statement identified that contemporise education are lacking ways to prepare learners as self-regulated and independent individuals (§ 1.2). Through the use of ICT learners questioning minds can be stimulated and supported the learners in the development of their own ICT skills. Teachers who use ICT can become more creative in classroom practice and therefore broaden the scope of subject knowledge. The use of ICT tasks of cognitive complexity and less teacher support indicate a change in the learner's motivation, self-directed learning and attitudes towards science education. Collaboration with specialist and peers expand the learners' use of ICT and subject knowledge. Traditional teacher-centred approaches remain a problem as teaching still consists of the transfer of information from teacher to learner.

With **chapter two** the aim was to unpack the science approach and pedagogical use of Norway, Canada and Hong Kong, countries that participated in SITES 2006. Australia was identified as a country that is known for its inclusive implementation of outcomes-based education similar to the South African context. A pertinent view of science education in South Africa provides the reader with knowledge about improvement of teaching and learning through application of ICT (§ 2.2). The aim with the use of ICT for teaching is to motivate the learner to develop an eagerness to put ICT knowledge into practice. Furthermore the chapter shed light on the different approaches and views regarding the role of ICT in education. The power of e-policy on the pedagogical use of ICT in science education was highlighted and unravelled.

Conclusion:

The South Africa science education approach strongly resembles the science curriculum approaches of Norwegian, Hong Kong, Canada and Australia. All mentioned countries are directed by e-Education policies engaging different priorities. Globally there is significant support towards the use of ICT as communication tool that communicate with the learners to grasp in-depth understanding and knowledge. South African White Paper on e-Education (Department of Education, 2004b) recommends that ICT support and promotes the achievement of science learning outcomes by the creative use of the result of the science and technology system with regard to innovative technology. Through pedagogical use of ICT in science education, learners can take part in collaborative group work, interact with their peers, increase their ICT skills and build better subject knowledge. The attitude change in teachers towards ICT is beneficial as the use of ICT can make science education more versatile and goal oriented to raise potential value of schools.

The emphasis of pedagogical use of ICT correlates with different teaching approaches e.g. active learning, collaborative learning, executed across the natural science curriculum. The White paper on e-Education envisages empowering all learners with ICT skills to change their knowledge, be confident and competent using technology to contribute to an innovative developing South Africa (Department of Education, 2004b). ICT use for educational purpose is still inadequate, although ICT can manage teaching and learning together with conventional methods.

The significance of the e-Education policy can be described as a directive that goes beyond the issues of accessibility. A change is needed in the availability of ICT and the attitude of teacher and learners transform the grade 8 natural science educational environment. The use of ICT in science education cannot be successful on its own merits, but needs the actions of learners and teachers.

Chapter three clarifies the two SITES Modules. SITES module 1 was a comparative study developed to estimate the participant countries position, relevant to 26 system countries, regarding the use of ICT in science and mathematics education. SITES M1 data collection took place between the end of 1998 and beginning of 1999. SITES M2 focused on the use of ICT around the globe to be creative

in the application into science education. A comparative case study consists of 28 education systems, which resulted in 174 case studies (§ 3.2). The SITES M2 addressed three main research questions:

- What are the pedagogical practices adopted in schools and how is ICT used in them?
- What and how is ICT used in specific situations where ICT has been used relatively extensively within the pedagogical practice?
- What are the teacher, school, community and systems factors that are associated with different pedagogical approaches and ICT use, and can explanatory model be identified?

Conclusion:

The pedagogical use of ICT in grade eight science natural classes were collected through teacher questionnaires. The data investigated science classroom practice in detail. Law et al.(2008b, pp. 1-3) explain the *consistence with SITES 2006 view of pedagogical practice and ICT-use should be understood within school and system level*. The SITES M2 data collection endeavour ended with an astonishing 174 innovative grade eight natural science target classes. Many schools indicate promising pedagogical use but large differences were identified between the participating countries application of ICT was identified. An example is Hong Kong scoring 36 while Norway scored 71 on a scale from 0-100. SITES 2006 delivered valuable percentages of ICT-use in science education classrooms.

