Chapter 1

Introduction to the study and its context

This case study explores the factors impacting on teachers' use of information and communication technology (ICT) for meaningful learning within the context of a private secondary school. The initial aim of the study was to evaluate how suitable an instructional multimedia software package, which claimed to have been designed for use within the new national curriculum being implemented in South Africa, would be for supporting teachers struggling to implement new curriculum requirements. While evaluating the software package it became evident that teachers using technology were using it for purposes other than teaching, which meant that learners could not benefit from any potential support software could offer. The study was expanded into a case study investigating the factors affecting teachers' use of technology for teaching and learning. A number of factors impacting on teachers' use of ICT emerged. Then the introduction of an innovation promoting the use of digital technology for instruction at the school made it possible to expand the study, firstly by investigating the impact of the innovation on teacher use of technology and, secondly, to examine, with a larger group of teachers, three of the factors which had earlier emerged as influencing teachers' use of ICT, which were addressed during the innovation. These were providing more time to use technology for teaching and learning, the provision of in-service training, and the effect of teachers' levels of innovativeness on their use of ICT. The study reports on the factors influencing teachers' use of ICT at the school, with a specific focus on the factors addressed by the innovation. In spite of being a case study, generalisable insights which could be useful for schools, teachers, curriculum developers and policy makers emerged from the study.

Figure 1 is an outline of the argument that will be presented in this chapter for the reader to better understand the motivation behind the study.

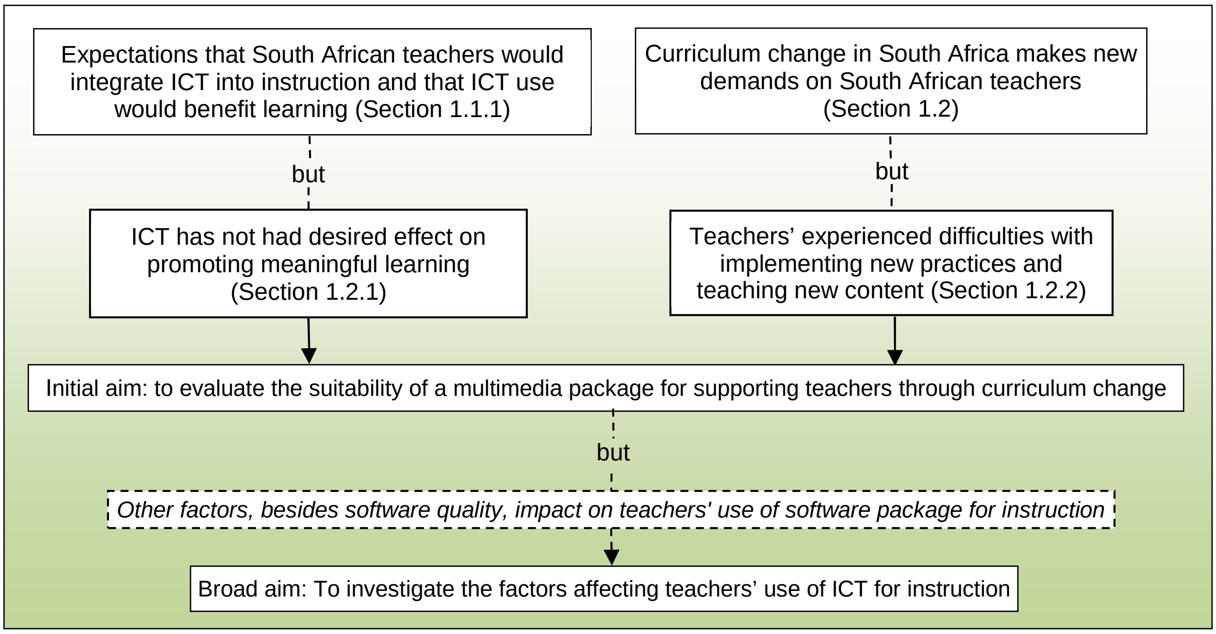


Figure 1. Outline of the argument to be presented in this chapter

This study is set against the expectation of governments worldwide that information and communication technology (ICT) would be integrated into education, and that such integration would impact positively on teaching and learning, and, ultimately, contribute to social and economic development (Kozma, 2008; Wellington, 2005).

1.1 THE INFORMATION AND COMMUNICATION TECHNOLOGY IMPERATIVE IN EDUCATION

1.1.1 The information and communication technology revolution

A review of the literature reveals that since the 1980s there has been a global trend towards incorporating information and communication technology into education. Countries in which integrating computer technology into education has been made national educational policy include the United States (Cuban, Kirkpatrick & Peck, 2001); Australia (Navigator Schools Project, 1995, as cited in Ng & Gunstone, 2003); the United Kingdom (Fulfilling the potential – transforming teaching and learning through ICT in schools, Department for Education and Skills, as cited in Priest, Coe, Evershed & Bush, 2004); Brazil (Brazilian Guidelines and National Education, 1996, as cited in Castro & Alves, 2007); Singapore (Masterplan for ICT in education, 1997, as cited in Hew & Brush, 2006); Syria (Albirini, 2006); New Zealand (New Zealand Ministry of Education, 2002, as cited in Lai & Pratt, 2004); Holland (Ministry of Education, Culture and Science, 1999, as cited in Drent & Meelissen, 2008) and South Africa (Kozma, 2008). The literature also reveals that governments have spent large amounts of money placing technology in schools (see Castro & Alves, 2007; Drent & Meelissen, 2008; Ficklen & Muscara, 2000; Gülbahar, 2007; Inan & Lowther, 2010; Ng & Gunstone, 2003; Russell et al., 2003; Ward & Parr, 2008) and suggests three main reasons why such large investments have been made. Wellington (2005) refers to these reasons as the imperatives driving ICT in education:

- **The pedagogical reason.** Governments believe that the use of ICT in schools will enhance teaching and learning (Albirini, 2006; Chiero, 1997; Drent & Meelissen, 2008; Kozma, 2008; Marcinkiewicz, 1993; Pelgrum, 2001; van Braak, 2001; Wellington, 2005).
- **The vocational reason.** The vocational argument is based on the belief that the use of technology in schools will prepare learners for the workplace in the technological age (Albirini, 2006; Chiero, 1997; Kozma, 2008; Pelgrum, 2001; van Braak, 2001; Wellington, 2005).
- **The societal reason.** According to this argument technology in education will promote social development by better preparing "*students for the information age*" (Albirini, 2006, p. 374). Individuals who are prepared for the information age may be better equipped, for example, to access government services, "*share knowledge*" and "*foster cultural creativity*" (Kozma, 2008, p. 1086).

Of the three imperatives driving ICT in education, the pedagogical argument for using ICT in education is the most fundamental and the most important, as any vocational or societal benefits that can be accrued through using ICT in schools rely on technology being successfully integrated into education.

In keeping with global trends, the South African government had the expectation that integrating ICT into education would enhance the quality of instruction which would, in turn, contribute towards social development and economic growth in the new democracy (Department of Education, 2004; Kozma, 2008). Since the new curriculum was introduced in 1998 there has been an increased focus on integrating ICT into South African schools. In his State of the Nation address during the opening of parliament in February 2001, President Mbeki stated that *"... a critical and pervasive element in economic development in the current age is the optimum utilisation of information and communication technology*" (Gauteng Provincial Government, 2001). In its White Paper on e-Education, subtitled *Transforming learning and teaching through information and communication technologies (ICTs)*, the South African government acknowledged that

> *A global revolution is currently taking place in education and training. It is driven by the changing nature of work, the realities of the information age, new global partnerships and an awareness of the need for equal distribution of educational opportunities.* (Department of Education, 2004, p. 8)

In order for the integration of ICT into education to deliver on the pedagogical, vocational and social improvements that the government expected it to catalyse, the South African government undertook a number of initiatives to supply schools with basic facilities required to use ICT. Some of the major government initiatives (e.g. providing for schools to connect to the Internet at a reduced rate), collaborations with the private sector to place ICT resources in schools in specific provinces (e.g. the *Khanya Project* in the Western Cape) and other collaborative ventures undertaken by the South African government (e.g. *SchoolNet SA*) have been described in Appendix A.

