Chapter 2
Literature study

2.1 Introduction

Even though using computer technology as a cognitive tool constitutes a departure from the way in which technology has traditionally been used in education, it will be useful to reflect on the various learning theories on which the use of educational technology is based. This will facilitate a more extensive understanding of how instructional technology has come to be used as a cognitive tool that is able to model thinking, rather than one that simply delivers subject matter for students to absorb.

What follows is a discussion of the various learning theories that have informed technology-based instructional design with particular emphasis on those that have encouraged the use of technology as a cognitive tool. This discussion begins with an outline of the behaviourist approach to learning and instruction, which highlights overt observable behaviour and an objective instructional goal. This is followed by an exploration of cognitive learning theories, which emphasise the mental processes involved in learning. These theories are discussed extensively as they are relevant to a discussion that focuses on using technology as a cognitive tool. An analysis of the various theories is concluded with an exploration of constructivist learning theories that focus on individual learners who construct their own knowledge. The latter will be discussed in detail as cognitive tools are widely considered to have evolved from a constructivist approach to instruction and learning. Using technology as a cognitive tool has been both informed by and has been a reaction to many of the principles that are embodied in the above-mentioned learning theories. The discussion that follows, in 2.2 of this chapter, attempts to place the relationship between the various learning theories and the employment of computer technology as a cognitive tool in context.

Because this study focuses on conjectures and principles related to a learning environment that aims at facilitating higher-order thinking skills, a discussion of higher-order thinking is presented. This discussion includes a definition of higher-order thinking together with issues related to critical thinking, social interaction and problem-solving.

Using computers as a cognitive tool to model understanding that will bring about conceptual change is the focus of the discussion on employing technology as a tool to enhance the capabilities of the mind during the learning process. This discussion places particular emphasis on constructing computer-based expert systems to model both domain and conceptual knowledge. The section concerning expert systems includes a definition of an expert system as well as how it can be used as a cognitive tool. The components of an expert system are outlined in order to explicate the essential parts of its construction.

Both design-based research and grounded theory form an important part of the research design for this study and a comprehensive understanding of these approaches is required to understand their applicability and utility fully. The chapter concludes with an exploration of design research and grounded theory. The reasons for these research methods and theories being appropriate to this study are clarified during this investigation.

2.2 Learning theories applicable to educational computer technology

What follows is a discussion of the various learning theories that have had the greatest impact on computer technology use in education. These theories are behaviourism, cognitivism and constructivism.

2.2.1 Behaviourism

The first part of the twentieth century was dominated by behaviourist learning theories that contended "that learning involves the formation of associations between stimuli and response" (Schunk 1996, p. 12). Boyle (1997, p. 9) states that the "central feature of behiorism is extreme reductionism". This reductionism involves reducing the psychological study of behaviour to "overt observable behavior" and then to offer an explanation of this behaviour in terms of certain fundamental laws of learning such as operant conditioning (ibid.).

2.2.1.1 Emphasis on observable behaviour

Behaviourists are mainly concerned with overt behaviour and therefore they consider the cognitive activities that may lead to these behaviours to be of little consequence when they endeavour to explain this behaviour (ibid.). This is supported by Alessi and Trollip (2001, p. 18) who indicate that Skinner, one of the leading proponents of behaviourism, is of the opinion that any endeavours aimed at understanding memory, beliefs or the mind are superfluous and can even detract from the study of learning. According to them Skinner advises that the adoption of "strict behavioral principles could improve education dramatically" (ibid.). Skinner maintains that only environmental events and behaviour that are able to be observed are of any importance in the study of learning (Alexander 2006, p. 67). This view is supported by Schunk (1996, p. 64) who asserts that Skinner raises objections to those cognitive approaches that emphasise the way in which people process information. Schunk (ibid., p. 87) maintains that a behaviourist approach to instruction involves shaping. This is a process in which the objectives of the instruction are clearly defined and the student's entry behaviour is determined. Various sub-steps, each being a slight modification of the previous one, are then formulated. These are designed to lead the student from the entry behaviour to the desired behaviour.

Instruction based on behavioural principles of learning, therefore, is predominantly concerned with the design of learning events that result in demonstrable behavioural change. Uden and Beaumont (2006, p. 5) concur by stating that “learning in behaviorism is defined as a change in the probability of an observable behavior”. The emphasis is primarily on the role of instruction in the learning process in which the learner is relegated to the role of a passive recipient of information. Uden and Beaumont (ibid., p. 5) maintain that in behavioural learning, learners are “reactive to the conditions in the environment as opposed to taking an active role in discovering the environment”. Minimal attention is paid to individual learners because the focus falls on a transfer of the objective body of knowledge that exists outside of the learner that then leads to a predictable behavioural change. The purpose of learning is to achieve a predetermined reaction from the learner who is presented with a stimulus (ibid.). Instructional design models have traditionally been built on behaviourist principles operating on the assumption that desired outcomes and definitive conditions can be determined by the analysis of a situation. Teaching strategies that utilise the “repetitive conditioning of learner responses” subscribe to the behaviourist approach to instruction (Dalgarno 2001, p. 184).

2.2.1.2 Instructional System Design

Behaviourist learning theories led to the formulation of the Instructional System Design (ISD) approach, which was aimed at producing a large volume of effective instructional material primarily aimed at the acquisition of skills in adult learners (Alessi & Trollip 2001, p. 18; Boyle 1997, p. 68). Boyle (ibid.) maintains that even though this approach to instructional design has been widely criticised and rejected, it remains useful for designers to understand this perspective and the reasons for the censure. The ISD approach focuses on behavioural objectives, determining learning tasks and adapting teaching strategies depending on the learner’s performance. Instructional Systems Design provides prescriptive guidance for the design of instruction and prescribes three main stages in the development of instructional material (ibid.). These stages are "needs analysis, selection of instructional methods and materials, and evaluation" (ibid.). A precise evaluation of the nature of the task takes place during the needs- analysis stage and involves the identification of every sub-task that students are required to perform, as well as every item of knowledge that they are required to assimilate (ibid.). This systematic analysis provides a clear map that outlines the learning process, which learners can follow to acquire knowledge. Learning objectives are clearly stated in terms of measurable outcomes that can be assessed using a series of tests "which will indicate whether or not each learning objective has been met" (Boyle 1997, p. 69). Instructional methods and resources are selected once the learning objectives have been specified. Methods used to achieve the instructional objectives are prescriptive and consist of a sequence of steps that need to be followed (ibid.). Formative assessment is used to develop prototypes of the learning program. This is an iterative process and is done until the specified standard of performance has been achieved, after which the learning program is made available for general use (ibid.). Mastery of the learning objectives is determined by an evaluation of observable target behaviour (Alessi & Trollip 2001, p. 19).

2.2.1.3 Behaviourist teaching and learning environments

Established educational practices within a traditional classroom have concentrated on behavioural learning (Uden & Beaumont 2006, p. 5). Conventional teacher-centred approaches to instruction are based on the "direct instruction model" (Neo 2003, p. 294) that places the teacher in control of the instructional process. In this approach the teacher delivers content to the learners with an emphasis on factual knowledge. This information is communicated to students in a classroom situation where they are meant to absorb information passively (ibid.). There is little active engagement with the learning material or with the learning process due to the fact that the focus is predominantly on the subject matter that the lecturer presents to the student and on how much of this material the student has learnt (ibid.). Teacher-centred instruction has resulted in traditional education being described as a mindless experience through which students passively receive information and are required to demonstrate only simple recall and superficial understanding during various levels of assessment (Tan, Aris & Abu 2006, p. 141). A behavioural approach to learning does not seem to explain or cultivate the acquisition of higher-order thinking skills adequately but is more suited to learning that involves the recall of facts, applying explanations and performing a specified procedure (Uden & Beaumont 2006, p. 5). This is supported by Ally (2008, p. 20) who suggests that behaviourist instructional strategies can be used to teach facts; cognitive instructional strategies are suited to teaching processes and principles and constructivist strategies are suited to the development of higher-level thinking that promotes personal meaning, as well as situated and contextual learning.

2.2.1.4 The influence of behaviourism on computer-assisted learning and teaching

Traditional computer assisted instruction has primarily involved content presented to the learner in the form of structured tutorials, followed by assessment questions that determine the extent to which the learner has assimilated the material (Dalgarno 2001, p. 185). These computer-assisted interventions have included drill and practice of content aimed at transferring knowledge to the learner through repeated reinforcement (ibid.). This reinforced the belief that there is a proper sequence to assimilating information and that this sequence can be transferred to all learners on the assumption that it is an ideal learning model (Young 2003, p. 3).

Alessi and Trollip (2001, p. 37) maintain that instructional software based on behaviourist learning principles is often uninteresting, uninspiring and the learning that takes place is difficult to transfer to novel situations. They emphasise that a behaviourist approach to instruction places little value on the learners' requisite to adjust to their environment, to be creative and to work collaboratively with others. Traditionally, the deployment of technology in education has been built around the communication and retention of objective knowledge and skills that are passively received by learners (Young 2003, p. 2). This knowledge has been presented to learners out of context and has incorporated a degree of “technical rationality” that is expected to “address predetermined” objectives (ibid., p. 4). The designs of these computer-assisted learning programs have been based on objectivist beliefs that regard reality as existing independently of the learner. These designs presume an explicit outcome, inflexible achievement and the “application of concrete instances” (ibid. p. 3). Clearly this type of instructional design is based on the behaviourist assumption that learners react predictably to external stimuli (ibid.). Jonassen (2006, p. 1) suggests that educational technologists usually assume that if instruction has been properly designed, inserted into computer applications and then presented to students they would learn the content as the instructional designer has intended. Implicit in this thinking is the notion that computers are able to communicate content and opinions as effectively as a teacher and the better this communication, the more effectively students will learn. Jonassen (ibid), however, points out that people learn from thinking, not from technology.