Chapter four provides an outline of the methodology and statistical analysis followed during the SITES 2006, the variables for the SDA were identified, the study population for the SDA, ethical considerations, as well as how the SDA was conducted. Three indicators, *reflecting the strengths of the traditionally important, lifelong learning, and correctness orientations* were constructed (§ 4.3). The teachers were asked to respond if ICT had been used in the target classes through the following

Conclusion:

SD analysis methodologies were followed. The data set of the responses of South African grade 8 natural science teachers on the teachers' questionnaire collected during SITES 2006.

The data set is available in the public domain and no new data were collected. The researcher gave acknowledgement to SITES 2006.

Chapter five present the research findings in detail. There is a lack of quality science teaching in South Africa (§ 5.2). Existing availability of the pedagogical use of ICT in science could prove to be a valuable tool in creating motivated and interested learners in the science classes. Excellent science teachers should be trained and employed to improve and encourage science in South African schools (Department of Education, 2006). Descriptive data analysis of the SDA was used to establish better understanding of *the pedagogical uses of ICT in grade 8 natural science in South African schools*. SD was examined for factor analysis to identify clusters variables that reflect specific themes (or factors). The internal validity of the different constructs in the questionnaire was determined by Statistical Consultation Services of the North-West University: Potchefstroom Campus. To gain a clearer

perspective on the second question: *To determine how the pedagogical uses of ICT in grade 8 natural science contributes towards science education in South African schools*; a factor analyses (§ 5.6) was used to identify categorical constructs (variables) of ICT impact and contribution, as pertained by the items of the SITES 2006 teachers questionnaire.

Conclusion:

The main research findings of the study is investigated, reported and discussed in **chapter six**. SD from the third international comparative study (SITES 2006) was used to determine the pedagogical use of ICT in grade 8 natural science in South African schools. Furthermore SD was used to investigate how the pedagogical use of ICT in grade 8 natural science contributed toward science education in grade 8 natural science classes. The core component of the SITES is to discover the pedagogical approaches of teacher using ICT. The teachers' questionnaire comprises eight parts that are straight in line with the pedagogical use of ICT in the target classes. Conclusions were made from the responses to the teachers' questionnaire. The perceived impact on self and on students were generally positive, seemingly the maximum impacts on teachers themselves were ICT skills and empower teaching.

To clarify what the pedagogical use of ICT is and how it contributes towards grade 8 natural science education, the research findings was offered in three main subdivisions: descriptive data analysis using frequencies, Kaiser-Meyer-Olkin factor analysis and Spearmans' effect sizes to identify correlations between variables.

6.3.1 Descriptive data

The descriptive data was used to establish a better understanding on the first question: *the pedagogical uses of ICT in grade 8 natural science in South African schools*. Descriptive data analysis are used to help address the first research aim, i.e.to determine the pedagogical uses of ICT in grade 8 natural science in South African schools. Descriptive is used to answer the research aims through interpretation of the available data.

6.3.1.1 Proportion of learners that are competent in ICT

Teacher participants indicated the proportion of learners that has competence in ICT. According to the teachers participants the majority of learners are not competent in ICT use in the grade 8 natural science classes (§ 5.5.1.1).

6.3.1.2 Teachers' indication that they use ICT for specific activities in the target classes

ICT can be implemented in a variety of ways in grade 8 natural science teaching activities by teacher. ICT can support teachers in the planning of activities in the teaching and learning situation. A clear majority of teachers reveal that they do not make use of ICT in teaching activities, in grade 8 natural science classes, only a few teachers indicate that they do make use of ICT in their teaching activities in science (§ 5.5.1.2).

6.3.1.3 Science teachers who indicated that they use ICT to carry out assessments

Assessment in OBE is seen as vital towards the achievement of the expected outcomes of the grade 8 natural science curriculum. A majority of teachers, between 76.85% and 88.54%, indicate they do not apply ICT to assess the grade 8 natural science learners in the classes (§ 5.5.1.3).

6.3.1.4 Science Teachers who indicated that the learners use ICT to perform activities

The pedagogical use of ICT can provide learners with valuable ways to perform activities. ICT tools can be applied in many ways to enrich teaching and learning processes. A vast majority of learners do not use any available ICT tools to perform activities in the grade 8 natural science classrooms (§ 5.5.1.4).