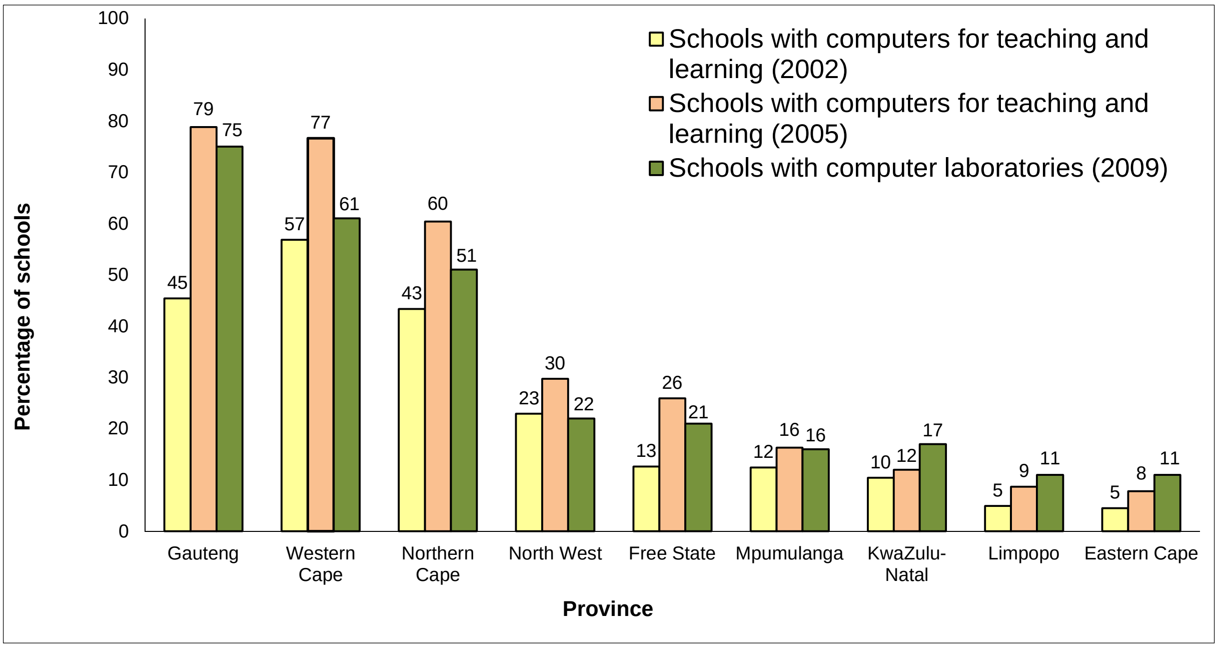


Figure 2. Comparison of the percentage of schools with computers for teaching and learning in the nine provinces in 2002 and 2005 (National Department of Education, 2004; *South African Draft ICT in Education Implementation Plan*, 2006, cited by Isaacs, 2007)**, and schools with computer laboratories in 2009** (Department of Education, 2011)

Although the initiatives undertaken by the government have had mixed success, one area that has improved is the number of computers available in schools. Figure 2 compares the numbers of schools using computers for teaching and learning in 2002 and 2005 (National Department of Education, 2004; *South African Draft ICT in Education Implementation Plan*, 2006, as cited in Isaacs, 2007). Figure 2 also shows more recent figures from 2009, as reported in the May 2011 report supplied by the National Education Infrastructure Management System (a database of all the government schools in the country, operational since 2007). The decreases in some provinces from the 2005 figures to the 2009 figures must be viewed in the light of new data collection methods being used since 2007. The data used to compile the 2009 figures shown in Figure 2 may not be up to date for all provinces, as the 2011 report issued by National Education Infrastructure Management System states that

> *This report is based on the **infrastructure provided to each site** from 2009 to March 2011 especially for KZN province as their assessment forms have been received and captured. Other Provinces we only updated schools that are merged and closed.* (Department of Education, 2011)

Other factors to take into account when comparing the 2005 and 2009 data are, firstly, that different methods might have been used when collecting the earlier figures and the 2009 figures. Secondly, the 2002 and 2005 figures are based on 'schools with computers for teaching and learning', while the 2009 figures focused on 'schools with computer laboratories', so it is not clear exactly what was counted in each case. In addition, the 2009 figures only took into account schools with fully stocked computer laboratories, although the National Education Infrastructure Management System report of May 2011 does not clarify what qualifies as a fully stocked computer laboratory. Finally, the total number of schools decreased from 25,582 in 2005 to 24,795, which, the report explains, is due to schools being merged or closed, which could have contributed to the decreases for the some provinces.

Overall, the number of schools with computers for teaching and learning has increased in all nine provinces since 2002. However, the gains in the numbers of schools with computers have not been equally distributed across all provinces. The provinces where collaborative initiatives were implemented (Western Cape and Gauteng) have significantly higher percentages of schools where computers are available for teaching and learning (see Figure 2). In six of the nine provinces, the Northwest Province, Free State, Mpumalanga, KwaZulu Natal, Limpopo and Eastern Cape, fewer than half of the schools have computers available for teaching and learning.

1.1.2 The uses of ICT in education

Historically, the role of ICT in education has evolved since computers were first introduced into schools in the late 1970s. As a young secondary school pupil at that time, I recall using drill-and-practice software on Apple computers to learn English vocabulary. This memory is indicative of the way computers were mainly used at that stage for instructional purposes – to "*drill, tutor, and test students"* (Kulik & Kulik, 1991, p. 75). Since the late 1980s computers have been regarded more as a tool to be used in the classroom to support teaching and learning (Lai, 2008). The advent of the Internet, together with the development of the World-Wide Web in the 1990s, meant that ICT could be used for accessing information, and for communication and networking (Lai, 2008). The evolving role of computers in instruction is the result of rapid advances in the range and capabilities of technological devices available for use in teaching over the last 10-15 years. These new technologies include data projectors, interactive whiteboards and mobile devices (e.g. laptops, cell phones and iPads), all of which have found their way into classrooms (Koehler et al., 2011; Martinovic & Zuochen, 2012; McGrath, Karabas, & Willis, 2011). Furthermore, Sánchez, Salinas, Contreras, and Meyer (2011, p. 543) point out the existence of a "*new generation of learners*". Numerous authors explain that recent generations of learners (post 1980) have different cognitive capabilities and sets of skills which allow them to learn better using technology than without technology (Prensky, 2001; Tapscott, 1998, 1999).

The wide range of technological devices, coupled with "*technologically savvy*" (Looi, Lim & Chen, 2008, p. 489) generations of learners, has led to the widespread belief that technology holds much potential to benefit learning.

Despite the plethora of technological devices that can be incorporated into instruction, it is through software applications that these devices can be turned into instruments of learning (Martinovic & Zuochen, 2012; Newton & Rogers, 2003; Rogers & Finlayson, 2003). Rogers (2003, p. 259) describes hardware as "*the tool that embodies the technology in the form of a material or physical object*" and software as "*the information base for the tool*". Table 1 (starting on page 6) shows some of the software applications that can be used in instruction. The applications described in Table 1 range from generic software such as *Microsoft Word* and *Microsoft Excel*, to web-based applications like simulations and virtual learning environments, which allow users to interact with the content, communicate in real time and collaborate online. The range of applications in Table 1 provides some indication of the number of ways ICT may be used in educational settings, with different applications offering different potential benefits to teaching and learning.

Table 1. Some software applications used in education, and their potential benefits