2.2.1.5 Critique of behaviourism

Boyle (1997, p. 68) indicates that ISD has fallen “into disfavor on many quarters”. The behavioural emphasis of the ISD approach to instructional program development has been criticised for ignoring important aspects of learning that cannot be directly observed, such as “thinking, reflection, memory and motivation” (Alessi & Trollip 2001, p. 19). ISD has also been criticised for placing insufficient emphasis on the learner and focusing primarily on the instructional material. Boyle (1997, p. 70) also maintains that this type of instructional design is considered to be “over-prescriptive and mechanical”. The prescriptive and sequential nature of instructional systems design seems to contradict the view that learning is a dynamic process during which people are encouraged to construct their own knowledge (Alessi & Trollip 2001, p. 19). Setting instructional goals, employing instructional strategies and then assessing the effectiveness of the instructional event are clear indications of an objectivist approach to the transmission of knowledge. In this approach learning is considered to be a process that involves the "transmission and acquisition of knowledge structures which exist independently of the learner" (Boyle 1997, p. 71).

Though Schunk (1996, p. 97) points out that a behaviourist approach to learning has many advantages, he raises various objections. Firstly, behaviourism disregards the role that human understanding plays in learning. Secondly, Skinner's behaviourism makes no distinction between learning and performance. Schunk (ibid.) indicates that "performance may not accurately reflect learning because factors can intervene between learning and performance". He goes on to state that learning and performance need to be separated because people often learn "without demonstrating learning at that time" (ibid.). Thirdly, the necessity for reinforcement as a prerequisite for learning has been questioned, therefore he suggests that reinforcement primarily has a motivating influence on human behaviour rather than being a "response strengthener", as assumed by Skinner. The fourth area of criticism involves minimising the incidence of errors. Schunk (ibid.) suggests that this may not always be desirable as it is possible to learn from occasional failure.

2.2.2 Cognitivism

The cognitive approach to learning emphasises the internal processes involved in learning and understanding and incorporates mental structures and processes into a theory of learning (Alessi & Trollip 2001, p. 19). Attention is focused on learning as a process and the student's role in facilitating this learning process (Uden & Beaumont 2006, p. 6). A cognitivist approach to the study of learning challenges the limitations of behaviourism, which focuses on objective observable behaviour. According to cognitivist theories of learning, an understanding of the inner workings of the mind is a necessary part of understanding how people learn, as people are not merely programmable entities that respond to external stimuli (ibid.). It is not what people do that is important, but rather what they know and how they come to acquire that knowledge (ibid.).

Cognitive learning theories are concerned with the distinct changes in the form that knowledge takes in the mind of the learner and not with the likelihood of a certain response (ibid.). Internal constructs are identified in the cognitivist approach to learning and include “the mind, memory, attitudes, motivation, thinking” and reflection (Alessi & Trollip 2001, p. 19). Uden and Beaumont (2006, p. 3) expand on this by stressing the inclusion of cognitive processes such as concept formation, reasoning and problem-solving among these unobservable constructs. This is in contrast to the behaviourist approach to learning which seems to discourage the study of the thinking process, by emphasising observable changes in behaviour.

There are various schools of thought within the cognitive learning approach, inter alia the information processing approach, semantic networks and schema theory (Alessi & Trollip 2001, p. 19). The most influential of these approaches seems to be the information processing approach (Alessi & Trollip 2001, p. 19; Uden & Beaumont 2006, p. 6).

2.2.2.1 Information processing approach to learning

Dabbagh (2005, p. 26) maintains that from the information processing perspective “the mind manipulates symbols in the same manner that a computer manipulates data”. She goes on to suggest that this perspective appears to have its roots in both behaviourist and cognitive approaches to learning. Behaviourists could view input as the stimuli and the output as behavioural change while cognitivists would add cognitive processing as the “intervening and impacting variable between input and output” to account for the transformation that information undergoes in the learning process (ibid.).

In the information processing approach to learning, learning is defined as a process in which information enters through the senses. This information is then stored temporarily in the short-term memory where it needs to be used or organised before it can be stored in the long-term memory (Alessi & Trollip 2001, p. 19). According to Schunk (1996, p. 150) this approach assumes that learners select and focus on certain elements from the environment and then modify and rehearse this information. The new information obtained is then associated with or connected to existing knowledge and organised to make it meaningful. This suggests that the brain effects learning by utilising a system that processes information from the time it is perceived by the senses until it is stored in long-term memory (ibid.).

2.2.2.1.1 Stages of information processing

According to the information processing approach, processing occurs in three stages. These stages are related to the storage of information in the sensory register or memory, short-term memory and finally in long-term memory. Figure 2.1 illustrates the information processing processes of transferring information from the environment to the sensory register, short-term memory and then into the long-term memory.

2.2.2.1.1 (a) Storing of information in the sensory register

Representations of external environmental stimuli are briefly stored by the sensory register before they are transferred to the short-term memory (Schunk 1996, p. 151). Even though there is a separate memory associated with each of the senses, it is assumed that they all function in similar ways (Uden & Beaumont

2006, p. 6). Assigning meaning to stimulus input occurs in the sensory register and is known as the perceptual stage. Perception involves pattern recognition and entails connecting the input with previously stored information (Schunk 1996, p. 151).

Information processing

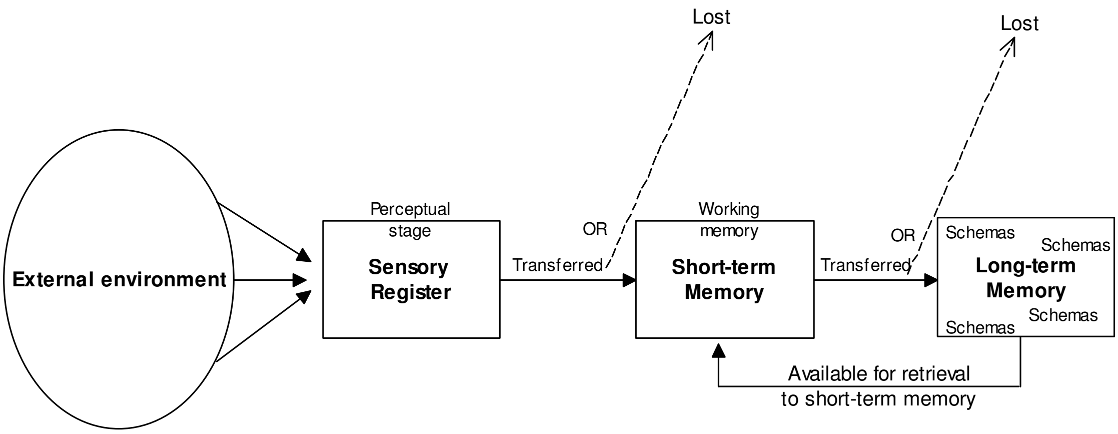

Figure 2.1 Stages of information processing according to the information processing approach to learning

2.2.2.1.1 (b) Storage of information in the short-term memory

The input from the sensory register is then transferred to short-term or working memory where the information becomes conscious to the individual who is then able to interpret and transform it (ibid.). Schunk (ibid.) indicates that working memory "corresponds roughly to awareness, or what one is conscious of at a given moment". If the stimuli are not transferred to short-term memory they are assumed to be lost and not available for further processing. Information can only be stored in short-term or working memory for a very short time before it is lost. Once in short-term memory the information undergoes further processing that allows it to be transferred to long-term memory (ibid.).

2.2.2.1.1 (c) Storage of information in the long-term memory

Information from short-term memory undergoes a process called semantic encoding that involves the integration of new and existing information that is then transferred to long-term memory (Uden & Beaumont 2006, p. 6). Long-term memory is thought to have a virtually unlimited capacity and is able to store information permanently and make it available for later retrieval (ibid.). Retrieval occurs when information from long-term memory is returned to working memory. Long-term memory is comprised of a network of related knowledge called schemata that provide "slots into which new knowledge is placed" (ibid., p. 7).

2.2.2.2 Schema learning theory

According to schema theory learners build cognitive constructs, referred to as schemas, to organise information in their long-term memory (Al-Issa 2006, p. 41). These schemas are based on an individual's experiences and cognitive processes; therefore they are context specific and unique (Louw & Edwards 1997, p. 291; Al-Issa 2006, p. 42). These schemata represent complex networks of information that are actively constructed by learners and revised or adapted when new information is presented to the individual (Al-Issa 2006, p. 42). Schemata facilitate assimilation of information as well as retrieval of information. Alexander (2006, p. 73) suggests that schemata "serve as the prototypes against which the world and its information can be judged".

From the schema theory perspective on learning, information is derived from two resources. One is information that comes from outside the individual and the other is information that has already been stored as part of long-term memory. Information accessed from outside the individual is considered to be data driven, because it is dependent on data accessed via the senses. Information stemming from prior knowledge, which affects our expectations, helps us to interpret this data-driven information. The part played by prior knowledge in interpreting this information is known as “top-down or concept-driven processing” (Louw & Edwards 1997, p. 294). Schemas influence the expectations an individual may have when encountering a situation, especially a familiar one (ibid.).

An individual's long-term memory is structured, using schemas, into “frameworks of meaning” and people assimilate information in a form that is most closely matched to these existing schemas (ibid. p. 292). When an event is recalled both episodic information about the event and generic information in the schema are relied or drawn on to interpret this information. Episodic information is information related to a specific “event or episode” (Louw & Edwards 1997, p. 289). Rebuilding a recalled event from familiar schemata implies that people do not remember perfectly; consequently there are usually distortions or inaccuracies involved in the recall. The more clearly a student can see how information fits into “existing frameworks of knowledge” (ibid.), the more effectively this information can be transferred to long-term memory (ibid., p. 294). This would then be an integration of information with existing knowledge rather than an attempt to learn information by rote (ibid.).