6.3.1.5 Science teachers indicated that they incorporate ICT in their classes

In the fast changing technological age teachers should be prepared to empower learners with the advantages of ICT. The response of teachers to the question that mention the incorporation of ICT learning resources and tools show that the majority of the teachers never incorporate ICT in the grade 8 natural science classes (§ 5.5.1.5)..

6.3.1.6 General use of ICT and pedagogical use

Learners are part of a changing world with changing demands on the way they are educated. The general use of ICT in the context of everyday activities helps people to organise their lives according to their own pace. The user can apply ICT in activities like ATM use, social networking for swift communication needs; mxit, sms, Twitter or Facebook to keep in touch with friends and family. Teachers point out that they rarely make use of ICT in their everyday life (§ 5.5.1.6).

Teachers need profound knowledge of ICT tools if they want applications of ICT to enhance pedagogical practices. The findings (§ 5.5.1.6) indicate that ICT for pedagogical purposes are inadequately utilised. Teachers' use of ICT in grade 8 natural science curriculum is poorly implemented.

6.3.2 Factor analysis and correlations

The variables in SITES 2006 were categorical in nature. The impact and contribution of ICT towards the pedagogical use in science education was identified by the results of correlations between the different variables. The majority of the correlations compare well with the literature review. Factor analysis and correlations identified variables of the impact and contribution of ICT as pertained in the SITES 2006 teacher questionnaire. The aim is to answer the second research question: *How does the pedagogical use of ICT in grade 8 natural science contribute toward education in South African schools?* The findings of the factor analysis and correlation study are incorporated into a proposed framework for the pedagogical use of ICT in grade 8 natural science (§ 6.4).

6.4 PROPOSED FRAMEWORK FOR PEDAGOGICAL USES OF ICT IN GRADE 8 NATURAL SCIENCE

The proposed framework for pedagogical uses of ICT in grade 8 natural science classes (Figure 6.1) is based on the findings of the correlation study (§ 5.7) that was conducted between the different variables or constructs. As explained in § 5.7, for the purpose of this investigation, an effect size $0.5 \leq R \leq 0.7$ is considered a medium effect which tends towards a practically significant correlation, an effect size $R \geq 0.8$ is considered a large effect which indicates a practically significant correlation and an effect size $R \leq 0.4$ is considered a small effect which is only statistically significant. However, according to Cohen (1988), a correlation of 0.5 can already be considered a large effect size which indicates a practically significant correlation. Cohen's criterion of large effect size interpretation is followed by most researchers.

Grade 8 natural science teachers who use ICT in a pedagogical way are more positive towards the use of ICT as part of the curriculum than the teachers who do not make use of ICT in the target classes. The pedagogical uses of ICT in grade 8 natural science indicate a positive impact on teachers. The teacher who experienced a positive impact through the pedagogical use of ICT on their teaching methods in the grade 8 natural science classes mostly display a more positive attitude towards the use of ICT in the curriculum. As illustrated by Figure 6.1, the more confidently teachers use ICT for pedagogical practices, the more ICT positively impact on teachers ($R=0.52$). A significant correlation is indicated between the positive impact that ICT have on a teacher and the self directive learning skills of the grade 8 learners ($R=0.5$). The positive impact on the teacher indicates that teachers who are positive towards the natural science curriculum and ICT will promote self directive learning skills amongst their learners. Self directive learning skills are a combination of subject matter knowledge (curriculum) and ICT skills, for which a practically significant correlation ($R=0.84$) is calculated for this studies data. Strong correlations were found between self directive learning skills and subject matter knowledge ($R=0.84$) as well as ICT skills ($R=0.72$). The exposure to sustainable self directive learning will positively influence the learners' problem solving skills ($R=0.95$). Learners who pertains self directive learning skills in a process to exploit their subject knowledge require problem

solving skills to explain abstract and concrete concept in natural science in a simulated environment supported by ICT tools. In turn the more problem solving skills learners acquire, the higher their ICT skills ($R=0.66$) and their subject matter knowledge ($R=0.77$) will become. The teachers indirectly encourage the grade 8 natural science learners to utilize ICT skills in the natural science subject field.