Computer application	Intrinsic properties	Potential benefits
Publishing tools (word-processors, desk-top publishing software, web-authoring packages)	Allow learners "*to communicate their ideas to others*" using technology (Newton & Rogers, 2003, p. 117).	Less threatening than pen-and-paper for weaker writers (Newton & Rogers, 2003).
	Allow editing of work using spelling and grammar checking tools (Bialobrzeska & Cohen, 2005; Newton & Rogers, 2003).	Contributes to improved grammar and spelling in the immediate document, but over a longer time period can contribute to improved spelling and grammar on the part of learners (Newton & Rogers, 2003).
	Allow graphics and images to be included (Bialobrzeska & Cohen, 2005; Newton & Rogers, 2003).	The use of different formats may aid some learners with assimilation of information (Newton & Rogers, 2003). This could apply to learners who prefer a visual style of learning.
	Provide templates (Newton & Rogers, 2003).	Saves time by providing a ready framework for text, e.g. letter formats (Newton & Rogers, 2003).
	Allow use of hyperlinks (Newton & Rogers, 2003).	Reduces learner dependence on linear format and encourages exploration of information via electronic links to additional content (Newton & Rogers, 2003).
Spreadsheets e.g. *Microsoft Excel*	Allow large quantities of data to be processed.	Saves time (Frost, 1997; Rodrigues, 1997; Bialobrzeska & Cohen, 2005).
	Provide "*accessible and meaningful presentations*" of analysed data (e.g. as graphs or tables) (Rodrigues, 1997, p. 35).	Presentation of data as graphs or tables allows learners to focus on analysing the data by looking for patterns rather than on the drawing of the tables or graphs (Barton, 1997; Frost, 1997).
	Allow for rapid calculations.	Saves time and results in fewer calculation errors (Newton & Rogers, 2003).
	Allow for manipulation of data, e.g. hierarchical sorting.	Makes it easier to identify patterns in the data (Bialobrzeska & Cohen, 2005; Frost, 1997; Newton & Rogers, 2003).
Presentation software, e.g. *PowerPoint*	Allows information to be projected "*directly from a computer onto the screen*" (Bartsch & Cobern, 2003, p. 77).	Can be used to deliver content in an attractive manner (Craig & Amernic, 2006). Allows the use of both text and graphics (Bialobrzeska & Cohen, 2005). Limited amount of space on each slide (e.g. when using *PowerPoint*) may help learners identify the main points of the information they want to present (Newton & Rogers, 2003; Tebbutt, 1997). Learners who respond strongly to visual stimuli may be motivated by seeing images on a screen (Lewis, 2003).
Graphing software, e.g. *Autograph*	Allows for automatic plotting of data and immediate display of graph (Frost, 1997).	Computer-aided graphing saves time and reduces the possibility of learners producing incorrect graphs due to incorrect scale selection and plotting (Barton, 1997; Newton & Rogers, 2003). Learners can focus on interpreting data from graphs rather than collecting and recording data and plotting graphs (Barton, 1997; Frost, 1997; Newton & Rogers, 2003; Rogers, 1995).
	Allows for a variety of visual formats (Rogers, 1995).	Different graph formats allow learners to experiment with the best format for representing data (Newton & Rogers, 2003; Rogers, 1995). For example, learners can choose between line and column graphs and experiment with changing the scales of the graph to see the effect this has on the shape of the graph.
	Provides tools for analysing graphs (Rogers, 1995).	Relationships between variables can be explored, e.g. changing scales (Newton & Rogers, 2003; Rogers, 1995).
Modelling software e.g. *STELLA; RasMol*	Allows for modelling of relationships through the manipulation of variables (Fisher, 1997; Rogers & Finlayson, 2003; Sander, Schecker & Niedderer, 2002). For example, the dynamics of predator-prey relationships could be modelled. Some types (e.g. *RasMol*) allow for modelling of biological molecules (Millar, 1996).	Learners can develop and evaluate models and predict and test theories (Harris, 1994; Rodrigues, 1997). Modelling of biological molecules allows learners to explore the three-dimensional structure of proteins, etc. by rotating and zooming in on the model (Millar, 1996). Promotes active engagement of learners by allowing them to be both mentally and physically involved in their learning (through actively controlling the variables or manipulating models) (Fisher, 1997; Lewis, 2003; Rogers & Finlayson, 2003; Sander et al., 2002).
Multimedia CD-ROMS	Allow for multiple forms of presentation of information involving combinations of video, audio, animation and text (Rodrigues, 1997). Certain designs may allow learners to interact with the software.	According to dual coding theory (Paivio, 1986) presenting information in both text and pictorial formats, where correctly used, is believed to enhance learning compared to a single format (either text or pictures). Dynamic images are believed to offer an advantage over static images when showing processes that change over time (Tversky, Bauer-Morrison, & Betrancourt, 2002) by providing external models for internal representations (Höffler & Leutner, 2007; Lowe, 2003). Where interactivity is present, it may foster deep learning by engaging learners in the learning process (Evans & Gibbons, 2007). The use of hyperlinks (electronic links to additional information) allows learners to choose their own path (Moos, 2010).
Computer-aided practical work (data logging – United Kingdom; microcomputer-based labs – United States)	Allows the automatic recording of experimental readings (data logging) using sensors (Denby, 2003). The recorded data is displayed immediately on-screen, usually in table or graphic form using graphing software (Frost, 1997).	Allows laboratory experiments to be conducted that might not otherwise have been possible because of time or other constraints (Denby, 2003). The immediate display of data on a graph allows learners to view the data qualitatively before quantitatively analysing data, which may facilitate the recognition of patterns and trends in the data (Newton & Rogers, 2003; Rogers, 1995).

Computer application	Intrinsic properties	Potential benefits
Simulations (including one-player simulation games)	Simulates concepts using virtual images (Jimoyiannis & Komis, 2001).	Provides opportunities for conducting **virtual** experiments (Rogers & Finlayson, 2003; Lai, 2008). Allows experiments to be conducted that might not have been possible for safety reasons, expense or time constraints (Rodrigues, 1997; Lai, 2008).
	"*Emulate physical systems and processes*" (Rodrigues, 1997), e.g. the *PhET sims* (open source software) or *STELLA* offer a number of models of physical systems and processes which learners can manipulate.	Where the software has been designed so that learners are able to change the parameters of a system this creates the possibility of learners interacting with the content as well as allowing for self-paced learning (Yaman, Nerdel, & Bayrhuber, 2008). Learners may be motivated to learn by actively controlling the simulation (Rutten, van Joolingen & van der Veen, 2012). In the case of simulations which model a system or process or real world phenomenon which "*changes over time depending on internal functions and as a consequence of the user's decisions*" (Leutner, 2002, p. 686) learners could be required to solve problems, for example, through formulating hypotheses and making predictions, thereby contributing to meaningful learning (de Jong, 2006).
Internet [including 'learning objects' – "*digital resource(s) that can be reused to support learning*", (Wiley, 2000, p. 7) and which range from smaller digital content, like digital images, video or audio segments, to larger digital resources that constitute a complete course of instruction].	Anderson (2007, p. 5) describes the Internet from the perspective of its inventor, Sir Tim Berners-Lee, as "a *collaborative workspace where everything was linked to everything* ". The Internet allows access to information, communication and collaborative projects (Anderson, 2007).	The Internet allows access to a wide range of information sources (Lai, 2008; Martinblas & Serrano-Fernandez, 2009), including real-time data like weather information, and original and historical documents (Windschitl, 2000). Kuiper, Volman, and Terwel (2005) maintain that the nonlinear and associative hypertext nature of the World-Wide Web has the potential to promote critical thinking through learners acquiring information literacy skills when searching for and evaluating the appropriateness of information. According to Jackson and Bazley (1997) Internet use promotes the sharing of ideas via rapid communication using different forms of communication such as e-mail, newsgroups and web-based forums. The Internet also promotes the sharing and distribution of knowledge (Jackson & Bazley, 1997). The "*interactive and communicative capabilities of IC*T" have the potential to foster a deeper understanding of concepts through the sharing of ideas in online learning communities (Lai, 2008, p. 225).
Educational video games/ online gaming	Games in which players play with or against each other over the Internet e.g. multiplayer online games in which learners are playing on their own computers and interact virtually through the game with their teacher (Echeverría et al., 2011).	Educational video games which "*encompass educational objectives and subject matter*" (Papastergiou, 2009, p. 1) have the potential to be highly interactive and motivational (Amory, Naicker, Vincent, & Adams, 1999). In addition, educational video games could require learners to use and develop their problem-solving skills, and allow self-paced learning (Bekebrede, Warmelink, & Mayer, 2011; Echeverría et al., 2011; Liu & Chu, 2010).
E-learning platforms [learning management system (LMS)/ course management system (CMS) – United States] [virtual learning environments (VLE)/ managed learning environment (MLE) – United Kingdom]. Examples of LMS platforms are *Blackboard* (commercial) and *Moodle* (open source software).	Web-based software systems which allow many different kinds of objects, e.g. text documents, videos and scanned images, to be uploaded for storage and/or for other users to access (Martinblas & Serrano-Fernandez, 2009; Sánchez & Hueros, 2010).	Provide a repository of information for teachers and learners (Martinblas & Serrano-Fernandez, 2009). Learners can access information posted by teachers outside of the classroom and submit detailed work to teachers via the learning platform. Hsieh and Cho (2011) claim web-based systems support learner interaction with teachers outside of the classroom. Can be used to deliver complete online courses (Siemens & Tittenberger, 2009).
	Typically include online communication tools such as wikis, chats and forums (Sánchez & Hueros, 2010; Siemens & Tittenberger, 2009); tracking tools for teachers; tools for designing and assessing multiple-choice quizzes and tools allowing learners to submit work for assessment by uploading it to the e-learning platform (Martinblas & Serrano-Fernandez, 2009).	Allow real-time communication between teachers and learners (Martinblas & Serrano-Fernandez, 2009; Siemens & Tittenberger, 2009). Teachers can see when learners submitted work and may be able to mark certain types of assessments online (e.g. multiple-choice quizzes).
Web 2.0 technologies/ social media/ social software [e.g. wikis (webpages that anybody can edit), blogging (web-logging), *Twitter* (microblogging) and social networks like *Facebook* and *LinkedIn*].	Newer web applications or services where different forms of information can be shared (Bennett, Bishop, Dalgarno, Waycott, & Kennedy, 2012). According to Bower, Hedberg, and Kuswara (2010, p. 184) the distinguishing features of these technologies are "*the modalities of representation (text, image, audio, video) that they incorporate and the degree of synchronicity they enable*".	Allows online collaboration between individuals. The type of collaboration differs across different applications, but generally includes the distribution of material that can be reproduced, transformed and re-used across many contexts. For example, *Twitter* permits the posting or 'tweeting' of text strings less than 140 characters in length (hence *micro*blogging) and images (Ebner, Lienhardt, Rohs, & Meyer, 2010; Siemens & Tittenberger, 2009). These posts or 'tweets' can be viewed by people who 'follow' the person who posted the original 'tweet' (Siemens & Tittenberger, 2009). The original tweet may be replied to, commented on or 'retweeted' by any of the 'followers', which leads to a rapid and potentially widespread dissemination of information. One of the main features of social media is "*openness of content, denunciation of copyright, distributed ownership*" (Bennett et al., 2012, p. 526). Examples of how social media could be used in education include sharing of resources; distributing work to or amongst learners or receiving feedback from learners (*Twitter*) and forming study groups (*Facebook*) (Siemens & Tittenberger, 2009). Lai (2008, p. 226) believes that the value of social software lies in its ability to allow computer-supported collaborative learning where learners "*can construct group knowledge exceeding the knowledge of individual group members*".