According to Piaget, people’s intellect allows them to make sense of their environment and to construct “useful mental representation” (McCown, Driscoll & Roop 1996, p. 31). An individual constructs meaning by arranging experiences, thoughts, emotions and behaviours into a “coherent system for constructing meaning” (ibid.). These structures change as information is incorporated into existing schemas. McCown, Driscoll and Roop (ibid. p. 32) suggest that one way in which existing schemas could change is through a process of simple assimilation.

2.2.2.2.1 Assimilation of information

Assimilation occurs when new information is incorporated into existing schemas without any changes in its basic structure. This would allow for information to be more clearly and easily understood as the information matches an individual's current understanding, making the task of comprehension less complex (ibid.).

2.2.2.2.2 Accommodation of information

When new experiences do not match existing mental structures, these structures would need to change. This process is known as accommodation and involves the modification or creation of new schemas when existing ones cannot assimilate the new information (ibid.). This implies that an individual's understanding is obliged to change to match the new experience (ibid.).

Schemata make provision for existing knowledge to be compared and contrasted with information that is still to be learned. This enables new information to be assimilated meaningfully within existing knowledge configurations while constantly restructuring these knowledge structures (Uden & Beaumont 2006, p. 8).

2.2.2.3 Critique of the cognitive approach to computer-assisted instruction

A cognitive approach to computer-assisted instruction emphasises the suitability of active learning and the importance of learner activities “being designed and selected to enhance the transfer of learning” or knowledge (Alessi & Trollip 2001, p. 31). Alessi and Trollip (ibid., p. 37), however, believe that the cognitive approach to learning has not given enough prominence to the importance of active learning. They suggest that a great deal of instructional software designed using cognitive principles has neglected to encourage learners to participate actively in the learning and focuses predominantly on processes that occur within the mind. Contrary to the belief that cognitivism succeeded or replaced behaviourism, Alessi and Trollip (ibid.) believe that it is "more of a merger" with behaviourist principles.

2.2.3 Constructivism

Dissatisfaction with behaviourist teaching strategies that involve repetition and conditioned learner responses together with a rejection of the objectivist assumptions, held by many cognitivists, of a single representation of knowledge, has led to the emergence of constructivist theoretical principles (Dalgarno 2001, p. 184). Constructivism is, however, not a single cohesive theory but is comprised of various schools of thought and perspectives (Schunk 1996, p. 209; Alessi & Trollip 2001, p. 31; Yilmaz 2008, p. 163). After an outline of the various constructivist assumptions, these schools of thought are discussed under the headings *exogenous constructivism*, *endogenous constructivism* and *dialectic constructivism*. Constructivism is also a philosophical approach (Alessi & Trollip 2001, p. 31) that seems to challenge an objectivist view of reality. It will therefore be useful to discuss constructivism under the headings *cognitive constructivism, radical constructivism* and *social constructivism* as these three positions are considered to be spread across the objectivist / subjectivist continuum.

2.2.3.1 Overview of constructivist assumptions

Dalgarno (2001, p. 184) suggests that there are “three broad principles that together define the constructivist view of learning”. The first principle is that individual representations of knowledge, based on individual experiences, are constructed by each person). The resulting assumption is that there are multiple representations of knowledge and not one single correct one. The second principle is that learning occurs when individuals encounter inconsistencies between their current knowledge structures and their experience through a process of active exploration. The third principle maintains that learning occurs as a result of interaction between people within a social context.

These principles are emphasised to differing degrees in the various schools of thought within the constructivist approach to learning. These are discussed under the headings *exogenous constructivism, endogenous constructivism* and *dialectical constructivism*. The philosophical foundations of constructivism are highlighted in the discussions under the headings of cognitive constructivism, radical constructivism and social constructivism.

2.2.3.1.1 The subjective nature of knowledge

Both cognitive and behaviourist theories of learning adhere to objectivist philosophical assumptions (Uden & Beaumont 2006, p. 10). An objectivist view proposes that there is an objective world that people are able to perceive with reasonable accuracy. The process of learning involves correctly interpreting this objective world via our senses and responding appropriately to its "objects and events" (Alessi & Trollip 2001, p. 31). Dalgarno (2001, p. 184) suggests that the "assumption, held by many cognitivists", which proposes that there is an objective reality that can be represented by learners, seems to have been gradually rejected by many constructivist thinkers. These constructivist thinkers propose that within each knowledge domain there may be numerous "individually constructed knowledge representations that are equally valid" (ibid.). Constructivists maintain that because people construct their own knowledge within their own minds, knowledge cannot be transferred objectively from outside the individual (Alessi & Trollip 2001, p. 31). The focus in a constructivist approach to learning would then shift from the transmission of objective knowledge to the construction of individual understanding.

Supporters of an objectivist approach to instruction, who are occasionally referred to as instructivists, propose that an instructional design model can be effective "to systematically identify what is to be taught, determine how it will be taught, and evaluate the instruction to determine if it is effective" (Kanuka & Anderson 1999, p. 5). From a constructivist perspective, there is nothing systematic about the way an individual constructs knowledge (ibid.). Alessi and Trollip (2001, p. 32) maintain that more conventional methods of instruction, "such as memorizing, demonstrating, and imitating, are considered incompatible with the notion that learning is a process of construction".

Constructivists see an instructivist approach to teaching and learning as an instant and simple solution to well defined educational problems that articulate clearly the breach between what is known and what should be known (Kanuka & Anderson 1999, p. 5).

2.2.3.1.2 Active construction of knowledge

Many educationalists have come to realise that instruction has been centred too closely on objectivist views that have resulted in learners being treated as though they are empty containers into which knowledge can be poured (Alessi & Trollip 2001, p. 32). Constructivists believe that education should "be viewed as learners actively constructing their own knowledge with teachers being coaches, facilitators, or even partners with learners in the learning process" (ibid.). Educational environments will then need to be designed in such a way that they support the construction of knowledge (ibid.). In a constructivist-learning environment, the emphasis will be on how individuals construct knowledge and on the notion that there is a variety of meanings that can be attached to any event or concept (Uden & Beaumont 2006, p. 10).

Because all constructivist approaches to instruction focus on active learning, learner activity is rated higher than the presentation of material (Alessi & Trollip 2001, p. 32). In constructivism, active learning involves exploration, experimentation, asking questions and searching for answers. Alessi and Trollip ibid., p. 33) argue that this differs from pure discovery environments, because instructors are required to be guides and partners in the learning process. Students construct their own knowledge by following a process of determining goals, devising plans, conducting research, “creating materials, evaluating them, and revising” (ibid., p. 33). Schunk (1996, p. 209) concurs that the concept of active learning stresses students’ “observing, collecting data, generating and testing hypotheses, and working collaboratively with others”. Meaningful comprehension of subject matter can only be achieved if learners “rediscover for themselves the basic principles” of the subject matter with which they are engaging (ibid.). Constructivist principles discourage instruction that merely delivers content that learners are required to absorb and supports the use of materials that promote the active involvement of learners through manipulation and social interaction (ibid.).

2.2.3.1.3 Context in which learning takes place

Learning and development cannot “take place in a vacuum but unfold in a specific time and place” (Alexander 2006, p. 84). Boyle (1997, p. 71) states that a significant “constructivist criticism of traditional school learning is that it is disembedded from” the learners' experience outside of the learning environment. Constructivists “argue that learning tasks should be embedded in problem-solving contexts that are relevant in the real world” (ibid.). This is supported by Alessi and Trollip (2001, p. 33) who maintain that because learning always happens within an environmental framework, learning is significantly affected by the context in which it takes place.

2.2.3.1.3 (a) Situated learning theory and anchored instruction

Schunk (1996, p. 209) suggests that constructivism emphasises the attainment of knowledge through an interaction between people and situations and indicates that situated cognition refers to the view that “thinking is situated (located) in physical and social contexts”. Anderson, Reder and Simon (1996, p. 5) point out that proponents of situated learning stress that “much of what is learned is specific to the situation in which it is learned”. They go on to indicate that greater "emphasis should be given to the relationship between what is learned in the classroom and what is needed outside of the classroom". This suggests that thinking and learning involve an association between a person and a situation, rather than being something that occurs merely in the mind. Herrington and Oliver (1995, p. 237) indicate that a situated learning environment "features the following characteristics":

"The environment will:

- *Provide authentic contexts that reflect the way the knowledge will be used in real-life;*
- *provide authentic activities;*
- *provide access to expert performances and the modelling of processes;*
- *provide multiple roles and perspectives;*
- *support collaborative construction of knowledge;*
- *provide coaching and scaffolding at critical times;*
- *promote reflection to enable abstractions to be formed;*
- *promote articulation to enable tacit knowledge to be made explicit;*
- *provide for integrated assessment of learning within the tasks".*

Allessi and Trollip (2001, p. 33) suggest that "the main implication of situated learning theory is that properly designing the situation in which learning takes place enhances transfer to other settings". They go on to point out that the anchored instruction approach to teaching and learning is often associated with situated learning theory and stresses that a learning environment "should be embedded in a context that is like the real world, with real world imagery, goals, problems, and activities". McCown, Driscoll and Roop (1996, p. 237) indicate that many constructivists suggest that in order to learn the skills and content of a particular discipline, a student would need to "engage in activities that are authentic to the discipline". When authentic activities are included in instruction, students are often able to see "the relevance of certain knowledge and skills, and then practice these skills in appropriate ways" (ibid.). A task can be authentic when learners are encouraged to think in the way people who are proficient in a particular discipline think. For instance, when students are asked to work out a mathematical problem, they are encouraged to think in the way a mathematician would (ibid.).