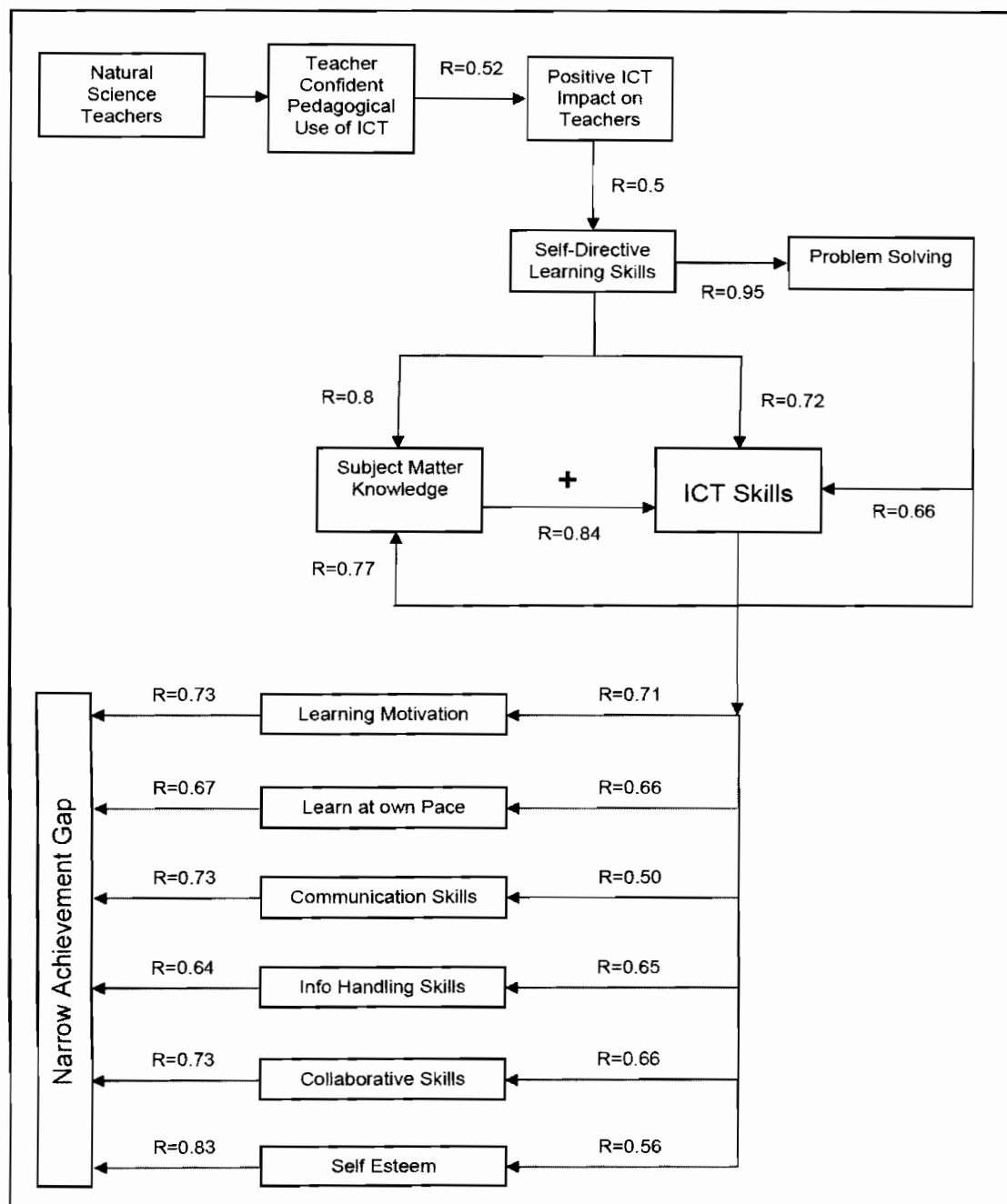


Figure 6.1 Framework for the pedagogical use of ICT in grade 8 natural science

As highlighted in chapter one, there exist a large achievement gap between learners and schools in the South African science educational context. Some learners and schools perform excellently in sci-