Teachers and learners[1], because of their different roles in educational situations, may use software applications, such as those described in Table 1, for different purposes. I have used the teacher/ learner distinction as the basis for classifying, in Table 2, the different ways ICT can be used in education, based on a classification system of ICT usage in education developed by Ward and Parr (2010), to show the shift in emphasis from teacher use to learner use, and the move from basic to more meaningful computer usage.

Table 2. Classification of ICT usage in education, based on Ward and Parr (2010)

Nature of use		Type of use
Teacher use of ICT	administrative tasks	For administrative purposes (i.e. processing learner grades; reports; attendance; database information etc.).
		Communicating with parents for administrative purposes.
		Communicating with colleagues/ other professionals for administrative purposes e.g. setting test dates or discussing syllabus requirements.
		Communicating with learners regarding administrative matters (e.g. dealing with queries about deadlines for tasks or submission of work or sending work to learners who have missed lessons).
	preparation of lesson material	Using computer applications such as word processing and spreadsheets to prepare instructional materials (i.e. handouts, tests, etc.) for school.
		Using the Internet to search for information for school preparation e.g. accessing research and best practice for teaching; accessing model lesson plans or exam resources.
		Communicating with colleagues/ other professionals to improve the quality of lesson material (i.e. sharing information or consulting about the accuracy of content).
		Creating basic multimedia presentations for use in the classroom consisting of text and pictures.
		Creating complex multimedia presentations for use in the classroom (i.e. includes elements like music and/ or animations and/ or hyperlinks to external material).
	presentation of lesson material	Presenting multimedia presentations for use in the classroom (ones created by the teacher or sourced elsewhere, e.g. on the Internet).
		Posting learner work, resources, or ideas and opinions on the Internet e.g. using *Twitter* or *Facebook* or a personal website.
Teacher requiring learners to use computers for tasks of different cognitive levels	promoting knowledge	Using computers for practice drills.
		Using subject-specific software to deliver content (electronic page-turner).
		Using computers for research/ assignments which require accessing reference material on CD ROMs or Internet.
		Using games for rote-learning (e.g. learning vocabulary).
		Using computers for corresponding with experts, authors, learners from other schools via the e-mail or Internet for learning purposes.
	promoting understanding	Using subject-specific software that develops understanding through the use of well-designed interactive tasks.
	requiring higher-order skills	Using game-based learning with educational objectives that require learners to find solutions to problems.
		Using simulations or exploratory environments requiring learners to solve problems by applying their knowledge and understanding to evaluate a problem and formulate a solution.

The classification system in Table 2 shows a move away from teacher use of ICT at the top of the table towards greater learner use at the bottom of the table. Teacher use of ICT centres around carrying out administrative tasks, and preparing and presenting material for use in the classroom. For example, teachers may use ICT to find resources for lessons or preparing worksheets and tests. The types of tasks learners can be assigned on computers range from those which promote learners

1 The term 'learner' will be used in this study (as has been done in other studies, e.g. Schweisfurth, 2011). This term will be used to include individuals at primary- and secondary-school level (pupils) and individuals studying at tertiary institutions (students).

acquiring knowledge (e.g. using drill-and-practice software) to tasks which promote learner understanding of concepts (e.g. using appropriately designed multimedia software), to more cognitively-demanding tasks (e.g. tasks which require learners to apply their knowledge or to solve problems using simulation or gaming software). The classification of ICT usage in education presented in Table 2 was used in this study to guide the development of instruments and the analysis of data, and is used when reporting on the findings.

The many different ways ICT can be used in education, by both learners and teachers, have been discussed in this section. However, as suggested by some researchers (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Karagiorgi & Symeou, 2005; Ward & Parr, 2010), the real value of integrating ICT into education lies in its potential to promote meaningful learning when learners use software which allows them to construct their own knowledge.

1.1.3 The potential of ICT use to promote meaningful learning

The emphasis placed by the South African government on providing ICT infrastructure so that technology could be used to improve the quality of teaching and learning provided part of the motivation for this study. For ICT to improve learning, technology would have to be used in ways that contribute to meaningful learning.

The concept of 'meaningful learning' is underpinned by constructivist principles (Andrew, 2007; Dexter, Anderson, & Becker, 1999; Ertmer & Ottenbreit-Leftwich, 2010; Huang, Chiu, Liu, & Chen, 2011; Jonassen, Peck, & Wilson, 1999; Jonassen, 2009; Nie & Lau, 2010; Shuell, 1988). The implications of constructivist beliefs for education are that learners should be provided with opportunities for engaging with new ideas and constructing their own knowledge *"in order to experience deep and meaningful learning*" (Schweisfurth, 2011, p. 425). After reviewing the literature for definitions of what researchers understand by learners 'engaging' with new ideas, Lim, Nonis, and Hedberg (2006, p. 213) concluded that it entails "*some kind of mindfulness, intrinsic motivation, cognitive effort, and attention"*.

A number of the potential benefits of ICT presented in Table 1 (starting on page 6) relate to ICT being used in ways which improve the efficiency with which teachers and learners are able to carry out tasks (e.g. producing professional-looking documents and saving time). However, these uses are unlikely to impact directly on the quality of learning. For ICT to improve learning, it must be used in ways which promote 'meaningful learning' (see uses towards bottom of Table 2, page 8), that is, in ways which promote learner understanding and assist the development of higher-order cognitive skills. The potential for ICT to promote meaningful learning appears to be greatest when

- learners, and not teachers, are using the technology (Ertmer et al., 2012; Inan, Lowther, Ross, & Strahl, 2010).
- learners are using ICT for tasks which help them to understand concepts [e.g. using multimedia software designed according to "*constructivist learning principles*" (Karagiorgi & Symeou, 2005, p. 23)] and for cognitively-demanding tasks (e.g. using simulations).

- learners are using ICT to construct knowledge in ways not possible without using technology (Kong, 2011).

Some researchers believe that ICT is only fully integrated into education when teachers are using it to promote meaningful learning, that is, when teachers are using technology to support more constructivist pedagogical approaches to instruction (see Drent & Meelissen, 2008; Ertmer et al., 2012; Kozma, 2003; Peeraer & van Petegem, 2012). In an attempt to measure to what extent teachers have integrated ICT into their teaching, various authors have classified typical ways of using ICT according to the pedagogical approach they promote. For example, Conole, Dyke, Oliver, and Seale (2004) developed a model based on theoretical approaches which could be used to map specific software tools to a more didactic or more constructivist approach, and Dede (2008) described the theoretical perspectives certain types of ICT are based on. Based on a construct map developed by Peeraer and van Petegem (2012) of how teachers' use of software applications would change as they integrate ICT into instruction, and the classification of ICT usage proposed in Table 2 (based on the system used by Ward & Parr, 2010), I suggest a continuum relating teachers' use of ICT for instruction to their underlying beliefs about how learning takes place. The continuum is shown in Figure 3 below.

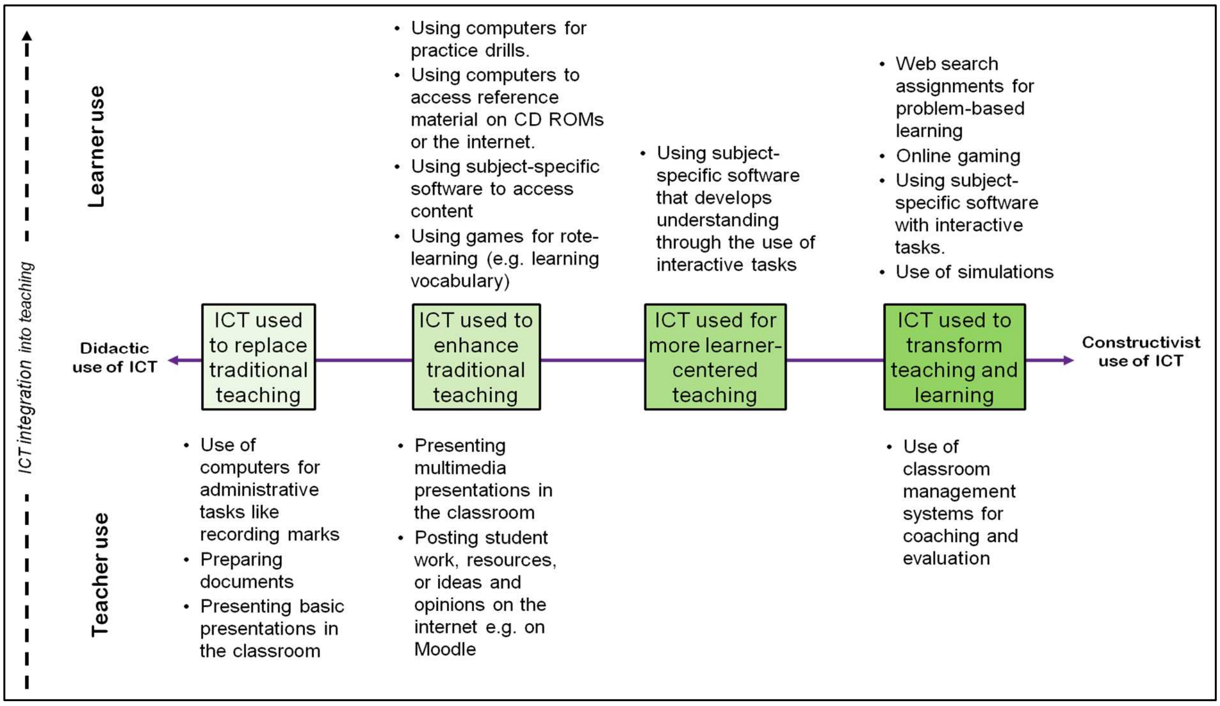


Figure 3. Continuum showing how teachers' technology usage changes as ICT is integrated