Under the influence of constructivist learning theory and in the light of the advancement of technology, the role of authentic activities in instructional design has been expanded "to the point where they are no longer relegated to the role of a vehicle for practice of a skill or process" (Reeves, Herrington & Oliver 2002, p. 562). Constructivist thinking regards the activity that students engage in as they study to be a central aspect of the curriculum (ibid.). This is in contrast to a more instructivist approach where activities are merely seen as a "vehicle for practice" (ibid., p. 563).

Schunk (1996, p. 212) suggests that situated learning is significantly linked to the study of motivation as this perspective advocates that motivation is not exclusively an internal state or "wholly dependent on the environment" but rather "depends on cognitive activity in interaction with social-cultural and instructional factors". Constructivists tend to view traditional learning environments as teaching simplified skills that cannot easily be applied to real world situations. This leaves learners unmotivated and unable to transfer what they have learnt to environments beyond the classroom (Alessi & Trollip 2001, p. 35).

Schunk (1996, p. 209) points out that constructivism differs from both behaviourism and the cognitivist perspective on learning, given that behaviourism emphasises environmental stimulus while cognitive viewpoints focus on processes that occur within the mind. The cognitivist perspective seems largely to ignore the context in which learning takes place (ibid.). An emphasis on context and social interaction is in contrast to the information processing perspective which emphasises the "processing and movement of information through mental structures" such as the sensory register, working memory, and then into long-term memory (ibid., p. 211). The information processing perspective largely disregards the importance of the situation or context subsequent to the reception of environmental input.

2.2.3.1.4 Collaborative learning

Constructivists consider learning to be an inherently social process, "because knowledge is distributed across individuals" (Mc Cown, Driscoll & Roop 1996, p. 239). Understanding is the result of learners accepting or rejecting the views of fellow learners and instructors while proposing ideas of their own, "and eventually build on or reconstruct the network of concepts and principles that make up their knowledge" (ibid.). The dialogue that is a consequence of a collaborative effort "provides students with the opportunity to test and refine their understanding in an ongoing process" (Uden & Beaumont 2006, p. 11). This is supported by Boyle (1997, p. 73) when he says that social "interaction is viewed as the primary source material for the cognitive constructions that people build to make sense of the world". Schunk (1996, p. 209) points out that the constructivists' emphasis on student activities involves "working collaboratively with others". Uden and Beaumont (2006, p. 11) support this by saying that collaboration "is essential because students learn through interaction with others". They go on to expand on this by suggesting that there are "two kinds of collaboration in constructivist learning: student-to-student and teacher-to-student". Collaborations could also enhance levels of motivation and improve metacognitive skills (Alessi & Trollip 2001, p. 34).

2.2.3.1.5 Emphasis on autonomous learning

In a constructivist approach the importance of giving learners choices of what and how to learn is stressed as well as the opportunity to act more autonomously (Schunk 1996, p. 209; Alessi & Trollip 2001, p. 35). Karagiorgi and Symeou

(2005, p. 19) maintain that empowering “students to make choices about how and what they will learn results in a shift from having all learners learning the same things to allowing different learners to learn different things”. The goals and activities of a learning intervention should be determined jointly by both the learner and instructor (Alessi & Trollip 2001, p. 35). Students are encouraged to be more self-regulated and to adopt an active approach to their learning through determining their own goals, assessing their own progress and by moving beyond the basic requirements through an exploration of their own interests (Schunk 1996, p. 209). This could effectively make these goals and activities more meaningful for the learner, while at the same time improving the learner’s awareness of the ways in which the material is being learnt (Alessi & Trollip 2001, p. 35). Alessi and Trollip (ibid.) suggest that learners should be encouraged to think strategically by determining ways in which learning goals can be achieved and what can be done when they encounter problems.

2.2.3.2 Different constructivist perspectives

Schunk (1996, p. 209) points out that constructivism “is not a unified perspective” but manifests in different forms. This is supported by Dalgarno (2001, p. 184) who maintains that, although “there is general agreement” concerning the basic assumptions of constructivism, “the consequences for teaching and learning are not as clear cut”.

2.2.3.2.1 Exogenous constructivism

The exogenous constructivist view holds that knowledge is reconstructed to represent an external reality; therefore, a learner’s mental structures develop to mirror the organisation of an objective world (Applefield, Huber & Moallem 2001, p. 6). An exogenous constructivist approach to learning supports the notion that a learner’s understanding is accurate depending on the extent to which it reflects the real world (Schunk 1996, p. 10). Schunk (ibid., p. 210) states that the influence of the external world on knowledge construction could be through experience, teaching and an exposure to models. The exogenous view of constructivism acknowledges the value of direct instruction while advocating that students should have a measure of control over the selection and sequence of the instructional content, as well as being given the opportunity to construct their own individual knowledge representations actively (Dalgarno 2001, p. 187). When direct instruction is used, it is important that provision be made for learners to have opportunities to put their knowledge into practice, as well as to receive feedback on their knowledge constructions (ibid. p. 190). Once classroom learning activities have taken place, learners should be encouraged to utilise their knowledge in realistic contexts (ibid.).

Dalgarno (ibid., p. 187) indicates that computer-assisted learning materials that have drawn on the exogenous approach “include tutorials that incorporate learner control over sequence” as well as “hypermedia browsing environments that include context sensitive pedagogical guidance”. Dalgarno (ibid.) suggests that the use of cognitive tools to support the construction of knowledge and to articulate understanding is consistent with an exogenous view of constructivism. Furthermore he indicates that by placing the emphasis on individual knowledge construction, constructivists stress the value of strategies “employed by the learner to improve their comprehension, retention and individual construction of knowledge”. Cognitive tools can be used to assist with these strategies (ibid., p. 189).

2.2.3.2.2 Endogenous constructivism

The endogenous constructivist view of learning proposes that knowledge is not constructed directly from environmental information, but rather from existing structures (Schunk 1996, 2009). This approach relies on a “learner directed discovery of knowledge” (ibid.) with a focus on the “individual nature of each learner’s knowledge construction process” (Dalgarno 2001, p. 185). In this view learners are required to negotiate the meaning of phenomena and experiences that are at variance with their existing mental structures or schemas (Applefield, Huber & Moallem 2001, p. 7). The discrepancy between existing knowledge and new experience creates an internal conflict that learners strive to resolve; this stimulates the construction of new knowledge (ibid.). Applefield, Huber and Moallem (ibid.) suggest that learners "may be said to author their own knowledge, advancing their own cognitive structures by revising and creating new understandings out of existing ones". The development of new understandings is achieved through discovery-orientated learning activities that are either socially mediated or individual (ibid.). The instructor needs to perform the role of facilitator by making available experiences or opportunities that are designed to challenge a learner's existing knowledge structures (Dalgarno 2001, p. 185).

According to Dalgarno (ibid.) hypermedia and hypertext that enable learners to browse content in a controlled way are informed by endogenous constructivism. Individual knowledge representations are formed when learners are able to browse content in a sequence that makes sense to them and over which the individual learner has complete control. This active exploration allows the learners to discover and construct their own individual knowledge base. Dalgarno (ibid., p. 186) proposes that simulations and micro-worlds can also present a lifelike environment in which students can explore and actively discover knowledge.

2.2.3.2.3 Dialectical constructivism

Dialectical constructivism proposes that knowledge is neither completely tied to an objective world nor purely derived from within the workings of the mind (Schunk 1996, p. 210). Rather, knowledge is constructed through interactions between people and the environment.

Dialectical constructivism implies that an individual's interaction with the environment results in contradictions, which lead to the construction of knowledge (ibid.). Applefield, Huber and Moallem (2001) suggest that dialectical constructivism “views the origin of knowledge construction as being the social intersection of people, interactions that involve sharing, comparing and debating among learners and mentors”. Within a social environment learners are able to establish their own meanings, while at the same time helping others to discover meaning (ibid.). As a consequence, knowledge is mutually constructed. The basic characteristic of dialectical constructivism “is collaborative social interaction” (ibid., p. 7), which differs from the cognitive constructivist focus on "individual investigation”. An individual's knowledge is constructed through a cognitive exchange which characterises social interaction (ibid.). Dialectical constructivism also places significance on the context in which learning takes place and considers it inseparable from the emergent knowledge constructions (ibid.). Dalgarno (2001, p. 185) suggests that dialectical constructivism advocates that learning takes place by means of realistic experiences and that learners need scaffolding, which is provided by both experts as well as through a process of collaborating with peers. The role of social interaction in knowledge construction is paramount in this approach to learning. This has led "to an emphasis on cooperative and collaborative learning strategies” (ibid., p. 190).

"Computer-supported collaborative learning tools" (ibid.) have been used to support collaborative and cooperative learning. These tools can be divided into three groups, “general purpose computer mediation tools, those that are designed for computer supported cooperative work and lastly those that have features specifically for group learning” (ibid.). Consistent with the dialectical constructivist perspective, computer-supported collaborative tools can be used to provide support or scaffolding as learners carry out tasks “at the edge of their capabilities” (ibid.).

2.2.3.3 Constructivism and the objective nature of knowledge

Due to the complex nature of the various forms of constructivism, Phillips (1995, p. 7) maintains that constructivism can be spread out along different axes or continua. He goes on to suggest that constructivism forms that are “close along one axis” could be “far along another”. The first axis concerns the cognitive apparatus used to construct knowledge and is concerned with the degree to which knowledge is individually constructed or socially constructed. The second axis addresses the issue of the nature of constructed knowledge, namely, whether knowledge is a reflection of what is created in the individual “knower’s” mind or it is imposed on an individual from outside. Phillips (ibid.) suggests that the latter axis lies at the heart of the constructivist debate and could in fact determine whether a certain approach to learning could be constructivist or not. Dalgarno (2001, p. 184) supports this when he suggests that the fundamental principle that defines a "constructivist view of learning" is "that there is no single 'correct' representation of knowledge" because individuals construct knowledge through experience. The third axis, as determined by Phillips (1995, p. 7), concerns the construction of knowledge as an active process. In this regard, Phillips (ibid.) indicates that “the activity can be described in terms of individual cognition or else in terms of social or political processes”.