ence education, while the majority of learners and schools perform way below average. One of the greatest challenges in the South African science education is to narrow the large achievement gap between learners and schools. In this study a significant correlation ($R=0.632$) was found between ICT skills and the narrowing of the achievement gap amongst learners. ICT skills improve grade 8 natural science learners; motivation ($R=0.71$), pace of learning ($R=0.66$), communication skills ($R=0.5$), the way of information handling ($R=0.65$), application of collaborative learning skills ($R=0.66$) and self esteem ($R=0.56$). In turn strong correlations exist between narrowing the achievement gap and learning motivation ($R=0.73$), learn at own pace ($R=0.67$), communication skills ($R=0.73$), info handling skills ($R=0.64$), collaborative skills ($R=0.73$) and self-esteem ($R=0.83$). This shows that by promoting certain skills (learning motivation, learn at own pace, communication skills, info handling skills, collaborative skills and self-esteem) supported by ICTs and facilitated through ICT skills, will indirectly narrow the achievement gap that haunts the South African education system.

ICTs generally used in science education classes include: word processors instead of hand written text, CD Rom and Internet as information source, IWBs, video conferencing, virtual learning environments, graphics packages, spreadsheets and databases and touch screen technologies, to name but a few (§ 2.3). Findings from this SD study indicate that if the mentioned ICTs are used purposefully to expand and encourage specific abilities and skills (i.e. learning motivation, learn at own pace, communication skills, info handling skills, collaborative skills and self-esteem) the achievement gap might be narrowed; favouring the learners performance in science education (e.g. grade 8 natural science).

6.5 EMINENT CONCLUSION OF THE STUDY

This study described the pedagogical uses of ICT in grade 8 natural science classes in South African schools. The literature review as well as the findings from the SDA indicates that the teachers and the learners' pedagogical uses of ICT in grade 8 natural science classes are below standard in comparison to the rest of the world as indicated by SITES 2006. The current study has immediate implications for pedagogical uses of ICT in grade 8 natural science classes. Pedagogical uses of ICT in the natural science classes can contribute towards the science education in South African schools by narrowing the achievement gap (§ 6.4) which may be associated with the poor pass rates or the grade 12 science learners.

As conferred in § 6.4 it is comprehensible that by the development of specific abilities and skills with the support of ICT skills (learning motivation, learn at own pace, communication skills, info handling skills, collaborative skills and self-esteem) indirectly narrow the achievement gap between learners, schools and the science subject matter. Although this study only focuses on grade 8 natural science, the skills and abilities that narrow the achievement gap by the use of ICT skills can possible apply for all school science curricula.

This chapter presented the conclusions and recommendations based on the findings in chapter five. It provided answers to the two research questions posed in the first chapter. The result of the analysis of the first question indicated that the pedagogical use of ICT in grade 8 science education is poor. Furthermore it is clear that the pedagogical uses of ICT can contribute toward science education in South African schools and that immediate steps can be followed to narrow the achievement gap that exist between learners and school that perform excellently and the majority of learners and schools with below standard performance in science education.

6.6 LIMITATIONS

It is suggested that the following limitations might contribute towards the learner performance regarding the pedagogical use of ICT in grade 8 natural science learners and are not clearly reflected in this study:

- The absence of the inclusion of the attitude of the teachers, as variable towards the pedagogical use of ICT in grade 8 natural science classrooms can have an effect on the way to narrow the achievement gap of the learners' performance.
- The inclusion of the utilization of ICT between rich and poor as variable to distinguish the influence thereof on factors that can narrow the achievement gap of the natural science learners.

6.7 RECOMMENDATIONS

In regard to the contribution towards science education in South Africa of pedagogical use of ICT in grade 8 natural science, certain aspects require further research:

- ICT uses and the influence of skills development (learning motivation, learn at own pace, communication skills, info handling skills, collaborative skills and self-esteem) as a way to narrow the achievement gap between learners, schools and the expected outcomes presented by the curricula.
- The pedagogical uses of ICT and the implementation of ICT skills can support future curriculum designers and programme evaluators.

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