The continuum depicted in Figure 3 shows how teachers' ICT usage changes as they integrate ICT into instruction. At the extreme left-hand side of the continuum, teachers use technology to deliver content. At this early stage of ICT use, teachers typically present content (e.g. videos) from the Internet (see 'learning objects' in Table 1, starting on page 6) or use presentation software like *PowerPoint* to "*support teacher-led presentations*" (Jacobson et al., 2010, p. 1704). The potential of *PowerPoint* presentations to impact on learning is believed to be related to the level of complexity of the presentation (Bartsch & Cobern, 2003) and its pedagogical purpose. Basic presentations *"having only text on a colored screen",* are less likely to promote learner understanding than complex presentations which effectively combine "*tables, pictures, graphs, sound effects, visual effects, video* *clips, etc"* (Bartsch & Cobern, 2003, p. 78). With reference to Figure 3, teacher use of more complex presentations is regarded as a higher level of ICT integration than their use of basic presentations. Despite *PowerPoint* presentations being regarded as representing lower levels of ICT integration (Craig & Amernic, 2006; Dede, 2008), they can be used effectively to promote understanding. In the sciences, *PowerPoint* presentations can be used to enhance learners' grasp of science concepts through visualisations of three-dimensional structures, animations, and the use of computer-aided practical work (Wellington, 2005). In subjects like biology, chemistry and physics, which rely heavily on observation, access to appropriate visual materials is critically important. Visualising structures and phenomena allows learners to see things which might not otherwise be seen, to better comprehend three-dimensional structures (Osodo, Amory, Graham-Jolly, & Indoshi, 2010) and to better understand processes shown as animations (Wellington, 1999).

A shift towards the more constructivist side of the continuum shown in Figure 3 (on the previous page) requires teachers to make two changes. Firstly, the teacher's role must change from being a transmitter of knowledge to being a facilitator who helps learners construct their own knowledge (Dede, 2008; Dexter et al., 1999; Tynjala, 1999). Secondly, teachers should choose software applications that promote meaningful learning through providing opportunities for adapting content and tasks to individual learners' needs and abilities and offering meaningful feedback (Mooij & Smeets, 2001). As discussed above, in this study the real benefit of technology for education is believed to lie in its ability to promote meaningful learning. The extent to which software applications provide opportunities for meaningful learning is influenced by the degree of interactivity offered by the application. At its lowest level technical interactivity involves clicking on menus and objects, typical of generic software and drill-and-practice software – a level at which Sims (1997, p. 158) believes the "*interaction may not be adequate or relevant to facilitate the acquisition of knowledge or the development of new skills and understanding*". In Figure 3, use of software which delivers content or practice drills and which offers limited interactivity is regarded as a low level of ICT integration. At its highest level technical interactivity involves learners interacting with a software application and receiving feedback that leads them to reflect on their choices, thus facilitating their construction of knowledge (Nunes & McPherson, 2007). Simulation applications, educational gaming software and well-designed subject-specific software, which offer high levels of interactivity, represent the highest level of ICT integration (see Figure 3).

The discussion in this section underscores the importance of learners using technology in ways that contribute to meaningful learning, if ICT is to improve education.

1.2 CURRICULUM CHANGE MEANS NEW DEMANDS ON SOUTH AFRICAN TEACHERS

Two developments in South Africa over the last two decades form the background to this study (see Figure 1, page 1). Both developments relate to new expectations being made of South African teachers. The first expectation was that South African teachers would integrate ICT into their teaching. This was based on the potential benefits ICT integration could offer education and the anticipated socio-economic benefits which could accrue from such integration (see Section 1.1.1). The second, which is more of a requirement than an expectation, was that teachers were expected to implement a new curriculum.

A new school curriculum announced in 1996 (at one stage known as *Curriculum 2005*[2]) required South African teachers to implement many new teaching practices (Chisholm, 2005; Isaacs, 2007). The new curriculum practices were in keeping with educational innovations being introduced worldwide (Mashalaba & Sanders, 2003) but were considered "*bold*" and *"revolutionary"* in South Africa (Chisholm et al., 2000, p. 1). Sanders and Kasalu (2004) identified and validated nine basic classroom practices required by the new curriculum. They also defined the distinguishing features of each practice, that is, aspects of each practice which teachers needed to be aware of to fully understand the meaning of each curriculum requirement (see Appendix B). These nine requirements also characterise the requirements for the latest CAPS-directed curriculum, although different terminology is used for some (e.g. the 'outcomes' are referred to as 'aims' in the CAPS documents). In addition to the new classroom practices required by the new school curriculum (as specified in the NCS documents) (see Appendix B), additional content was also added into various curricula, e.g. introducing the topic 'biodiversity' into the biology curriculum. Another change expected of teachers as part of the new curriculum was that teachers were required to produce their own learning support materials.

1.3 THE PROBLEMS WHICH MOTIVATED THIS RESEARCH

Two main problems motivated this study (see Figure 1, page 1). The first problem is the failure of ICT to impact on learning, despite the widespread belief that using ICT can promote meaningful learning. The second is the difficulties South Africa teachers experienced when implementing the requirements of the new curriculum.

1.3.1 The failure of ICT to fulfil its potential to improve learning

Despite the huge investments made by various governments in providing ICT infrastructure to educational institutions (see Section 1.1.1), the potential for ICT to improve learning has not been fully realised. Any benefits ICT offers for promoting meaningful learning lie in using it in ways consistent with constructivist approaches (see pages 8-10). However, the literature suggests that, globally, despite computers being ubiquitous, many teachers are using the technology to support their existing practices and not in ways which are likely to contribute to meaningful learning.

Teachers need to be **using** technology for any potential benefits to be realised. Where ICT is not being used as extensively or as effectively as expected, "*there may be insufficient use for any impact [on learning] to be perceivable*" (Ward & Parr, 2010, p. 113). Ward and Parr concluded this after a

[2] The name 'Curriculum 2005' was used to refer to the new curriculum from its first implementation in 1998, but fell away in 2006 and was not replaced. From 2006 to 2011 the curriculum in place was often erroneously referred to as the 'NCS', a name which refers to National Curriculum Statement documents which describe the new curriculum, and not the curriculum itself (Sanders, 2006). The NCS documents were, in fact, just a more recent version of the syllabus statements for the new curriculum (Chisholm, 2005). From 2012 a revised set of 'syllabus' documents called the Curriculum Assessment Policy Statements (CAPS) is being phased in to replace the NCS documents. Many of the basic classroom practices espoused in Curriculum 2005 are still relevant to teaching based on the more recent CAPS documents. Since this study took place before the CAPS documents started being introduced, I will refer to the NCS rather than CAPS as the curriculum statements relevant to this study.

recent study investigating the computer use of 199 secondary school teachers in four New Zealand schools, in which they found that "*overall levels of use are low*" (Ward & Parr, 2010, p. 120). Over the years a number of studies have similarly reported low levels of technology use (see Bauer & Kenton, 2005; Becker, 2000; Cuban et al., 2001; Drent & Meelissen, 2008; Karasavvidis, 2009; Ward & Parr, 2010; Ward, Parr, & Robinson, 2004). Ertmer et al. (2012) point out that in the United States, in the 1990s and early 2000s, the problem of teachers not using technology was attributed to a lack of resources, but that improvements in the learner-to-computer ratio have not been accompanied by concomitant increases in teachers' use of technology. Similar findings have been reported in other countries like the Netherlands (Drent & Meelissen, 2008) and Israel (Dori, Tal, & Peled, 2002) where the learner-to-computer ratio has improved without any perceivable benefit to learning. Albirini (2006) points out that the act of placing technology in schools does not suggest that it will be used or that it will be used effectively.

