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Evaluating a web-based computer package to help teachers use a science-technology-society (STS) approach to teaching human population dynamics

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CHAPTER TWO

THEORETICAL FRAMEWORK FOR THE DESIGN OF THE PACKAGE

INTRODUCTION

As discussed in Chapter 1, *Curriculum 2005* makes certain demands such as making lessons more relevant to the learners' lives and experiences, involving the active participation of learners in the learning process and making learners develop a range of skills. However, many teachers are finding it difficult to meet these demands because they are not familiar with alternative approaches to teaching and suitable learning theories to base their teaching on. One alternative approach to meet these demands is the Science-Technology-Society (STS) approach which most teachers are not familiar with. The STS problem approach requires that learners go out in the field to investigate problems. Because of time constraints, this approach could be taught using computers which most teachers in South African schools are not trained to use in their teaching. Therefore, this chapter explores in detail the issues of the STS approach, the importance of learning theories, the benefits of using computers in teaching and the need for professional development of teachers.

2.1 SCIENCE-TECHNOLOGY-SOCIETY (STS)

The science-technology-society approach emphasizes the use of real life situations to teach concepts. The STS approach is contrary to the traditional method of teaching which uses a teacher-centred approach and the role of the teacher becomes one which dispenses information to the learners. The STS approach includes the learners in the teaching and learning processes, therefore they become active participants in acquiring the knowledge. The involvement of learners in their learning process easily meets one of the demands of *Curriculum 2005* which requires learners to become more actively involved in the learning process.

Yager and Tamir (1993) state that STS is defined as teaching and learning science in the context of human experiences. STS focuses on the applications and use of knowledge which is relevant to the life of the individual and to society, and the central role of the teacher in curriculum development. Yager, Tamir and Huang (1992) have defined STS more broadly to include goals, curriculum, assessment, instruction strategies and teacher preparation/performance. The STS approach examines the interface between science, technology and the social world (Trowbridge and Bybee, 1990 and Hughes, 2000). The National Science Teachers Association (NSTA) defines STS as the latest effort to provide a real world context for the study of science and for the pursuit of science itself (Ajeyalemi, 1992). STS focuses upon

current issues and attempts at their resolution by identifying problems, planning activities to address them and moving to actions designed to resolve the issues investigated. STS means focussing on real-world problems instead of starting with concepts and processes which teachers and curriculum developers argue in terms of usefulness to learners. In teaching the content from the learners' real-life experiences also meets one of the demands of *Curriculum 2005* which requires that lessons are made more relevant to the learners' lives and experiences.

2.1.1 What is STS science teaching?

According to Aikenhead (1994a) STS teaching is learner oriented, as contrasted with the scientist orientation of traditional science teaching. The learner-oriented character of STS science teaching is where learners strive to understand their everyday experiences. Learners do so by making sense out of their social environment and their natural environment. The STS approach starts with what the teacher or learner thinks is important, with the learners' interests, and with what is relevant to their lives.

According to Aikenhead (1994b) and Solomon and Aikenhead (1994), STS science instruction demands a wide repertoire of teaching strategies such as divergent thinking, small group work, learner-centered class discussion, problem solving, simulations, decision making, controversies, debating, and using media and other community resources. Traditional science teaching methods on the other hand tend to be characterized by convergent thinking and lecture-demonstrations.

The content of the STS approach arises from human experience, either brought by learners to the classroom or through situations stimulated by the teacher. Yager and Tamir (1993: 37) identify five goals for the STS approach which are characterized as domains and includes the following:

- *Concept domain* - includes the facts, information, concepts, laws, principles, existing explanations, and theories being used by scientists.
- *Process domain* - being able to use the processes of exploring and investigation in a wide variety of situations. STS advocates personal use of skills acquired in new situations.
- *Application domain* - inclusion of information, skills, and attitudes that can be transferred and used in learners' everyday lives. For example, seeing instances of scientific concepts in everyday life experiences; applying concepts and skills to everyday problems; using scientific processes in solving problems that occur in everyday life; making decisions related to personal health, nutrition, and life style based on knowledge of scientific concepts rather than on hearsay or emotions; taking specific actions designed to resolve problems and/or contribute to the improvement of local, regional, national, and/or international problems and extending school experiences beyond the classroom. This means making the materials in a science course related to real-life situations.
- *Creativity domain* - encourages the development of creative abilities such as visualizing or producing mental images; solving problems and puzzles; predicting possible consequences; suggesting possible causes etc.
- *Attitude domain* - includes developing positive attitudes toward science in general, science in school and the science teacher; developing positive attitudes towards oneself; making decisions about personal values; making decisions about social environmental issues; and exploring arguments on various sides of an issue. This is important because learning is enhanced when learners have positive attitudes about the subject.

2.1.2 Methods of teaching STS

It is important that science should not be seen as an abstracted field of study concerned entirely with the concepts of science, but rather should be linked with both technology and society. Ramsey (1993) claims that "scientific knowledge is not de-emphasized, it is obtained and used on a need-to-know basis". His belief is that, as real life problems are investigated, learners search for scientific and technical information that can be applied to solve these problems.

This approach meets some of the learning outcomes for Natural Sciences such as;

- Scientific investigation: to investigate relationships and solve problems in scientific technological and environmental contexts.
- Constructing science: to interpret and apply scientific, technological and environmental knowledge
- Science, society and the environment: to demonstrate an understanding of the inter-relationship between science and technology, society and the environment (Department of Education, 2002).