Kanuka and Anderson (1999, p. 4) purport that constructivism falls along two dimensions. The first comprises a continuum with an objective reality at one end and a subjective construction of reality at the other. The second dimension has the social construction of knowledge at one end of a continuum and the individual construction of knowledge at the other. This dimension involves "the extent to which social, contextual, and cultural factors determine our constructed knowledge” (ibid.).

Doolittle (1999, p. 1) indicates that philosophically the essence of constructivism is dependent on an epistemology that relies on subjectivism and relativism, “the concept that while reality may exist separate from experience, it can only be known through experience, resulting in a personally unique reality". He goes on to point out that, broadly speaking, constructivism recognises four fundamental tenets of teaching, learning and the process of knowing. These are:

- Learners have an "active role in the personal creation of knowledge".
- Individual experience is important in the "knowledge creation process".
- Social experience is important in the knowledge creation process.
- The awareness that the knowledge created will "vary in its degree of validity as an accurate representation of reality" (ibid).

Different constructivist positions assign different weight to these tenets (ibid.). These will now be discussed under the headings *cognitive constructivism, radical constructivism* and *social constructivism*.

2.2.3.3.1 Cognitive constructivism

The cognitive constructivist view considers knowledge to be a reflection of an external reality which exists independently of the individual, but which is knowable to the individual (Doolittle 1999, p. 1). This approach to constructivism, therefore, is at the objectivist end of the continuum. It is considered to be a weak form of constructivism because it stresses only two of the four fundamental constructivist tenets (ibid.). These are that knowledge is both an active and an adaptive process (ibid.). Knowledge, from this perspective, results when learners accurately internalise or construct external reality (ibid.). Alexander (2006, p. 68) suggests that from the cognitive constructivist perspective, it is the idiosyncratic and personal nature of knowledge that is emphasised, irrespective of whether "knowledge results from the linear processing of information or is constructed from experience". The internalisation of knowledge leads to "cognitive processes and structures that accurately correspond to processes and structures that exist in the real world" (Doolittle 1999, p. 1). The cognitive constructivist view suggests that individuals construct mental models or schemas, based on their individual experience; “these experiences are then developed, modified and made more sophisticated over time” (Neo 2003, p. 295). The assertion that reality is able to be known by the individual, distinguishes cognitive constructivism from both social and radical constructivist perspectives. Learning is a process of internalising and constructing or reconstructing an objective reality and involves the construction of exact internal representations that correspond to the external structures that exist in the real world (Doolittle 1999, p. 2). Kanuka and Anderson (1999, p. 5) expand on this by pointing out that interaction with the environment will inevitably lead to encounters with phenomena that are inconsistent with an individual’s current knowledge structures. As the individual processes this new information into an integrated system, it is either consistent with pre-existing knowledge structures or it is inconsistent with these structures (ibid.). If the information is consistent with existing knowledge structures (schemata), it will be assimilated; if it is inconsistent it will be accommodated (ibid.). Knowledge is, therefore, constructed based on what the individual already knows. Cognitive constructivism emphasises the changes that occur as a result of information that is inconsistent with current understanding (ibid.).

The focus in this approach is on the procedures involved in the learning process, the way in which learning is represented in the mind of the learner "and how these representations are organized within the mind” (Doolittle 1999, p. 2). The construction of knowledge is, therefore, considered to be principally "a technical process of creating mental structures”, and has little to do with the "nature of the subjective knowledge within the mind" of the individual (ibid.). Kanuka and Anderson (1999, p. 5) suggest that the cognitive constructivist approach to learning assumes that individuals construct knowledge “through a reasoned integration of internal contradictions though our internal contradictions occur as a result of interaction with the environment”. The individual who continuously builds on prior learning consequently acquires an improved understanding of the external world (ibid.). Kanuka and Anderson (ibid., p. 5) describe this as “a dynamic and successive process". They go on to indicate that even though a cognitive constructivist approach is centred on "the individual, it does not" reject the significance of "social interaction" as it is within a social setting that "cognitive disturbances typically occur".

2.2.3.3.1(a) Cognitivism and cognitive constructivism

Both information processing theory, discussed under cognitivism, and cognitive constructivism consider knowledge to be "individually formed" and an "individual possession" (Alexander 2006, p. 68). These two approaches to learning view the storage of knowledge in the long-term memory to be central to the learning process. The distinction between the two learning theories seems a matter of difference in emphasis. The information processing theory focuses primarily on the mental processes that are involved in converting information into knowledge, while social constructivists "emphasize the manner in which human minds grow or develop biologically and socially" (ibid., p. 69). The cognitive constructivists' "developmental orientation to knowledge" is based primarily on Piaget's theories (ibid.). Piaget purported that cognitive development involves individuals progressing through various stages of mental maturation, with each of these stages being characterised by certain mental constraints and capabilities. Alexander (ibid., p. 69) maintains that each successive stage incorporates an "increased level of mental sophistication" which is "reflected in more complex constructions of knowledge". Even though not every cognitive constructivist considers mental development to involve developmental stages, "most accept that the level of mental maturation has a great deal to do with the information individuals can grab from their environments" (ibid.). She goes on to suggest that individuals' interpretations and constructions that eventually form their "mental histories" are effected by their mental maturation. From a cognitive constructivist perspective, educators should include only learning experiences and materials that are appropriate to the developmental stage of the learner (ibid.).

2.2.3.3.2 Radical constructivism

Radical constructivism operates from the assumption that, while an external objective reality may exist, it cannot be known by any individual (Yilmaz 2008, p. 164). This is because an individual's experience of external forms and objects is mediated by the senses and the senses do not have the ability to render a precise version of "these external forms" and objects (Doolittle 1999, p. 3). This represents the opposite end of the spectrum from that of cognitive constructivism. According to the radical constructivist perspective knowledge is adaptive in nature, therefore knowledge can never be representative of objective truth but it is always a viable representation of experience (ibid.). Von Glasersfeld (2008, p. 7) indicates that the "radical difference concerns the relation of knowledge and reality". Knowledge, in the traditional epistemological and cognitive psychological view, is seen as a "more or less picture-like (iconic) correspondence or match" to reality, while "radical constructivism sees it as an adaptation in the functional sense" (ibid.). Knowledge is, therefore, particular to the individual and not an objective depiction of an external reality. The improvement of knowledge is the process of improving viability in relation to the external world and not an attempt at matching an objective reality (ibid.). Knowledge can be considered to be something that an individual builds up in an attempt to bring order to the disorganised "flow of experience by establishing repeatable experiences and relatively reliable relations between them" (ibid., p. 18). Doolittle (1999, p. 3) holds the view that radical constructivism is considered to be a strong form of constructivism as it is concerned "with both the construction of mental structures, the position of cognitivists, and the construction of personal meaning".

Kanuka and Anderson (1999, p. 6) maintain that in a radical constructivist approach to learning, the teacher or facilitator needs to support what the learner resolves to do and be prepared to allow for "diversities of understanding within each learner". This point of view is augmented by Dalgarno (2001, p. 184) who indicates that radical constructivists maintain that learners need to be placed within the environment that "they are learning about and construct their own mental model, with only limited support provided by a teacher or facilitator". Derry (1996, p. 165) indicates that Von Glasersfeld, the leading proponent of radical constructivism, maintains that teachers should consider themselves to be "midwives who facilitate the birth of understanding, not as engineers of knowledge transfer". Multiple perspectives need to be accepted and encouraged as learners construct their own knowledge by engaging in activities that are authentic in the sense that they are analogous to the environment in which the learning will be applied (Kanuka & Anderson 1999, p. 6). This would seem to be consistent with the radical constructivist view that people construct knowledge based on their experiences within a particular environment and that no two individuals will ever have exactly the same experiences so each individual will construct knowledge in a different way. An individual's understanding is therefore embedded in his or her experiences and each person cannot possibly know exactly "what exists in reality as we can never compare our assumptions of realities with others" (ibid.). The responsibility rests with the learner to decide what will be learnt and how the learning will be achieved (ibid.).

2.2.3.3.3 Social constructivism

Social constructivism emphasises the social nature of knowledge as knowledge is considered to be constructed through a process of social interaction and the use of language. Neo (2003, p. 295) indicates that while cognitive constructivists focus largely on the "individual mental construction of knowledge", social constructivists emphasise the "social context of the learning environment". Knowledge is, therefore, a shared experience that is never entirely individually constructed (Doolittle 1999, p. 4). Kanuka and Anderson (1999, p. 8) state that the way in which an individual constructs knowledge has little to do with "truth validation" and that meaning is determined by patterns of unique "experiences that occur over time in a contextual, situated, and changing synthesis".

Knowledge is dependent on experience as the experience is “critical to the understanding of and ability to use that knowledge” (ibid.). The construction of knowledge requires an examination and understanding of the context in which it occurred (ibid.). It would, therefore, seem that what is known cannot be separated from the knower, as the two are interdependent.

The social constructivist view of knowledge construction appears to agree with radical constructivism regarding the existence of multiple realities but differs from this view that stresses the construction of knowledge as an individual process. The social constructivist view, therefore, seems to lie near the middle of the objectivist-subjectivist continuum. Social constructivists point out that any social interaction takes place within a specific socio-cultural context, linking knowledge to a particular time and place (Doolittle 1999, p. 4). The social constructivist view, therefore, maintains that knowledge comes about as a consequence of social interaction which is facilitated by language that takes place within a particular setting and that knowledge is not a purely individual experience that takes place within an individual's head (ibid.).