The failure of ICT to fulfil its potential to improve learning may lie in many teachers failing to make the "*appropriate integration of computer tools*" (Keengwe, Onchwari & Wachira, 2008, p. 560).Technology use does not automatically invoke constructivist principles, as instructional software can be used to support both constructive and didactic ways of instruction, depending on the learning theory underlying the design of a particular software package (Niederhauser & Stoddart, 2001). A number of researchers (see Cuban et al., 2001; Judson, 2006; Kang, Choi & Chang, 2007; Niederhauser & Stoddart, 2001) have warned against automatically linking technology integration to constructivism. As Kang et al. point out, ICT use in education may be mistakenly thought of as

> *... a representative metaphor of constructivism where the subject of learning is shifted from the teacher to the student, placing an emphasis upon the autonomous, reflective, and responsible role of the student.* (Kang et al., 2007, p. 403)

A number of early studies reported teachers' failure to use computers in constructivist ways (see Becker, 2000; Cuban et al., 2001; Dori et al., 2002; Niederhauser & Stoddart, 2001). Recent studies suggest that, despite technology being more widely available in many educational institutions in many countries (as suggested by lower learner-to-computer ratios), teachers are still not adopting the constructivist approaches which best make use of the benefits technology offers education. In the New Zealand study investigating the nature and extent of computer use in four schools, Ward and Parr (2010) reported lower levels of learner use of technology for tasks involving higher-order cognitive skills than for tasks promoting the acquisition of knowledge. Similarly, Chen, after investigating the lesson practices of 12 Taiwanese high school teachers, reported that, despite professing to hold constructivist beliefs about teaching, the practices of the 12 teachers "*remained teacher centered and lecture based*" (Chen, 2008, p. 72). Comparing South African and Chilean data on teachers' ICT practices, Blignaut, Hinostroza, Els, and Brun (2010) found that teachers in both countries displayed higher levels of traditional practices compared to more constructivist pedagogical approaches. As evidence for teachers' tendency to maintain their traditional practices when using technology, Craig and Amernic (2006, p. 149) refer to the "*widespread"* use of *PowerPoint* in education. These authors claim that *PowerPoint* has replaced overhead transparencies and chalk-and-talk as the delivery mode of choice. While visualisations using software such as *PowerPoint* may enhance learner motivation, they do not necessarily promote meaningful learning. Craig and Amernic (2006, p. 150), after reviewing the literature, found little evidence *"to show that teaching with PowerPoint leads to significantly better learning and significantly better grades than teaching by more conventional* *methods".* The process of getting teachers to adopt more constructivist approaches which better take advantage of the benefits technology use offers instruction appears to be a complex phenomenon involving "*teachers' motivations, perceptions, and beliefs about learning and technology*" (Keengwe et al., 2008, p. 560). Zhao, Pugh, Sheldon, and Byers (2002, p. 483) referred to the "*complexities and intricacies of how classroom teachers actually incorporate technology into their teaching*". These researchers offered a list of possible explanations why teachers were not using computers in constructivist ways, including the incompatibility between technology and prevailing school culture, the "*inherent unreliability of technology*", teachers' lack of technology training and "*the poor quality of educational software*" (Zhao et al., 2002, p. 484).

Another possible reason why ICT has failed to deliver perceptible benefits to education lies in the motive behind integrating technology into education. A number of researchers (Fisher, 2006; Lai, 2008; Maddux & Johnson, 2006) question whether technological innovations are being adopted because of "*technological determinism*" (Fisher, 2006, p. 296) rather than their potential to improve teaching and learning. 'Technological determinism' refers to technological devices and software being used in education "*simply because they are there*" (Maddux, 2003, p. 5). To illustrate this point, some software applications, e.g. the Internet and *PowerPoint*, were not originally designed for instructional use but have been adapted for use in education. Since these applications were not designed for instructional purposes, their design is not based on current learning theory and their use does not automatically contribute to meaningful learning, even though they can be used in ways that help learners construct their own knowledge. For example, *PowerPoint* was designed for the purposes of presenting content in a lecturing format and is not associated with a constructivist approach to instruction (Dede, 2008).The onus would therefore lie on teachers' propensity and ability to be able to use the technology in constructivist ways for ICT use to contribute to meaningful learning.

The failure of ICT to improve learning is further complicated by the fact that researchers are divided on whether technology positively affects learning (Cox & Marshall, 2007; Cuban et al., 2001; Mama & Hennessy, 2013). Although early studies supported the idea of a positive effect for ICT use on learning (see Fabry & Higgs, 1997; Harrison et al., 2002; Watson, 1993), this research has subsequently been questioned. Mitchell (1997) questioned the basis on which educational researchers were assigning scores to "*variables like an attitude, opinion or even knowledge"* (Mitchell, 1997, p. 49) and then treating these scores as if they represented quantitative data about such variables. According to Mitchell the lack of a sound mathematical basis for generating such 'quantitative' data would render meaningless any statistical analysis conducted on data which has been generated by this method. Mitchell further questioned the use of parametric statistical analysis to analyse data by simply assuming a normal distribution in the population from which the sample has been drawn. The issue of valid statistical analysis has relevance for one of the questionnaires used in this study and is discussed further in Chapter 5.

Other researchers claim that the absence of large-scale longitudinal studies; a failure to consider possible interactions between ICT use and other school-based factors; and a lack of knowledge about whether earlier studies had matched "*learning objectives to instruments/procedures*" have prevented us from fully understanding the impact of ICT on learning (Cox & Marshall, 2007, p. 59-60). These authors attribute our inability to understand whether and how ICT impacts on learning to "*policy and* *methodological problems*” with the research that has been conducted (Cox & Marshall, 2007 p. 59). Cheung and Slavin (2013, p. 92) similarly point out “*serious methodological problems*” with some previous studies investigating the effectiveness of using technology for teaching on levels of achievement in mathematics. These researchers, after reviewing 74 studies conducted since 1980, described educational technology as “*making a modest difference in learning of mathematics*” (Cheung & Slavin, 2013, p. 102).

Another possible problem with the research being conducted in the field of educational technology relates to the failure of the research to impact on teachers. The emphasis in the literature on the ‘innovative’ use of computers for teaching (see e.g. Drent & Meelissen, 2008; Loogma, Kruusvall, & Ümarik, 2012; Molenaar, Boxtel, & Sleegers, 2010; Voogt, 2010) may not be usable or relevant to the broader community of teachers. McKenney (2013) points out that research often focuses on what is possible in the field of educational technology rather than what is possible in practice in classrooms. Some researchers have questioned why, in spite of the volume of research being conducted and published in the field of educational technology, the levels of educational achievement have not improved, and have called for more meaningful research (Reeves, McKenney, & Herrington, 2011).

Technology’s perceived lack of impact on learning does not appear to lie in its lack of potential to benefit education, but rather centres on how teachers choose to use ICT in the classroom. As far back as 1983 Clark stated that “*media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries cause changes in our nutrition*” (Clark, 1983, p. 445). Continuing this analogy he stated that “*only the content of the vehicle can influence achievement*” (Clark, 1983, p. 445). This means that unless teachers use technology in ways that take advantage of the potential benefits ICT has to offer education, technology is unlikely to improve learning. The range of tasks which are believed to promote meaningful learning include using software applications which foster learner understanding (e.g. using subject-specific software which develops understanding through the use of well-designed interactive tasks) and which require learners to use higher order cognitive skills (e.g., using simulations and game-based learning) (see Table 2, page 8).

1.3.2 South African teachers experienced problems implementing recent curriculum changes

The second problem motivating this research related to South African teachers having to implement a new school curriculum. Curriculum change is a complicated process, especially in developing countries (Kozma, 2008). South African teachers proved no exception to this rule, experiencing a number of difficulties implementing the bold and revolutionary changes introduced by the new curriculum. The difficulties teachers were experiencing with the new curriculum requirements was one of the motivating factors for this study, which initially investigated the suitability of a multimedia software package which claimed to be able to support teachers in making the changes to the practices required by the new curriculum.

Teachers' struggled to fully implement the practices required by the new curriculum

Although workshops were held to introduce the curriculum innovations to teachers, subsequent research showed that not all teachers understood what the new policies translated into in terms of changes they had to make to their teaching practice, even after attending the workshops (Aldous, 2004; Chisholm et al., 2000; Hattingh, Rogan, Aldous, Howie, & Venter, 2005; Khoali, 2012; Morar, 2004; Pabale & Dekkers, 2003; Rogan & Aldous, 2004; Rogan, 2004; Sanders & Kasalu, 2004). Curriculum ideas being distorted during transmission can lead to a discrepancy between the ideal curriculum and the curriculum as it is used by teachers in the classroom (the 'operational curriculum' described by Goodlad, Klein, and Tye, 1979). South African teachers failed to implement the NCS curriculum as intended by the curriculum designers, either because teachers lacked an understanding of the required practice and/ or teachers failed to comply with the practices. Research-based evidence for teachers' failure to fully implement the required practices is discussed in Appendix C.