Science educators have different views about what constitutes an STS programme. Some authors claim that STS is not a replacement for conceptual science but an essential supplement to it. (Lynch, Murtough and Nusirjan 2000 and Hughes, 2000). Thus, STS can either be taught alongside science or integrated into science courses. Hughes (2000) however, says that STS may also be viewed as part of the curriculum in its own right. It can be viewed as merely a vehicle for delivery of conceptual science content or the STS context may be included as a worthwhile subject for study along-side the concepts. Solomon (cited by Fensham, 1993) criticises these views because they do not reposition science into a social, economic, political, and moral context as only a brief social context is fused into science curricula. They normally add on a brief social context within rigidly prescribed science content in restricted topic areas. Aikenhead (1994a) has categorized different approaches to STS science teaching into 8 groups as shown in the table below.

Table 1: Categories of STS science based on Aikenhead (1994:45)

CATEGORY	DESCRIPTION OF TEACHING APPROACH
Motivation by STS content	Traditional school science, plus a mention of STS content in order to make a lesson more interesting. Learners are not assessed on the STS content.
Casual infusion of STS content	Traditional school science, plus a short study of STS content attached onto the science topic. Learners are assessed mostly on pure science content and usually only superficially on the STS content.
Purposeful infusion of STS content	Traditional school science, plus a series of short studies of STS content integrated into science topics, in order to systematically explore the STS content. Learners are assessed to some degree on their understanding of the STS content.
Singular discipline through STS content	STS content serves as an organizer for the science content and its sequence. The science content is selected from one science discipline. Learners are assessed on their understanding of the STS content.
Science through STS content	STS content serves as an organizer for the science content and its sequence. The science content is multidisciplinary, as dictated by the STS

	content. A listing of pure science topics looks like a selection of important science topics from a variety of traditional school science courses. Learners are assessed on their understanding of the STS content, but not as extensively as they are on the pure science content.
Science along with STS content	STS content is the focus of instruction. Relevant science content enriches this learning. Learners are assessed about equally on the STS and pure science content.
Infusion of science into STS content	STS content is the focus of instruction. Relevant science content is mentioned, but not systematically taught. Emphasis may be given to broad scientific principles. Learners are primarily assessed on the STS content, and only partially on pure science content.
STS content	A major technology or social issue is studied. Science content is mentioned but only to indicate an existing link to science. Learners are not assessed on pure science content to any appreciable degree.

This study infuses the STS content to teach the school science so that it could make learning interesting and motivating to the learners as well as applicable in their real-life situations. Assessment of the learners was continuously done through various activities on science content without much depth on the STS content.

2.1.3 Science-related problems

In this research, the STS approach used was based on problems. Ramsey (1993) suggested that a science-related social problem is one that has its roots in science and/or technology. It involves a problem surrounding which there are different beliefs and values. Therefore, within population dynamics, issues such as those involving human population decrease (mortality and emigration) and population increase (natality and immigration) for instance can be studied.

It is believed that the science-related problem provides the greatest potential for understanding science in a context of its political, economic, social and ethical implications (Ramsey, 1993). Furthermore, it provides learners with many opportunities for information processing, problem solving and decision making in science. Skills are learnt and applied to other science-related problems. Dealing with such problems involves activities and investigations, discussions and debates, where learners learn to understand scientific evidence and its limitations, assess risks and benefits, ask questions, and make decisions based on evidence rather than on pure emotion.

The teacher can approach problem solving in a wide variety of ways by creating situations where understanding of concepts can grow, where issues can be explored, and where learners can interact. The teacher may pose or ask open-ended questions, provide and make available a variety of materials for the solution of a problem and connect the lesson to learners' interests (Casey and Tucker,1994). In such instruction, the teacher shifts the role of being the dispenser of information to a provider of resources that would enable learners to acquire knowledge on their own.

2.1.4 Reforms in science education

In 1996, South Africa embarked on curriculum reforms which were to be implemented throughout the education sector in the country. This curriculum change was aimed at implementing a learner-centred outcomes approach to education (Graven, 2001). Some of the key principles on which the curriculum is based are relevance, participation and ownership, learner-centred learning, and critical and creative thinking (Graven, 2001). It was suggested that teaching would improve the quality of science education in the country by becoming more learner-focussed, relevant to the learners' lives and based on the development of relevant skills (Sanders, 1999).

According to Solomon and Aikenhead (1994) many science educators elsewhere are proposing a major science curriculum reform to prepare learners to understand the roles of science and technology in their personal lives. For this reason, STS is becoming important because the STS approach presents concepts in a context that is centred on the needs and interests of the learner, and can provide an experience-based understanding of the impact and importance of modern science and technology. Currently, science education presents science in the abstract, which is neither motivating nor inclusive of the majority of learners (Hughes, 2000), resulting in poor learner achievement, lack of participation in science courses, low standards, and inadequate requirements (Trowbridge and Bybee, 1990). Trowbridge and Bybee (1990) argue that science courses in general have not been directed toward personal or societal problems involving science and technology. They feel that science education must be taught in a way to bridge the gap between the search for knowledge and its utilization.

Even with these reforms, in many American and African countries science curricula are based on text books that present science as a body of information, a mass of disconnected facts and generalizations that required rote memorization (Hurd *et al.,* 1980, Rosenthal, 1985 and Ajeyalemi, 1992). Science education all along has been deemed to be out of touch with society, leaving learners poorly equipped to deal with a complex modern world of scientific and technological controversy (Fensham, 1993).