Doolittle (ibid.) maintains that social constructivism is considered to be a strong form of constructivism as it adheres to the following fundamental constructivist principles:

- Knowledge acquisition is an active process;
- understanding involves making sense of experience and does not entail an accurate representation of reality; and
- knowledge acquisition is a social process that takes place within a specific context.

Furthermore he points out that social constructivists do not place much emphasis on the mental construction of knowledge but rather stress the construction of meaning within a social context.

Instructional strategies that are consistent with the social constructivist view include those that encourage the exploration of multiple as well as varying perspectives and views (Kanuka & Anderson 1999, p. 7). Students should be prompted to test their understanding and perceptions against those of other members of the social group through a process of interpersonal negotiation and discussion. These interactions are intrinsically a rich source of conflict which has the effect of stimulating the knowledge construction process (ibid.).

2.2.3.3.3 (a) Scaffolding and the Zone of Proximal Development

Neo (2003, p. 295) maintains that the social constructivist approach emphasises the learners' Zone of Proximal Development, which is the process of developing understanding with the assistance of a more advanced individual when the learners are unable to do so on their own. Knowledge construction, therefore, takes place when learners interact with more capable peers "teachers and experts in a collaborative learning community" (ibid.). This is similar to the concept of scaffolding.

Schunk, (1996, p. 216) points out that although "scaffolding is not a formal part" of the Zone of Proximal Development theory, as proposed by Vygotsky, it fits comfortably within it. McCown, Driscoll and Roop (1996, p. 45) define scaffolding as the process whereby "a more advanced partner changes the degree and quality of support provided to the less skilled partner as he or she becomes more proficient". Schunk (1996, p. 216) indicates that instructional scaffolding refers to the process of controlling those elements of a learning task that are beyond the learner's current abilities so that the learner can concentrate on the elements of the task that can be quickly grasped. He goes on to suggest that scaffolding has five primary functions. These are "to provide support", to be used as a tool, to extend the range of the learner, to "permit the attainment of a task not otherwise possible" and to be utilised only when required. Initially the instructor will do the majority of the work until the learner is capable of sharing responsibility (ibid.).

The scaffolding can then be gradually withdrawn as the student becomes more competent and is capable of working independently (ibid.). It is important that the learner be kept within the bounds of the Zone of Proximal Development, which represents the amount of learning that the student is capable of, given the correct conditions (ibid.).

Marsh and Ketterer (2005, p. 3) state that social constructivists have placed a great deal of emphasis on the importance of the Zone of Proximal Development which, they suggest, has been "elevated to the status of quintessential core practice". McCown, Driscoll and Roop (1996, p. 45) argue that students' development may be impeded if they work without the assistance of a more capable peer and suggest that an "important implication of the Zone of Proximal Development is the emphasis it places on social interaction for facilitating development".

2.3 Computer technology as a cognitive tool

Instructional design has traditionally adopted a teacher-centred approach to teaching and learning that involves strategies that focus on how "teachers can partition and present content" in ways that enable learners to acquire knowledge (Hokanson & Hooper 2000, p. 543). There has, however, been a major shift from this teacher-centred approach to a more student-centred one to instruction that "attempts to engage students in activities that support knowledge construction" (ibid.). This is characteristic of a worldwide shift from a pedagogical approach that is based on behaviourist principles to a constructivist approach to learning that emphasises the construction of knowledge. Hokanson and Hooper (ibid.) suggest that this change has influenced the way in which computers are used in education and raises "the question; do we teach with computers or do students learn with computers?"

Jonassen (2006, p. xiii) is of the opinion that technology commonly makes an inadequate teacher and that in order to assist people to learn the focus must shift from the technology to the learning. Technology needs to assume a supporting role and must not assume the role of the teacher. He goes on to suggest that technologies “have the potential to enhance, expand, and amplify learning if we reconceptualise the ways that they are used”.

2.3.1 Technology in education - the traditional focus

Traditionally computers have been used to present instructional material to students and thereby assist them to achieve predetermined educational goals more effectively (Hokanson & Hooper 2000, p. 543). In this way computers are used as a tool that presents “prepackaged, unalterable pieces of instruction” (ibid., p. 548). Proponents of the inclusion of digital technology have commonly assumed that if an instructional designer constructs and embeds lessons in computer enabled learning material and then places these at the disposal of students, they will learn (Jonassen 2006, p. xiii). This implies that the role of technology is to communicate ideas and the better the technology is able to communicate these ideas, the better the potential for learning (ibid.). In this approach the focus is predominantly on the instruction and consequently on the technology, and not on the learner (ibid.).

To date computer technology has been used as an educational communication tool to convey information to students “with the assumption that they will learn something from these communications” (Jonassen & Reeves 1996, p. 693). These computer-mediated communications are developed by instructional technologists in conjunction with subject matter experts, often employing “systematic instructional design models” in order to “analyze develop, produce, and evaluate instruction” (ibid., p. 694). This systematic approach to instructional design has led to the creation of technological initiatives that allow students to receive and interact with messages that are encoded in the technology. The input from the student is then evaluated according to various pre-encoded criteria, which then elicit a pre-encoded response (ibid.). Jonassen and Reeves (ibid., p. 693) regard the use of technology in this type of technology-enabled instructional communication to be intrinsically unsound, as it does not perceive learners to be "active constructors of knowledge”.

2.3.2 A move towards constructivism

A technology-enabled learning environment that focuses on the presentation of instructional material is in stark contrast to constructivist learning environments that are both “student-centered and student-directed”, with scaffolding provided by an instructor in a collaborative and cooperative environment that challenges learners with authentic tasks (Karagiorgi & Symeou 2005, p. 19). Karagiorgi and Symeou (ibid.) suggest that a constructivist learning environment can involve various tools to enhance communication and access to authentic examples of the application of learning, “reflective thinking, multiple perspectives, modeling or problem solving by experts in a context domain and mentoring relationship to guide learning”. The focus of instructional designers, therefore, needs to shift from trying to make technology teach effectively, to considering how to encourage students to “think to learn more effectively” (Jonassen 2006, p. xiii). This shift will allow technology to be seen as a tool that supports meaningful learning, rather than a medium that communicates information to a relatively passive audience (ibid.). By scaffolding different forms of reasoning when engaging with various knowledge domains, computers can assist students to think about “what they know in different, meaningful ways” and will encourage them to think critically about what they are studying (Jonassen, Carr & Yueh 1998, p. 24).

2.3.2.1 Using computer technology as a cognitive tool: a departure from tradition

Jonassen, Carr and Yueh (ibid.) argue that technology should be used as a tool that learners learn with, rather than a medium of communication that acts like a teacher that instructs the learner. This would allow the learner to act as a designer and the computer to be used as a tool that interprets and organises their personal knowledge (ibid.). Computers would then function as an extension of the mind that supports and represents cognitive processes (Van Joolingen 1999, p. 389). When computers are used as instruments that support cognitive processes that extend people's cognitive capacity, they can be described as cognitive tools (ibid.). Jonassen and Reeves (1996, p. 694) maintain that considering computer technology to be a cognitive tool constitutes a departure from “traditional conceptions of instructional technologies”.

2.3.2.1.1 Technology as an intellectual partner

When using cognitive tools, learners become intellectually more capable than they would otherwise be (Jonassen 2006, p. 21). This is because the specific functions that the tool is more suited to are made the responsibility of the cognitive tool (ibid.). Making this the responsibility of the technology allows learners to “off-load some of the unproductive memorizing tasks to the computer", which would leave room for the learner to “think more productively” (ibid.). Kirscher and Wopereis (2003, p. 110) describe cognitive tools as “intellectual partners” and as “a partner in the learning process; they are responsible for that which they can perform best”.

Technology serving as an intellectual partner does not mean that these tools reduce the amount of information processing required of the learners, but rather that they support learning by allowing the learners to make effective use of their mental efforts (Jonassen 2006, p. 21; Jonassen, Carr & Yueh 1998, p. 30;

Kirscher & Wopereis 2003, p. 110). Using technology in this way would in fact require the learner to apply greater effort when engaging with the subject matter than they would without the use of the cognitive tool (ibid.). Jonassen (2006, p. 21) is of the opinion that this is because students cannot use cognitive tools "without thinking deeply about the content they are learning". Kirscher and Wopereis (2003, p. 110) point out that mind tools do not make learning easier but rather make it possible, because the limited capabilities of the human mind are enhanced when computers are used as cognitive tools. Hokanson and Hooper (2000, p. 548) seem to support this when they suggest that the computer's capacity to manipulate information and ideas is a significant "skill that humans can learn and apply as a cognitive strategy". Hokanson and Hooper (ibid. p. 549) maintain that "educational activities should be designed to stimulate cognitive effort and to integrate the computer into that effort". They go on to suggest that when using computers in education, more cognitive effort should be provided by the learner than is delivered by the computer (ibid.). The learner, who interacts with the computer, should be the provider of ideas, motivation and information (ibid.).

Cognitive tools are often generic tools that can be used within different settings and domains to facilitate cognitive processing and are not specifically designed for a particular purpose (Kirscher & Wopereis 2003, p. 110). Kirscher and Wopereis (ibid.) state that cognitive or mind tools are "critical thinking devices" that allow users to create new knowledge by thinking for themselves and making connections between concepts. They go on to indicate that "a mind tool is a concept" as it is a way of thinking about how computer technology can be used in a learning environment.

2.3.2.1.2 The use of cognitive tools as a constructivist approach to learning

The use of computer applications as cognitive tools represents a constructivist approach to learning as this approach discourages learners from reproducing what others have discovered but rather requires learners to represent, manipulate, and reflect on what they have conceptualised (Jonassen 2006, p. 21). Jonassen, Carr and Yueh (1998, p. 30) point out that using computer applications as a mind tool "represents a constructivist use of technology" as cognitive tools require learners to engage actively in interpreting the "external world and reflect on their interpretations". By actively engaging with a domain, learners "must participate and interact with the surrounding environment in order to create their own view of a subject" (ibid.). Van Joolingen (1999, p. 389) points out that learning processes are those entities that describe the activities an individual needs to engage in, to develop an understanding of a particular domain. He goes on to suggest that the basic entities of the learning process could be "to remember something, to practice a procedure, to solve a problem, to set a hypothesis or some other process". When these processes are properly executed they can contribute to the construction of knowledge by the individual (ibid.).