Teachers' inability to produce their own learning support materials

The difficulties South African teachers were experiencing with producing their own lesson materials provided some of the motivation for the initial aim of this study, viz., to evaluate the suitability of a software package that claimed to be able to provide support for teachers implementing the new curriculum. The South African Department of Education had the expectation that, as part of "*the efforts at transforming teachers' practices from the traditional to more progressive, constructive pedagogy"* (Stoffels, 2005, p. 534), teachers would develop their own lesson materials for the new curriculum. The National Department of Education (1997, p.27) was of the opinion that teachers are "*professionals who can make curriculum decisions in the best interests of learners and who do not have to rely on the dictates of a centrally devised syllabus*". While there could be advantages to teachers developing their own materials, *"given the context-specific nature of classrooms*" (Davis, 2006, p. 350), Karplus (1971) points out the impracticalities of requiring teachers to develop their own curriculum materials given time limitations and, in some cases, content knowledge constraints within which teachers work. In South Africa, where statistics argue against the majority of teachers being well-qualified and confident, requiring teachers to produce their own curriculum materials could be daunting even for well-qualified and confident teachers.

Research suggested that many teachers were struggling to produce their own materials for the new curriculum (Chisholm et al., 2000; Khulisa Management Services, 2002) and relied on text-books rather than producing their own material (Khulisa Management Services, 2002). Stoffels (2005), after observing and video-recording nearly 30 lessons given by two Grade 9 Natural Sciences teachers, reported that the teachers relied heavily on textbooks to plan the content to be covered and the activities to be carried out, even though both claimed to have moved away from the traditional idea of basing their teaching on a textbook. The two teachers said they were not producing their own learning materials because of the lack of time, the large number of administrative duties required by the new curriculum, and the amount of work involved in "*designing down from critical and specific outcomes, conceptualizing new phase organizers, range statements, assessment criteria and activity worksheets"* (Stoffels, 2005, p. 541). The findings in this study were in keeping with the earlier findings of the review committee which had previously looked at the reasons for South African teachers' inability to produce their own materials. The review committee had concluded that "*in the majority of contexts, teachers do not have the time, resources and often skill to develop their own materials*"

(Chisholm et al., 2000, p. 15). More specifically, a lack of understanding of what the curriculum required of them and an inadequate or incomplete content knowledge (Arnott & Kubeka, 1997; Dekkers & Mnisi, 2003) are likely to have made it difficult for teachers to produce effective lesson materials for the new curriculum.

Suitable curriculum materials can clarify what changes teachers are supposed to make and how they should be made (Stronkhorst & van den Akker, 2006). In light of teachers' inability to produce their own curriculum materials, due to an incomplete understanding of new curriculum practices and teachers' lack of adequate content knowledge, South African teachers could have benefited from the provision of suitable curriculum materials. Hausfather emphasises the importance of content and teachers having a thorough grasp of the content they are required to teach: "*the content and concepts that students must learn have to be at the centre of constructivist teaching*" (Hausfather, 2001, p. 18). A lack of adequate content knowledge has been identified as a problem among South African science teachers (Rogan, 2004), as shown by the following research findings. In a study involving 54 pre-service and in-service teachers in one province, one set of researchers found that the majority of the teachers did not have what the researchers termed a "*fully adequate understanding of the 'nature of science*'" (Dekkers & Mnisi, 2003, p. 31). Examples of the inadequate knowledge of the nature of science displayed by some of the teachers were a lack of understanding of what a theory is and the failure to appreciate that theories can be refuted. Dekkers and Mnisi (2003) suggested that some of the teachers in their sample would not be able to help learners develop an adequate understanding of the nature of science as required by the new curriculum. Khoali (2012) found that the knowledge about smoking and related matters of most of the 29 teachers in their study could, at best, be described as being at the level of 'general knowledge' and therefore not adequate for teaching purposes. These teachers knew that smoking affects the lungs but were unaware of the other negative effects associated with smoking. The same study identified gaps in teachers' knowledge and evidence of misconceptions about scientific concepts they were required to teach (Khoali, 2012).

1.3.3 South African teachers were not using computers

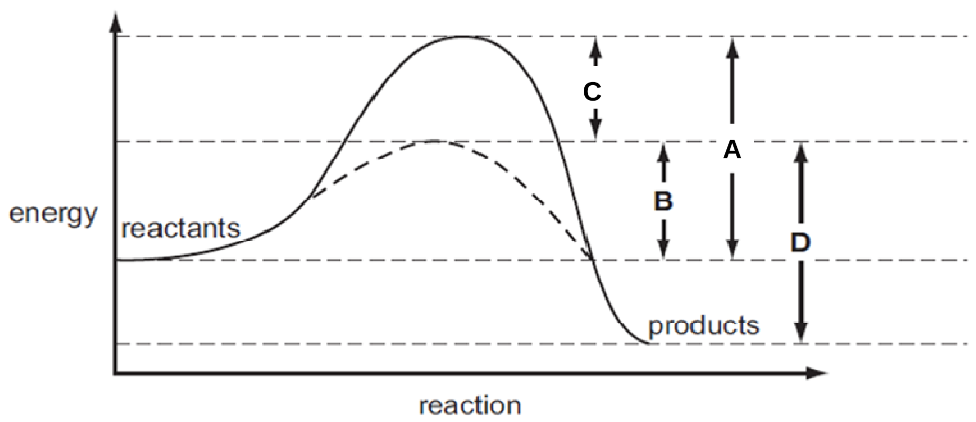
Despite the government's intention to bring more South Africans into the technological age (see Section 1.1.1, pages 3-4), the vast majority of South African teachers were not using computers sufficiently for any of the possible benefits computer technology can offer learning to be realised (see *Microsoft Partners in Learning* final report, 2005).

1.4 THE ROLE OF SUPPORT MATERIALS IN IMPLEMENTING CURRICULUM CHANGE

Given the difficulties South African teachers were experiencing with implementing the new curriculum practices, suitable materials (such as the multimedia package evaluated in this study) could have supported teachers to make the required changes to their teaching. Kozma (2008, p. 1087) believes that "*ICT can play a particularly important role in supporting education reform and transformation".* In 2009 the Deputy Director General of the National Education Department suggested that the use of computers could help South African teachers implement the new curriculum by accelerating training and making support materials available. The Department of Basic Education therefore began investigating the use of computers as a means of supplying teachers with support materials like lesson plans (Gower & Hoffman, 2009). The department also referred to "*the use of software to assist with training*" of teachers (Gower & Hoffman, 2009, p. 11). It was the use of software as support material for teachers implementing the new curriculum that formed the initial focus of this study.

Ottevanger (2002) provides a theoretical underpinning which explains the value of curriculum support materials when a new curriculum is implemented. He suggests that providing teachers with suitable support materials can 'catalyse' curriculum change in the same way that enzymes lower the activation energy required to initiate chemical reactions. The activation energy of some chemical reactions represents a barrier which must be overcome by the addition of extra energy for the reaction to proceed. Enzymes speed up the rate of reactions by lowering the activation energy requirement of reactions. Figure 4 shows the typical energy graph for an enzyme-mediated reaction, modified to represent the role curriculum support materials can play in facilitating curriculum change. The simple analogy shown in Figure 4 is highly effective in representing the role of appropriate curriculum materials in helping teachers to implement curriculum innovations. In the context of curriculum innovations, the barriers which prevent teachers from adopting curriculum innovations or from adopting the innovations correctly are analogous to the activation energy required to initiate a reaction. Suitable curriculum materials can be used to reduce the 'activation energy' requirement of curriculum change by reducing the amount of time and effort teachers have to expend to make the required changes.

Karplus (1971) pointed out the importance of providing suitable materials to help teachers implement curriculum change. In the South African context, given the problems of low teacher proficiency and the significant changes required by the new curriculum, it seemed feasible that teachers would benefit from the use of suitable curriculum materials to support the implementation of the new curriculum. As part of this study the *EduRom* software package, which claimed to have been designed for the new South African curriculum, was evaluated to assess its suitability to support teachers with implementing the required practices.



A: activation energy required to start the chemical reaction (*analogous to teachers implementing curriculum innovations* ***without*** *curriculum materials)*

B: activation energy required to start the chemical reaction with an enzyme catalysing the reaction (*analogous to teachers implementing curriculum innovations* ***with*** *curriculum materials)*

C: energy saved by using enzymes (*analogous to energy saved by teachers when implementing curriculum innovations* ***with*** *curriculum materials)*

Figure 4. Representation of how curriculum materials can facilitate curriculum implementation, using the catalyst analogy of Ottevanger (2002)

1.5 AIMS OF STUDY

The aims of this study were underpinned by the following assumptions and reasoning:

- ICT has the potential to promote meaningful learning;
- the South African government has emphasised the role of ICT in improving the quality of education;
- teachers were experiencing problems implementing the new curriculum (teaching new content and understanding and applying the new requirements);
- well-designed curriculum support materials have the potential to catalyse curriculum change.

The problems motivating this study can be summed up as being the new demands being made on South African teachers at this time, both in terms of the required changes to their teaching methods and approaches associated with the introduction of a new curriculum.