Many countries base their science education on goals that tend to emphasize academic preparation to the exclusion of personal, societal, and career goals (Harms cited by Harms and Yager, 1990). These curricula teach science that is not grounded in action, socially constructed, culturally relevant and providing a context of action. This is as a result of regarding and seeing scientific knowledge as separate from educational and social connections which is not the case (Jenkins, 1994). Such science does not considers learners as being participants in the teaching process (Watts *et al*., 1997) which permits learners to engage with issues or problems, allowing them to make decisions and suggesting practical actions. Such a science has local applications and is rich in values. The table below outlines some of the major differences that exist between STS and traditional instruction.

Table 2: Distinguishing characteristics of STS and traditional instruction (Yager, Tamir and Lellerman, 1994).

STS INSTRUCTION	TRADITIONAL INSTRUCTION
Learner-centered	Teacher-centered
Directed by learner questions and experiences	Directed by the textbook
Uses a variety of resources'	Uses basic textbooks
Teachers build on experiences	Teachers build on organized, easy-to-grasp information
Teachers plan teaching around problems and issues	Teachers plan from the prescribed curriculum guide and textbook
Learners considered active contributors to instruction	Learners recipients of instruction

2.1.5 Benefits of using an STS approach

Learners in the STS approach engage in science that emphasizes both scientific processes and the nature of inquiry (Pederson, Bowyer, Butts and Bybee, 1984). It is an approach that places learners in a central position of acquiring knowledge which promotes learning (Yager *et al*., 1992). This appoach also meets some of the learning outcomes mentioned in section 2.1.3.

STS integrates the interaction between science, technology and society (Solomon, 1993) and allows learners to use relevant issues around them (Costa, 1995). There have been a number of positive effects with the usage of the STS approach in teaching and learning such as;

- STS improves both learner interest and enjoyment of science (Aikenhead, 1994).
- Yager *et al.* (1992) in a study of 116 freshmen and sophomore nonscience majors enrolled in Taiwan in a Human Biology course using the test-retest reliability (0.80) found out that there was an enhancement of the mastery of basic concepts. This was a result of greater learner motivation because the organization of the course was more relevant (i.e. related to personal and social issues). There were also improvements in attitudes towards biology, learner understanding, use of science process skills and the ability of learners to use biology concepts. In addition, improvements were seen in creativity with questioning and the suggestion of causes as well as consequences of societal problems. However, Watts, Alsop and Zylbersztajn (1997) found no difference in learners' conceptual understanding and academic achievement.

Harding and Sutoris (1987), Sjoberg and Imsen (1988) and Fensham (1993) believe that the inclusion of STS is especially important for the motivation and retention of girls. Several educators claim that the personal aspects of STS, and also how it is taught are more suited to the way in which girls like to learn about science than is the traditional method of teacher-centeredness (Kahle in Yager *et al.* 1992 and

Hughes, 2000). It is also becoming more accepted that an STS curriculum can increase learner engagement with science, and thus has the potential to improve inclusivity (Hughes, 2000). Attempts to socialize school science have aimed to enhance learners' powers of decision-making and problem solving and have offered a balanced view of the very nature of scientific and technological knowledge (Watts *et al.*, 1997).

According to a research program that dealt with the impact of STS instruction on learners in grades 4 to 9 taught by teachers who had done an STS workshop (Yager *et al.*, 1994), learners in STS classes benefit more than those in traditional science classes in the following:

- Improving understanding of the social issues both internal and external to science, and to the interaction among science, technology, and society.
- Becoming more capable at applying science concepts to new situations.
- Applying information, to relate information to other situations, to act independently, and to make decisions.
- Improving attitudes towards learning science.
- Improving in science process skills achievement.
- Making modest gains in thinking skills such as applying science content to everyday situations, critical and creative thinking, and decision-making.

Mayer (1997) argued that the acquisition of traditional science content was significantly better for STS learners. He further states that STS efforts may be effective where traditional approaches fail because learners start with their own problems, collect data, apply to their problems, and make decisions. In an STS approach, learners learn beyond the ideas from activities in textbooks (Yager *et al.,* cited by Yager and Tamir, 1993).

2.1.6 The effects of contextualising science teaching

Peacock (1991) emphasizes that contextualising the science teaching improves access resulting in equity for disadvantaged groups and it improves learners' motivation to engage in learning (Yager and Tamir, 1993). However, the most important reason for contextualising science teaching is because it provides the aspects of applicability and usefulness (Campbell *et al.,* cited by Hughes, 2000). It is argued that learners who have been taught a contextualised science course often use science ideas to solve science-based everyday problems or to explain everyday situations (Dlamini, 1999).

Teaching STS demands a lot of time for learners to go out in the field to collect information. But this could be minimised through the use of computers which have advantages such as the ones discussed below.

2.2 THE BENEFITS OF USING COMPUTERS IN EDUCATION

This section looks at the benefits of using computers in science education. It has been increasing advocated that the use of computers can solve educational problems, for instance Topper (2000:1) argues that *"some people are claiming that the Internet will fundamentally change education at all levels"*. However, it is important to first find out to what extent and in what ways computers can improve teaching and learning.

2.2.1 Arguments for the use of computers in education

Recently, there has been an emphasis on the use of computers in South African schools. The structure of the new curriculum and the Department of Education demand that teachers should use computers when teaching. According to Sanders (2001: 1) *" the use of computers in education has been proposed as one way of addressing the crisis in mathematics and science education in the country."* The *Curriculum 2005* strongly highlights the necessity for schools to teach information technology i.e word-processing, spreadsheets, Internet search etc (Pretorius cited by Sanders, 2001). However, teachers will need a lot of support and help in terms of skills and competencies in order to undertake such a huge task. Teachers first need to know and understand some of the uses of computers in improving teaching and learning. Secondly, teachers need to understand theories that affect teaching and learning. Below is a table showing what teachers and learners do with computers and the advantages of doing tasks with computers rather than off-line.