2.3.2.1.3 Conceptual change

Jonassen (2006, p. 3) proposes that meaningful learning needs to involve conceptual change and that this concept is rooted in constructivist learning theories. He goes on to suggest that conceptual change takes place when learners "change their understanding of the concepts they use and of conceptual frameworks that encompass them" (Jonassen 2006, p. 4). These concepts and conceptual frameworks form the personal theories that individuals construct to make sense of the world. Conceptual change may be viewed as, not merely the enrichment of knowledge, but rather as a learning process "that requires the significant reorganization of existing knowledge structures" (Vosniadou, Ioannides, Dimitrakopoulou & Papademetriou 2001, p. 383). According to Vosniadou (2007, p. 8) the conceptual change approach is a constructivist approach that presumes information to be "organized in domain specific, theory-like structures, and that knowledge acquisition is characterized by theory changes". Although the former approach to learning stems from attempts to explain theory changes related to science education, it is not limited to physics "but makes a larger claim about learning that transcends many domains" (ibid., p. 9). According to Vosniadou (ibid., p. 10), "the theories that need to be changed are not the student's misconceptions, but the naïve, intuitive, domain-specific theories constructed on the basis of everyday experience under the influence of lay culture". Knowledge is organised in structures that are theory-like and during the students' learning and development process these structures undergo dramatic reorganisations that "can be described as theory-changes" (ibid.).

Conceptual change can take place through an implicit mechanism or a deliberate and intentional learning intervention (ibid.). According to Vosniadou (ibid.) an example of an implicit mechanism would be the process of assimilation and accommodation. She goes on to point out that a deliberate learning mechanism aimed at facilitating conceptual change could involve the use of models . This would require systematic instruction and is likely to result in "hybrid or synthetic models" (ibid.). As the individual reflects on experience, an understanding of the world is modified (ibid.). Mental model building and reflection involve a reorganisation of knowledge and the addition of cognitive complexity to their understanding (Jonassen 2006, p. 4). An individual is able to engage with information only to the extent that this information is "comprehensible, coherent, and plausible according to that individual's existing conceptual model" (Jonassen 2006, p. 4). The context in which information is being experienced, together with the "learner's prior knowledge, individuality" and the degree to which the content is useful will influence the type and amount of conceptual change that takes place (ibid.).

It is unlikely that conceptual change will take place when a learner engages with information at a superficial level or when an attempt is being made simply to memorise the information for the purpose of an examination (Jonassen 2006, p. 4). Conceptual change takes place when learners participate in tasks that require conceptualisation (ibid.).

2.3.2.1.4 Cognitive conflict and conceptual change

When a learner is faced with information that is in conflict with existing conceptualisation, conceptual change is likely to occur (ibid.). This is the basis of the cognitive conflict theory of learning and works from the premise that when an individual's current understanding does not allow that individual to make sense of experience or is unable to be used to solve a problem cognitive conflict takes place (ibid.). Once the individuals becomes convinced of the inconsistencies between their current understanding and the “standards of the subject-matter domain, the learners may recognize the need to change their conceptions” (ibid., p. 5). This recognition will, however, require the learners to be aware of both this inconsistency and of the need to modify their understanding (ibid.). Jonassen (ibid.) points out that this is often the most challenging part of the conceptual change process as learners with low domain knowledge typically find it difficult to detect inconsistencies “between their own conceptions and scientifically accepted ones”. This would make them unaware of the need for change. Individuals with high domain knowledge may recognise contradictions and inconsistencies but be reluctant to change their way of thinking unless they find doing so to be relevant and useful (ibid.).

Jonassen (ibid.) indicates that for cognitive conflict to be used successfully to facilitate conceptual change, it needs to be supported by “knowledge building activities”. He goes on to suggest that one “of the most powerful knowledge-building activities is model building”.

2.3.2.1.5 Using computer technology as a cognitive tool to model understanding

Jonassen (ibid. p. 4) suggests that an effective method of facilitating conceptual change is to use technology to develop models that "represent learners' internal conceptual models". There are several computer applications that can be used as modelling tools; these include "databases, concept maps, expert systems, systems dynamics tools, and graphic tools" (Jonassen 2011, p. 108). Cognitive tools are able to engage learners in such a way that they construct their own knowledge by building mental models that "facilitate intense cognitive and social activities that result in conceptual change" (Jonassen 2006, p. 23). Van Joolingen's (1999, p. 385) definition of cognitive tools "as instruments included in a learning environment allowing learners to make cognitive processes, like discovery skills, and their results explicit", supports the idea of constructing mental models to externalise thinking. Jonassen (2011, p. 108) points out that "mental models are enhanced and confirmed by the construction of external models". Kirscher and Wopereis (2003, p. 108) support this view by indicating that mind tools assist learners to represent what they know as they convert information into knowledge and "are used to engage in, and facilitate, critical thinking and higher-order learning". Jonassen (2006, p. 4) suggests that if learners are unable to construct a model of what they are studying then it is doubtful that any learning is taking place. He also points out that the building of a model of what is being studied will facilitate a better understanding of the material being learnt and will also present evidence of both conceptual change and learning as there is a clear relationship between the externally constructed models and the learners "internal conceptual models" (ibid. p. 5).

Jonassen (1995, p. 182) suggests that mental "models are the conceptual and operational representations that humans develop while interacting with complex systems". He goes on to indicate that mental models represent the structural relationship between objects and events in a system. Unlike "cognitive and conceptual models that describe how users should represent a domain or system", mental models indicate the way learners actually understand the information (ibid., p. 184). During the process of analysing problems, students "should be constructing models of the components and relationships in the problem" (Jonassen 2011, p. 108). It is these models that students will draw on when the need to "hypothesize and confirm solutions to" problems (ibid.). Vosniadou (2007, p. 19) supports this by stating that mental models are a fundamental characteristic of the human cognitive system and that "even young children can construct mental models which have predictive and explanatory power". These mental models can be used "as a mediating mechanism for the revision of existing knowledge and the construction of new ones" (ibid.). She reinforces this when she points out that mental models have an important role to play in conceptual change as they can be "a point where new information enters the cognitive system in ways that can modify what we already know" (ibid., p. 21). Hokanson and Hooper (2000, p. 546) suggest that diverse symbol systems are used to "help construct mental representations based upon the capabilities of each medium and the nature of the internal representations the learner wishes to construct".

Mental models usually differ significantly from the cognitive and conceptual models that are promoted as correct representations of a domain (Jonassen 1995, p. 184). This is because of varying existing knowledge, differing individual abilities and different beliefs concerning purpose and function. Mental models develop in the mind of the individual learner and form the basis for external models that are represented in the "equations, diagrams, computer programs, and other representational media" used by learners to indicated their conceptualisations (Jonassen 2006, p. 13). By using various "technology-based modeling tools" students are able to refine or "tune their internal models" (ibid.).

Mental models enable learners to construct and revise conceptual understanding, thereby initiating conceptual change (ibid.). External models cannot be constructed if internal models do not exist and by explicitly building mental models conceptual understanding is engaged and change is facilitated to the benefit of a learner's internal conceptual understanding (ibid.).

2.3.2.1.6 Constructing models to compare and contrast understanding

Not only does modelling enable learners to articulate their thinking externally but it also allows them to visualise and evaluate the different elements of their conceptualisations (ibid., p. 13). Comparing and contrasting the different models that each individual will inevitably construct will enable learners to achieve a deeper understanding of the concept being modelled (ibid.). The comparing and contrasting of different models will allow the learner to recognise that each individual conceptualises the external world differently and that the "activity of modeling can be used to test rival models" (ibid.). This, Jonassen suggests, is at the heart of conceptual change.

Different modeling tools allow for different "forms of representation" and this enables students to "construct syntactically and structurally different models" (ibid.). "Deeper understanding" is achieved by comparing and contrasting the different models constructed using the different "forms of representation" (ibid.). The different models will make it apparent to the student that every person's model of his or her understanding is unique in some way (ibid.).

2.3.2.1.7 Constructing models versus using models

Even though learning can be achieved by both using and constructing models, the construction of models by learners is far more effective than merely using them (ibid., p. 14). Jonassen (ibid.) maintains that this is because when learners are expected to solve a problem or respond to complex conceptual questions, they are consistently inclined to build a mental model of the phenomena and use that model as the foundation for "prediction, inference, speculation, or experimentation". Building mental models requires the model builder to determine "which elements fit together in order to represent" phenomena (ibid., p. 14). This involves "making certain choices and it is in these choices that the learning process lies". Learning takes place when learners construct, manipulate and experiment with the way models are put together (ibid.). The process of constructing tangible or computer-based models of phenomena "reifies the learners' mental model" (ibid.). These models are powerful learning tools as they are "independent of theories of the world" (ibid.). This independence allows the models to perform the role of a tool of investigation and a tool is necessarily detached from that on which it acts or operates (ibid.). The external construction of a mental model enables learners to articulate their thinking in a concrete way.

The advantage of constructing models as opposed to using them is supported by Jonassen, Carr and Yueh (1998, p. 30) when they suggest that the designers of a learning intervention generally learn more from the intervention than the students for which it is intended. The process involved in designing a learning intervention requires the designer to articulate what they know so that they can construct a knowledge base. This forces them to reflect on this knowledge in "new and meaningful ways" (ibid.).