The aim of the first phase of the study was to investigate the factors impacting on teachers' use of computers at an independent secondary school, including the suitability of a software package[3] purchased for the teaching of science subjects (biology, chemistry, mathematics and physics) as part of the school's drive to use ICT for teaching. As a biology teacher at the school, I was well-placed to gain access to the biology module of the software package which I evaluated in this study, and to assume the role of participant-observer, observing and documenting events relating to the use of computers at the school. At a time when the new curriculum was being introduced at the Further Education and Training level in South African schools, which included the addition of new content as well as imposing new demands on teachers' classroom practices, the claims made by the distributors of the software package sounded alluring. These included that the software "*provides the answer to the latest curriculum*", "*provides interactive educational software*", offers "*continuous evaluation*" and "*cover(s) the majority of the new curriculum, based on OBE and e-learning principles*". The claims made by the software company sound like a feasible mechanism for taking advantage of the benefits offered by integrating ICT into science teaching, while simultaneously helping teachers to address the new content, and apply the required principles of the new curriculum in their classrooms.

The aims of the second phase of the study were, firstly, to investigate the changes in teachers' computer usage after the introduction of an innovation promoting the use of digital technologies for teaching. Secondly, to investigate more deeply three factors which had emerged during the first phase of the study as factors affecting teachers' use of computers: the teacher training provided by the school; the provision of additional time for using technology for teaching and learning; and the effect of individual teacher's level of innovativeness on their use of computers for teaching and learning.

1.6 RESEARCH QUESTIONS

General research aims need to be operationalised into specific research questions by researchers (Cohen, Manion, & Morrison, 2000). Research questions serve to clarify the objectives of proposed

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[3] The software package evaluated in this study will be referred to by the pseudonym "*EduRom*" in this thesis.

research and to focus researchers on what data needs to be collected and how the data should be collected (Mertens, 2005). The following research questions were structured to guide the study:

1. What factors affected teachers' use of information and communication technology at a case study school?
   1.1. To what extent did the suitability of available software affect teachers' use of technology?
   1.2. What other factors affected teachers' use of technology?
2. To what extent and in what ways did teachers' use of technology change after the introduction of the *Digital School Project*?
3. What general factors influenced teachers' use of technology after the innovation?
   3.1. To what extent, and in what ways, did the amount and nature of the ICT training provided affect teachers' use of technology?
   3.2. To what extent, and in what ways, did the amount of time provided for using technology for instruction affect teachers' use of technology, according to the teachers?
   3.3. To what extent, and in what ways, did their level of innovativeness affect teachers' use of technology?

1.7 CONTRIBUTION TO THE FIELD

The requirements for a PhD are that the piece of work produced shows originality and contributes to new knowledge. My original contributions to science knowledge are evident in the new conceptual insights I offer which could be useful to researchers in the field of educational technology.

There exists a plethora of studies on factors affecting teachers' use of ICT for teaching. However, it is not helpful to have a long list of unrelated factors since it is difficult for researchers to know how the factors are linked. Some authors (e.g. Chen, 2010; Hossain & Brooks, 2008; Zhao & Frank, 2003) have produced models to look at relationships between factors. However, some models focused on only one group of factors, while others do not give an indication of relative seriousness of all factors or they do not group factors into easily identifiable clusters. Firstly, my review of the literature was quantified in a way which reveals the relative seriousness of the factors, based on reports in the literature. Secondly, by clustering the factors affecting teachers' use of ICT for teaching hierarchically into categories, sub-categories, and individual factors, I have both provided a more comprehensive overview of the many factors involved, and added insights to hierarchical relationships between the factors. Such insights allow those working in the field to get an inclusive overview of the factors in a way that will allow for targeting of specific areas or factors for further investigation or for interventions. I have presented these hierarchical relationships in a conceptual map, which is a new contribution to the field. In addition to being of potential use to researchers it could be useful to institutions trying to increase the use of ICT for educational purposes, and service-providers involved in the professional development of teachers to assist them use ICT in meaningful ways for learning. The value of the map is in allowing people to see the multitude of factors they need to consider if trying such ICT initiatives, but in a holistic way. Furthermore, clustering factors make it easier to address certain categories of problems, rather than individual isolated factors.

The findings which emerged from the study gave me further insights into the relationships between the categories and subcategories into which I had clustered factors in my map, leading to the production of a model (presented in Chapter 9) which is parsimonious and provides a holistic overview of how the complex web of factors affecting teachers' use of technology are related. The insights offered could help researchers understand the complex interplay between the myriad factors which influence teachers' use of computers when planning and conducting research into teachers' uptake of ICT for teaching. Because the clustering of factors is an original way of looking at the factors affecting teachers' use of ICT, the model represents a new contribution to the field. A better understanding of the relationships between the different factors is useful for other education stakeholders, for example educational leaders and ICT trainers. It can help them understand that changing one factor is unlikely to be sufficient to promote the successful use of ICT for meaningful learning, and allows them to identify, in their particular context, factors which could be addressed to promote the use of ICT for meaningful learning.

Another contribution I provide in this thesis to the field of ICT use in education is a new perspective on how teachers using ICT can be grouped in a way which looks not only at their behaviours but at the reasons behind their behaviours. The idea of grouping teachers into adopter categories is well established in the literature, e.g. Rogers (2003) classifies people into groups based on rate of adoption of an innovation, but knowing how fast they adopt ICT is not helpful in findings ways to help certain teachers use ICT in a more purposeful way to improve the quality of learning. Donnelly, McGarr, and O'Reilly (2011) group teachers into one of four adopter categories based on their behaviours, and propose that teachers can be supported to move from one adopter group to one which makes more use of ICT. I realised that identifying teachers' behaviours is not sufficient to help them make more effective use of ICT, and that it was critical to understand the reasons why teachers were using computers in a particular way. Identifying the reasons and linking them to teachers' behaviours allowed me to see that within a category of behaviour, there could be subgroups based on teachers' reasons for using ICT. This new insight has important applications for educational institutions and/ or trainers wanting to promote the use of ICT in ways which benefit learning, discussed further in Chapter 9.

During the course of my research I developed a number of useful new tools which are of potential use to various stakeholders in the educational field, thus contributing to new work in the field. The first of these is a model for the context-based evaluation of software. Because I was unable to find a single unifying framework for the software evaluation aspect of the study, I analysed several existing theories to identify criteria I could use to evaluate a software package. This analysis allowed me to realise that the usefulness of a software package is influenced by two sets of factors, context-dependent and context-independent factors. Based on this insight I developed a model of factors which should be considered when evaluating educational multimedia software (see Chapter 5). The model could be used by software designers, to better help them understand the factors which influence the effectiveness of a software package for enhancing learning.

I also developed a questionnaire and associated classification key to place teachers into adopter categories based on their levels of innovativeness, but which incorporates a broader set of characteristics of innovators than the limited 'rate of adoption' proposed by Rogers and used in many other studies (see Chapter 7). Classifying teachers into adopter categories could help educational institutions and ICT trainers provide differentiated support for teachers based on their particular needs, which could promote teachers' uptake of ICT in ways which benefit learning. However, using only speed of adoption is limiting, and the potentially lengthy and arduous process of identifying other characteristics, e.g. by interviewing teachers and analysing the data to be able to classify teachers into adopter categories, is likely to discourage educational management teams from wanting to undertake such a classification. The brief multiple-choice questionnaire and associated classification key I developed provides a quick and easy way of classifying teachers into groups based on their levels of innovativeness, and could reduce the need for lengthy interviews and analysis of data. These two instruments could be used by educational leaders and ICT trainers to classify teachers into adopter categories and to plan suitable strategies to integrate ICT in meaningful ways which benefit learning.

The final new contribution offered in this thesis relates to a set of open-ended checklists I developed to evaluate a software package (described in Chapter 3). Checklists usually consist of a list of criteria against which something is evaluated, and they are limited value other than to score the product being evaluated The checklists I developed to evaluate the software package in my study were open-ended, meaning that I could record comments explaining why I had made a particular evaluation. This is useful in that anyone else, e.g. for example product developers, would be able to understand the reasons behind the evaluations. The concept of open-ended checklists could be useful, for example, where teachers give feedback to designers of software packages, so that future versions of the software better meets teachers' needs.

1.8 CONCLUDING REMARKS

This chapter described the context of the study and the problems which motivated my research, and gives a broad overview of the aims and specific research questions which guided the study. The remainder of the thesis describes the conceptual framework underpinning the research, the research methods used, and the findings of the study. Chapter 2 describes the conceptual framework for the investigation of the factors affecting teachers' use of computers at the case study school. The rest of the thesis is structured according to the two distinct phases followed during the research. The research design for the whole study, and the methods used to investigate the factors affecting teachers' use of computers during the first phase of the study are presented in Chapter 3, with the findings for the first phase presented in Chapter 4. One aspect of this first phase involved an evaluation of the *EduRom* package, which is described in its own chapter, Chapter 5. The methods and findings for the second phase of the study are discussed in Chapters 6, 7, and 8. Chapter 9 is a summary of the findings and recommendations arising from the study.