Even though not all these uses were applied to this research, as a designer of instructional material it was important to find out what computers could generally be used for in teaching and learning, then draw out the advantages or benefits. It is important to realize that it would be wasteful in terms of time and resources to simply develop a package that does not consider the merits of using computers in teaching because it might even be better to present the same material in another medium like notes or a book.

Table 3: Uses and advantages of using computers.

USES OF COMPUTER		**ADVANTAGES OF USING THE COMPUTER**
1. Preparation		
word-processing	1. Creating and writing materials such as assignments, notes and notes (Stephen, 2001).	• Save time to re-write scripts due to mistakes, thereby reducing the workload and in the process improving writing skills.

2. Record keeping & management		
spreadsheets	1. Calculating statistical data in tables (De Klerk, 1994; Pogge and Lunetta, 1987). 2. Visually display of data in graphs and charts (Nicol, 1990; Carter, 1999).	• Calculates data automatically and quickly because of the in-built calculator software rather than using a manual calculate. • Learners can change the values for the programmed equations in the table and see the visual effect on the graph or chart (Nicol, 1990; Carter, 1999). Computers are the best medium for dynamic processes requiring understanding of relationships between moving objects.
Database	1. Accessing data that has been stored on the database. 2. Updating stored data	• Easy accessibility of stored data by a click of a mouse as compared to finding data in files which takes time to find and tedious. • Easy to update data by deleting un-necessary data and typing in the new information as compared to re-writing the old and new data in files again.
3. Electronic communication		
e-mail	1) Sending mail between learners and teachers of the same school, teachers and learners of the same school or outside, teachers and parents. 2) Asking questions and getting responses from teachers, parents or learners.	• It is convenient and quicker to send mail in seconds rather than using the letters which take long. • Gives quick/immediate response assuming that the computer is working well without any interruptions and the receiver is available at that particular time to respond. • It is convenient to send queries through e-mail whilst working on tasks without closing the programme.
Information source		
1 . multimedia 2. Internet 3. libraries	1. Easy accessibility of huge information from other libraries, schools, databases etc. 2. Provision of largest data resource and can easily access many libraries on-line.	• Quicker to retrieve information on the Internet than travelling to these places to obtain information, which is costly and time constraining (Crovello, 1982).
As a source of teaching material		
Graphics	1. Drawing and painting. 2. Manipulation of images. 3. Provision of images in 3-D or microscopic nature.	• Allows for experiences otherwise not possible in a normal teaching classroom such as elucidating parts of a difficult process in more detail (microscopic items, nuclear power station, photosynthesis, cellular respiration etc.). • Allow to present material that is in 3-D which is difficult to visualize with traditional AV aids like textbooks and those that are difficult to visualize.

Instruction		
Tool	1. Tutoring	• Allow learners to work and to proceed at their pace unlike the teacher who rushes to cover the tasks because of time constraints. Computers have longer office hours than teachers and rarely get grumpy (Stephen, 2001; Crovello, 1982; Matray and Proulx, 1995). • Allow learners who are slow in finishing their work to take their time because they can always go back to work at their own time and pace. The teacher can never repeat a lesson twice because the teacher is often impatient, biased and ratty. • Computer software are patient to repeat a task at any time than the teacher because they never get tired of repetitive tasks. • Well-designed computer programmes allow for self-paced learning in a non-threatening environment and are nonjudgmental (Matray and Proulx, 1995). This is essential for learners who have low self-esteem and who tend to lack confidence (Sanders and Ayayee, 1997, and Crovello, 1982). • Offers learners tasks that are accessible and always available making it flexible than a teacher who can only be available at specific times (Draper, 1998). • Using computers allow learners to get actively engaged mentally even though they are just reading, in contrast to whole class teaching where some learners may not be listening to what teachers are saying. • Individual feedback which is instant can be given to learners on specific problems.
	1. Simulation	• Can provide simulations for experiments that are expensive, complex or dangerous to use in the laboratories (Crovello, 1982 and Draper, 1998). • Provide simulations of real world events which are closely based on real world simulations providing experiences which may not be possible (Mandell and Mandell, 1989). For instance, it would be difficult and unacceptable for learners to perform surgery on a human body.
Oral presentation		
slide shows e.g Power point/Corel presentation	1. Presentations of lessons and projects	• Introduce features with movement unlike transparencies which are stationed. • Allow smooth discussion by introducing one point at a time over transparencies which display all points at a time. • Helps maintain the attention and focus of the audience by discussing one point at the time rather than glancing through other undiscussed points on transparencies that have not been introduced.

2.2.2 Arguments for the benefits of using computers

Apart from the general uses of computers, there are several advantages that teachers can derive from using them in their teaching. Benefits of using computers in this research included the following;

• *Computers if well-designed mentally engage learners in tasks*

The time spent working on the computer is more efficient because learners are actively engaged in their learning, even if it is just reading (Sanders, Mckenney and Van der Laan, 1999, and Sanders and Linkonyane, 2001). This is better but still needs caution. In the package developed, teachers would offer their learners an opportunity to not only master the science content required but also develop in learners a number of skills which could not be possible in a normal teaching session. For instance, the learners may be motivated to do activities using the computers as compared to writing, access information on the Internet etc.

• *Computers are patient*

Computer aided instruction is infinitely patient, allowing learners repeated trials (Mayer, 1997) A computer is never biassed and ratty like the teacher (Sanders and Linkonyane, 2001). Unlike the teacher who has limited time for a session, the use of computers would let the learners repeat activities on their own without the presence of their teachers.

• *Computers allow for experiences otherwise not possible*

Computers can present materials which are difficult, complex, abstract and/or microscopic processes to visualize with traditional visual aids (Sanders and Linkonyane, 2001, and Phillips, 1997). Computers also elucidate parts of a difficult process in more detail such as microscopic items, cellular respiration etc (Draper, 1998 and Stephen, 2001). The use of simulations allow learners to visualize the processes and be able to understand as well as to explain such difficult processes. In traditional teaching, it is hard to visualize complex processes using technology such as whiteboard or overhead transparencies which are two-dimensional and static (Phillips, 1997). He also claims that the use of simulations can be made available for learners in a self-paced manner for use as reinforcement tools. The use of a spreadsheet in the computer package developed provided an easy way to present the increase and decrease of population that would let learners easily visualize the trends than traditional visual aids like transparencies.

• *Computers allows the transmission of different medium*

Computers can present a variety of messages within one lesson such as animation for processes and graphics for spatial interpretation. According to Phillips (1997) *"this offers clear advantages in some teaching situations over mono-media resources, such as whiteboards and audio cassettes".* He claims a particular advantage is the possibility of using the most appropriate mediumm for the required message like text for thought, graphics for spatial relations and animation for dynamic information. Some graphics were used in the package to make a connection between the text and the topic (Sanders and Linkonyane, 2001).

Other benefits of using computers that may have not necessarily been applied in this research included;

• *Computers provide simulation*s *and visualization*

Computers if well-designed can permit experiments which are expensive, complex or dangerous to be carried out (Crovello, 1982 and Draper, 1998).

• *Computers allows learners to control their learning*

According to Phillips (1997) most instructional materials haas the ability to allow users to take their own path through the material and therefore, computers allow learners to work and proceed at their own pace (Crovello, 1982; Matray and Proulx, 1995 and Stephen, 2001). This is important because the users will be able to build up their own knowledge promoting a learner-centred approach to learning.

• *Computers are always accessible*

Computers are often accessible and available at any time for learners to work on their tasks (Draper, 1998).

• *Computers provide safe working environments*

Computers provides learning in a non-threatening environment and are nonjudgmental (Matray and Proulx, 1995).

• *Computers give individual feedback*

Computers can be designed to give an individual learner feedback on specific problems, unlike a teacher who cannot attend to many learners at a time (Sanders and Linkonyane, 2001).

Even though teachers and learners can use computers for the above purposes, it is important to point out that it is not the use of computers as such which will improve education. Effective teaching will occur only with well-designed educational software which is used effectively. However, caution has to be noted that computer software cannot replace the teacher nor can it improve the teaching ability of a weak teacher. Rather computer software can allow a conscientious and creative teacher to present material in more interesting and effective ways (Matray and Proulx, 1995). Secondly, it is not any computer software that can improve learning, but if well-designed and properly used by teachers, effective teaching and learning can take place.

2.2.3 Research findings on learning in the sciences using computers

The uses and benefits of computers mentioned in 2.2.1 (tables 3) are based on logic and theoretical arguments. But does research find that using them does in fact make a difference to teaching and learning? It is important to find out what research says about effective teaching and learning because important lessons can be learned from personal knowledge derived from participation in or observation of others regarding good educational practices. It is these lessons which instructional designers of software can adopt and transfer into their design in order to improve teaching and learning. Sanders and Mckenney (1998) claims that teachers who are aware of research findings on effective teaching and learning are more likely to make successful choices in their classroom practices than those who are unaware of them, and the same holds true for instructional designers.

Below are some examples from research findings on uses of computers in science education.

• *Using computers often improves learner' attitudes to learning.*

In the study that Jegede, Okebukola and Ajewole(1991) carried out with 64 learners in Nigerian Joint Matriculation Examination in biology, they found that computers significantly changed learners' attitudes resulting in significantly higher course averages and improved performance. The group of learners who interactively used the computer had a more favorable attitude toward the use of computers in learning biological concepts than learners who had no such opportunity.

• *Using word-processors can improve learner's writing skills*.

Wainwright (1989) carried out research with 100 learners in Minnesota (USA), where he evaluated the attributes of a microcomputer software package. The results showed that computer software can be designed to correct errors such as improper subscripts, and spelling errors. The computer software can

prompt following the second error in order to obtain a correct answer and to let the user proceed. In this study, the use of the microcomputer material by an experimental group clearly showed that it contributed to effective learning of the subject area.

- *Learners using computers for educational purposes are often more actively engaged in the learning process.*

The study conducted by Schoefield, Evans-Rhde and Huber (1989) on the implementation of a mathematical package, *Geometry Tutor,* in a public high school showed that teachers were spending more time with learners having problems. In this study, the learners were more involved in carrying out academic tasks. This package was believed to have altered the role of educators in the study from that of a transmitter of knowledge to a guide and/or resource person. However, Schoefield *et al.* caution those designing computer materials to choose topics/concepts which are to be taught very carefully because not all topics can be effectively taught using computers.

Even if there are many benefits of using computers in teaching that one can be aware of, it is not enough to ignore other factors that affect effective learning. It is important to be aware of other instructional strategies that can be expected to facilitate learning, such as theories of learning.

2.3 THEORIES OF LEARNING

2.3.1 Why consider learning theories?

Many designers do not design their programmes on sound educational principles. Leshin *et al.*, (1992 cited by Reeves and Hedberg, 2001:23) argue that *the major problem with existing instructional materials is that the designers of instructional materials have totally ignored guidance as to what makes good instruction*. Reeves and Hedberg (2001:4) also claim that in many cases, *educational software tools such as word-processing, spreadsheet, and database programs have failed to improve teaching and learning significantly because they have not been integrated with an appropriate instructional design*. Most instructional designers have not seriously considered the advice on good design which are important for success in effective instructional materials. According to Hannafin (1992:45) *"prospective computer assistance instruction developers have been led to believe that developing CAI requires little knowledge. This is a dangerous misconception, one that has contributed to the glut of substandard software presently available"*. Materials designed by such people are unlikely to be good quality instructional materials.

According to Ausubel, Novak and Hanesian, (1978: 15)*" learning theories offer us the most feasible point of departure for discovering general principles of teaching that can be formulated in terms of cause-effect relationships"*. It is from theories of learning that one can have the ability to develop notions of how crucial factors in the learning-teaching situation can most effectively be handled.

The purpose of looking at these theories are;

- to be familiar with and to understand the processes of teaching and learning,
- to know the advantages of using these theories so as to make right choices on which teaching methods could contribute to effective teaching and learning,
- to form a basis on which to build teaching strategies which allows for professional decisions that are likely to make more effective teachers (Sanders, 1988).

Below are some detailed explanations on each learning theory that were considered in the design of the computer package.

2.3.2 What is situated cognition?

The focus of situated cognition is on relevance and transfer of information learnt in a specific situation to different situations in life (Anderson, Reder and Simon, 1997 and Watson, 1998) and its importance of learning within the context of real-world applications (Herrington and Oliver, 1997). This is different to the traditional method of teaching and learning where much of the knowledge taught in schools is not retrievable in real-life and does not involve real-life problem-solving contexts, because the traditional approach ignores the interdependence of situation and cognition (Herrigton and Oliver, 2000). Herrigton and Oliver contend that when learning and context are separated, knowledge itself is seen by learners as an end product of education rather than as knowledge to be used to solve problems in real life. However, they argue that it is not suggested that formal instruction should be abandoned in favour of the situated cognition approach. Rather, it is important to determine the pedagogical significance of the findings from situated learning which could promote appropriate and effective classroom techniques and practices in promoting meaningful learning. This could be achieved if the theory of situated cognition is researched and developed for practical classroom applications.

The theory of situated learning describes the way in which learning is linked to the situation or context in which it takes place (Lave cited by Boaler, 1998). Situated learning occurs when learners work on authentic tasks that take place in real-world setting (Harley, 1993 and Jonassen, 1994), whereby learning becomes a function of the activity, context and culture in which it occurs (Lave and Wenger, 1991, McLellan, 1996 and Lave, 2002). Secondly, situated learning focuses on the connection between school situations and real world situations (Wofson and Willinsky, 1998) where one needs to use the knowledge learned. There has to be a relationship between what is learned in the classroom and what is needed outside of the classroom (Watson, 1998). That is why learning theorists who support the ideas of situated cognition suggest that learning must be set in contexts which have meaning for the learners so that they can understand new concepts and establish ideas by using real life examples. In doing so, learning of concepts is claimed to improve if the learning is situated in a context, which is meaningful to the learners (for more detail see table 4 on page 28).

2.3.3 Research findings on situated learning

Research findings are equally important as theories of learning because one is able to learn from the experiences of others on effective classroom teaching, thereby avoiding making or repeating the same mistakes that others have made.

Boaler conducted ethnographic, three year qualitative case studies (Eisenhart, 1988) in two schools in the United States of America, where she wanted to monitor the relationships between the learners' day-to-day experiences in classrooms and their developing understanding of mathematics. She found that at one school where booklets and textbooks were used for teaching, the learners developed an inert, procedural knowledge that was of limited use to them. They could not use the knowledge in any other situation than the textbook. On the other hand, the school that encouraged learners to take responsibility for their own action and to be independent thinkers had lessons with a relaxed atmosphere and allowed learners to work on open-ended projects acquired some learning that was usable. According to Gibson (cited by Boaler, 1998), the learners at this second school were able to use the knowledge acquired in their instruction because of the willingness and ability to perceive and interpret different situations and develop meaning from them. Further, they could relate to the knowledge acquired, had sufficient understanding of the procedures and had confidence that enabled the learners to adapt and change procedures to fit new situations. According to Boaler (1998), the study showed some indications that the traditional way of teaching was ineffective in preparing learners for the demands of the real world and was no more effective than a process-based approach for preparing learners for traditional assessments of content knowledge. She concludes that a traditional textbook approach that emphasises rules and procedures, at the expense of depth of understanding, is disadvantageous to learners because it encourages learning that is inflexible, school-bound, and of limited use.

2.3.4 The situation of the teacher in situated learning

The link between the classroom and the real world viewed in situated learning means that the teacher is no longer regarded as the only expert of knowledge in the classroom situation. The teachers' role changes from that of depositor of knowledge to that of a facilitator and guide (Watson, 1998; Wofson and Willinsky, 1998, and Cobb and Bowers, 1999). The teacher forms part of a team of mentors and guides for learners, and is as much a facilitator of the situation of learning, able as such to draw on the experience of the mentors in arriving at an assessment of the learning that has taken place in the learner (Watson, 1998 and Anderson, Reder and Simon, 1996 and 1997). Most of the time, the teacher spends time helping groups and individuals meet the demands of their tasks. In this teaching approach, the teacher does not become the centre of the teaching process, but rather involves the learners as well in the activities.

2.3.5 Constructivism

As much as it is important to situate the content with what learners already know, making sure that learners have constructed what they are learning is also crucial in effective teaching and learning. According to Jaworski (1994: 14) *"constructivism is a philosophical perspective on knowledge and learning"*. Constructivism is concerned with the process of how learners construct meaning and knowledge in the world as well as with the results of the constructive process (Reeves and Hedberg, 2001). Constructivism views knowledge not to be about the world, but rather as a constitutive of the world. This entails that knowledge is not a fixed object, but it is constructed by an individual through her own experience of that object. As a result, constructivist theory of learning acknowledges that individuals are active agents who engage in their own knowledge construction by integrating new information into their schema, and by associating and representing it into a meaningful way (Driscoll, 2000a).

But while it is important for educators to understand constructivism, it is equally important to understand the implications this view of learning has for teaching and teacher professional development. It is argued that how learners construct knowledge depends upon what they already know, their previous experiences, how they have organised those experiences into knowledge structures and the beliefs they use to interpret the objects and events in the world (Reeves and Hedberg, 2001). Learners learn situations with knowledge gained from previous experience, and that prior knowledge influences what new or modified knowledge they will construct from new learning experiences. Secondly, learning is an active process rather than passive. Learners confront their understanding in light of what they encounter in the new learning situation. If what learners encounter is inconsistent with their current understanding, their understanding can change to accommodate new experience. Learners remain active throughout this process: they apply current understandings, note relevant elements in new learning experiences, judge the consistency of prior and emerging knowledge, and based on that judgment, they can modify knowledge (Driscoll, 2000a).

Therefore, constructivism's central idea is that human learning is constructed and that learners build new knowledge upon the foundation of previous learning. This view of learning sharply contrasts with the traditional approach in which learning is based on passive transmission of information from the teacher to the learner, a view in which reception, not construction, is a major key (Kelly, cited by Cohen and Manion, 1994, Jaworski, 1994 and Driscoll, 2000b). The constructivist approach proposes that individuals construct knowledge by modifying their experiences. In the process of construction, individuals build their own meaning and ideas in a way that these fit with real-world experiences and surroundings. In so doing, learners need to construct explanations which fit the situation they have encountered, emphasising the way learners come to know rather than about the knowledge being learned.

Constructivism has important implications for teaching. According to the constructivist theorists (Lave, 1991; Anderson *et al.*, 1997; Watson, 1998; Boaler, 1998 and Driscoll, 2000a).

- teaching cannot be viewed as the transmission of knowledge from enlightened (teacher) to unenlightened (learner). The teacher does not make all the decisions and dump the information on learners, rather learners are involved in the process of learning. The teacher gives guided instructions that puts learners at the centre of learning process by providing guidance and teaching whenever necessary.
- since learning is based on prior knowledge, the teacher notes that knowledge and provide learning environments that exploit inconsistencies between learners' current understandings and the new experiences before them.
- since learners must apply their current understandings in new situations in order to build new knowledge, teachers must engage learners in learning, bringing learners' current understandings to the forefront. Teachers can also encourage group interaction, where the interplay among participants helps individual students become explicit about their own understanding by comparing it to that of their peers.
- since learning is an active and a constructive process, instruction must be designed to provide opportunities for such construction. (See table 4 for more details)

2.3.6 Meaningful learning

Thirdly, it is important to note that learners are not blank slates and therefore, learning must be meaningful to the learners. Learners participate in tasks with performed cognitive structures. During learning, they expand and revise these structures based upon the new experiences to which they are exposed (Heinze-Fry, Crvello and Novak, 1984). The most important factor that influence meaningful learning is what the learner already knows.

Therefore, Meaningful learning *"takes place if the learning task can be related in a nonarbitrary, substantive (nonverbatim) fashion to what the learner already knows, and if the learner adopts a corresponding learning set to do so*" (Ausubel *et al.*, 1978: 27). It means that learning will only be meaningful if the new idea or concept to be learned is consciously related the relevant concepts which the learner already knows (Ausubel, 1963). In order for learners to acquire meaning in their learning, there should be potentially meaningful material and meaningful learning environments.

Table 4 summarises how learning takes place and what kind of activities a teacher needs to use when using situated learning approach to teaching.

SITUATED LEARNING	
Definition	• Emphasis the importance of learning within the context of real-world applications (Herrington and Oliver (1997) and Lave (2002). • Is the learning of skills in contexts that reflect the way the knowledge will be useful in real life (Collins, 1988; Anderson *et al.*, 1996 and Herrington and Oliver, 2000).

Instructions	• Instruction for the acquisition of knowledge needs to be presented and learned in an authentic context, i.e. settings and applications that would normally involve that knowledge (Lave, 1991) . • Direct instruction towards social interaction and collaboration (Lave and Rodoff cited by Cobb and Bowers, 1999).
How learning takes place	• Learning occurs as a function of the activity, context and culture in which it occurs, it is situated (Lave, 1991; McLellan, 1996; Collin cited by Herrington and Oliver, 2000; and Anderson *et al.,*, 1996). • Knowledge is constructed through interacting between learners, learning activities and situations (Driscoll, 2000b and Lave, 2002).
Types of activities necessary for learning.	• Provide activities which have real-world relevance (Herrington and Oliver, 2000). • Provide ill-defined activities (Herrington and Oliver, 2000). • Provide activities that require social interaction (Lave, 2002).
CONSTRUCTIVISM	
Definition	• *Knowledge neither come performed in the genes nor in the environment, but is actively constructed by the developing individual* (Saxe, 1991: 13). • Learners actively construct knowledge for themselves by inventing their ideas as each learner individually and socially construct meaning as he or she learns (Jaworski, 1994 and Driscoll, 2000a).
Instructions	• Instruction must be concerned with the experiences and contexts that make the learner willing and able to learn (readiness). • Instruction must be structured so that it can be easily grasped by the learner • Instruction should be designed to fill in the gaps by going beyond the information given (Bruner, 1985). • Instruction should be directed to encourage learners to discover principles by themselves. Learners should engage in active learning.
How learning takes place	• Learning is as a result of mental construction which involves problem solving, reasoning, critical thinking, and the active and reflective use of knowledge (Driscoll, 2000b). • Learners learn by fitting new information together with what they already know and when they actively construct their own understanding. • Learning is an active process in which the learners construct new ideas or concepts based upon their current or past knowledge (Bruner, 1985). • Learning is not the passive acceptance of knowledge which exists out there but learning involves the learners engaging with the world.
Types of activities necessary for learning	• Activities that engage the mind (mental) • Activities that require physical actions, hand-on experience • Activities that engage learners in talks, discussions etc. • Activities that involve multiple representations of reality that reflect the real world complexity ((Jonassen, 1994). • Activities that requires the process of knowledge construction (Jonassen, 1994). • Activities that provide real-world settings and provide reflection on experience (Chen, 2001).
MEANINGFUL LEARNING	
Definition	• *Meaningful learning involves the acquisition of new meanings, and new meanings, conversely, are the products of meaningful learning* (Ausubel *et al.*, 1978: 41). • Learning will only be meaningful if the new idea or concept to be learned has personal relevance to the learner he/she already knows (Ausubel, 1963 and Sanders, 1999).
Instructions	• Instruction for meaningful learning should link with the real-word knowledge of learners (Sanders, 1999).
How learning takes place	• Learning happens when the material has a particular pattern or purpose and is related to the corresponding relevant ideas (Ausubel *et al.,* 1978).
Types of activities necessary for learning	• Activities that has relevancy to the learners. • Activities that require the application of what learners already knows.

2.4 PROFESSIONAL DEVELOPMENT OF TEACHERS TO MEET *CURRICULUM 2005* REQUIREMENTS

The new curriculum demands that teachers meet the requirements and demands discussed in 1.4. However, teachers have experienced difficulties in making these changes. According to Chisholm (2000) the implementation of *Curriculum 2005* has been hampered by;

- the complex structure and design of the curriculum,
- the inadequate quantity and poor quality of training provided,
- the poor quality, the lack of availability and the lack of training in the use of learning support materials,
- the inability of provinces to support implementation, especially teachers in classrooms,
- the lack of human and financial resources and unrealistic time-frames.

As a result of the above problems, teachers have been faced with many challenges in the implementation of the new curriculum in their classrooms (Newstead and Bennie, 1999; Roux, 1999; Taylor and Vinjevold, 1999; Themane and Mabasa, 1999; Khulisa, 2002 and Pillay and Sanders, 2002). Teachers need to be able to,

- use learner-centred activities in their lessons,
- prepare lessons (assessment practice, lesson plans, outcomes),
- carry out instructional practices or handle classroom teaching approaches (learner-centred and the production of teaching aids),
- teach paced learning,
- use relevant examples,
- interpret the specific outcomes,
- teach the content, and
- develop a conceptual understanding,.

In order to overcome such challenges and difficulties that teachers are experiencing, there is need to provide a progression of training for the teachers who are implementing the changes in the classrooms. This is important because the implementation and success of any curriculum innovation lies with the teachers and the provision of professional development becomes crucial (Sanders, 1999). According to Hargreaves and Lo (1998: 4) *"it is teachers, more than anyone, who are expected to ..... develop the capacities for innovation, flexibility and commitment to change that are essential....."*.

The difficulties that teachers have been experiencing in making changes demanded by the new curriculum based on learner-centeredness (Black and Atkin; Van den Akker cited by Sanders, 1999) are partly because of poor qualification as outlined earlier. According to Fleisch, *"there were deeper problems beneath the teacher performance crisis, aided by the fact that educators were poorly prepared during pre-service training"* (The Teacher Newspaper, 1997). For instance, The review of Curriculum 2005 reported that *"although most teachers received some form of training, the training was generally regarded as insufficient and at times inappropriate"* (Chisholm, 2000: 7). A study on the understanding and implementation of *Curriculum 2005* in some primary school classrooms in KwaZulu Natal and

Mpumalanga provinces in 1998 showed that some teachers felt that their preparation for *Curriculum 2005* implementation was inadequate and incomplete (Jansen, 1999a/b). Themane and Mabasa (1999) reviewing the literature also claimed that even after workshops in 1998, teachers still did not know what was expected of them in the classrooms because they were not well trained to implement *Curriculum 2005.* This reduces the level of confidence in teachers to engage in professional development.

Secondly, Sanders (2000) argues that the government has placed responsibility for the success of *Curriculum 2005* and the development of materials squarely on the shoulders of the teachers. Teachers are expected to be equal partners in the development of programmes and materials. This has been a huge responsibility for teachers who are not trained for *Curriculum 2005* and who are poorly qualified to undertake these demands without help (Rogan, 2000).

This study was carried out to try and assist teachers to meet the requirements and demands of *Curriculum 2005*. A computer package was developed which integrated learner-centred activities and real-life examples to teaching human population dynamics. The next chapter looks at the development of the package before it was administered to the teachers and expert reviewers.