2.3.2.2 Models for representing different types of phenomenon

Modelling can be used to represent various types of phenomenon. These include domain knowledge, problem-solving processes, systems thinking, experiences and the thinking process (Jonassen 2006, p. 15-19).

Domain knowledge commonly consists of a collection of facts that we present to the learners in a linear way (ibid., p. 17). This method may preclude learners from realising or recognising any associations between these facts (ibid.). By modelling domain knowledge, learners will be able to relate the facts to one another in a way that will allow them to gain a better understanding of both the concepts and the facts associated with the domain (ibid.). Jonassen suggests that the relationship between the elements of domain knowledge can be represented using "complex associated maps (concept maps), causally related systems (spreadsheets and system models), or different forms of hierarchical representation (expert system or flexible hypertext system)" (ibid.). He goes on to point out that these computer applications are being used as modelling tools and will enable learners to evaluate their mental models and to compare the conceptualisations of different students to their own, which may facilitate conceptual change. The structural and causal relationship between elements within subject matter could be modelled using system modelling tools. This will enable learners to view content "as systems, thereby developing a more integrated view of the world" (ibid., p. 17).

When solving problems a problem space that maps the various associations within the problem is mentally constructed (ibid.). Modelling tools can be used by learners to represent this problem space (ibid.). Thinking processes can also be modelled to encourage metacognition and self-reflection that will enable learners to better understand how to learn (ibid.). This type of modelling will involve the modelling of the thinking process that is necessary to solve a problem or to make a decision.

"Systems modeling tools" allow students to construct "models of complex, dynamic systems and test the models" (ibid., p. 164). "Systems thinking" entails recognising phenomena as a series of elements that "interact with each other" and allow the student to "achieve a more integrated view of the world" (ibid., p. 17). Systems thinking, therefore, encourages students to move away from a focus on "discrete facts or characteristics" of a particular phenomenon.

Jonassen (ibid. p. 18) proposes that students can contribute to "conceptual change by modeling people's experiences". Various modelling tools can be used to model experiences or stories. Databases are an effective tool for storing stories related to people's experience (ibid.). The "intellectual power" behind modelling experience using databases "lies in determining the indexes, then fitting excerpts from the stories into those" (ibid.).

Cognitive simulations or modelling thinking involves modelling "the kind of thinking" that students need to engage in to "solve a problem, make a decision, or complete some other task" (ibid., p. 20).

2.4 Expert systems

Expert systems are defined as computer-based tools that are developed "to function as intelligent aids to decision making" (Jonassen & Reeves 1996, p. 708) in a variety of situations. They are designed to mimic the reasoning a human expert will employ to solve a problem and will, therefore, be "artificial decision makers" (Jonassen, Carr & Yueh 1998, p. 28). Jonassen and Reeves (1996, p. 708) point out that expert systems typically consist of a "knowledge base, inference engine, and user interface". The facts and rules that are incorporated into the design of the system make up the knowledge base, which is acted on by the inference engine "and current problem data to generate solutions" (ibid.). When sufficient information is not included within the knowledge base, the inference engine prompts the user to provide the system with the missing information. "The inference engine continues to seek information until it is able to reach a solution which the system then presents to the user" (ibid., p. 708-709). The inference engine will, therefore, be the logic unit of the system (ibid.).

Expert systems are most suited to problems to which the solutions comprise suggestions based on a combination of decisions (ibid., p. 708).

2.4.1 The simulation of intelligence

Expert systems developed out of "research in the field of artificial intelligence" (Jonassen 2006, p. 11). This field is concerned with the formulation of "programming techniques" that allow inanimate machines "to perform tasks that are regarded as intelligent when done by people" (ibid., pp. 11-12). Chen, Jakeman and Norton (2008, p. 379) point out that artificial intelligence (AI) "mimics human perception, learning and reasoning to solve complex problems".

While "intelligence is the capacity to learn, reason, and understand", artificial implies a simulation of these capacities (ibid.). Simulate, in turn, "means imitating a real object of event". Jonassen (2006, p. 134) stresses that an expert system does not apply real intelligence when solving a problem, but rather simulates the way a human expert is believed to think when confronted with a problem. Real intelligence implies a more generalisable skill that can be transferred and utilised in other situations besides those in which they were acquired (ibid.). In simulating the way a human expert would solve a problem, the system would obtain information from a novice individual who requires guidance to solve a problem (ibid.). The expert system will then search its knowledge base of previously stored information for applicable facts and rules, "process the information, arrive at a decision, and report the solution to the user" (ibid*.).* This would be similar to the way a human expert would solve a problem.

2.4.2 An expert system shell as a cognitive tool

Jonassen and Reeves (1996, p. 709) maintain that "the part of the expert system that makes it a cognitive tool is the knowledge base", as assembling the knowledge base compels the designer to articulate the "expertise that the system provides, not only in the form of facts but also rules". They go on to point out that the identification of the causal relationships and procedural knowledge that form the foundation of the knowledge domain, requires the designer to engage in higher-order thinking. Procedural knowledge is “the knowledge of how to use domain knowledge” (Jonassen 2006, p. 39). To build the knowledge base the designer would need to express an understanding of causal knowledge (Jonassen, Carr & Yueh 1998, p. 28). Jonassen (2006, p. 61) states that solving “all problems requires some form of causal reasoning” and the more complex the problem, “the more sophisticated the causal reasoning must be”.

2.4.2.1 Using versus designing an expert system

For an expert system to be considered a cognitive tool, it is not sufficient for learners to be simply users of the expert system (Jonassen & Reeves 1996, p. 708). They must be the designers of the system, as merely "using existing knowledge bases to get advice does not engage users as deeply as building a knowledge base to reflect their own thinking”. This is supported by Jonassen, Carr and Yueh (1998, p. 29) when they state the development of an expert system will result in a deeper understanding because it provides "an intellectual environment that demands the refinement of domain knowledge, supports problem solving, and monitors the acquisition of knowledge”. This is emphasised by the fact that the user of the expert system is typically not able to reference the "predetermined rules for solving the problem" as these are hidden within the system (Jonassen & Reeves 1996, p. 709). The knowledge of the expert is modelled by the developer of the expert system (Jonassen 2006, p. 139). Expert knowledge comprises facts and knowledge, as well as the interrelationship of these concepts together with the knowledge of how to apply these interrelationships to solve a problem (ibid.).

Jonassen and Reeves (1996, p. 709) suggest that expert systems are one of the few mechanisms that are able to represent procedural knowledge. This type of knowledge is often described in terms of IF-THEN rules and an understanding of the nature of a decision-making process will become more meaningful once learners identify the rules that apply to a particular domain.

2.4.3 The components of an expert system

Jonassen (2006, pp. 134-138) maintains that an expert system comprises seven components and points out that each of these components is an essential part of its construction. These components are the following:

- User. The user's role is to supply the system with information that initiates the solving of a problem. Without a user, an expert system will not be able to apply its knowledge and skills.
- Current problem information. Current problem information is collected from the user to enable the "computer to help guide the expert system to a solution" based on current information as indicated by the user. These situation-dependent answers received from the user are integrated with the facts and rules that make up the expert system's knowledge base.
- User interface. Communication with the user is facilitated by the user interface, which allows the system to gather current or relevant data concerning the problem from the user, explain the reasoning employed by the system, and present a solution to the user or offer advice for solving the problem. The answers to the questions provided by the user through the interface define the conditions that are to be evaluated by the rules stipulated in the system's knowledge base. As the user interface facilitates a dialogue with the user, careful attention need to be given to the way in which information is presented to the user to make sure that suitable information is easily obtained.
- Knowledge base. The knowledge structures used by human experts when solving a problem are represented by the expert system's knowledge base. This knowledge base is made up of the facts and rules that govern the relationship among the various objects involved in solving a problem within a particular domain. Facts state or indicate given conditions while rules comprise "conditions and decisions". These rules are structured in the form of IF-THEN statements, which suggest that if a certain condition

is true then a certain decision is suitable. “Sets of IF conditions are combined using conjunctions (condition 1 AND condition 2 must exist), disjunctions (condition 1 OR condition 2 must exist), and negotiations (condition 1 but NOT condition 2 must exist) for a decision to be reached” (ibid. p. 136). A decision could be comprised of an action or it may present another condition, which could be combined with more conditions that could then lead to another decision .

- Expert editor. Jonassen (ibid. p. 137) indicates that an expert system generally includes an expert editor. This enables an expert to “enter information into the knowledge base”.
- Inference engine. Once a user has entered information that defines the parameters of a particular problem, the inference engine examines this information in relation to the facts and rules specified in the knowledge base. It “evaluates the current problem situation and seeks rules that will provide advice about the situation”.
- Solution/Advice. The solution generated by the inference engine “based on the permanent knowledge base and current problem information” is presented to the user. This, Jonassen (ibid., p. 138) states, is the “final feature of an expert system”.

2.5 Higher-order thinking

Lewis and Smith (1993, p. 132) indicate that there is general consensus regarding the fact that there is a distinction between higher-order and lower order thinking. They do, however, suggest that a student’s personal and educational background may result in a situation “that requires higher-order thinking by one person… [but] only lower order thinking by another” (ibid.). It is also reasonable to assume that the teaching of lower and higher-order thinking skills is “likely to be interwoven” (ibid.). Classroom practice should include the close employment of both basic and higher-order thinking skills (ibid., p. 136).

Lewis and Smith (ibid., p. 136) propose that a definition of higher-order thinking needs to include concepts commonly associated with the terms critical thinking as well as problem-solving, creative thinking and decision-making. They offer the following definition of higher-order thinking:

> *Higher order thinking [sic] occurs when a person takes new information and information stored in memory and interrelates and / or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations.*

Decisions regarding what to believe and what course of action to take as well as creating new ideas, novel objects, an artistic interpretation, predicting an outcome, and "solving a non-routine problem" can be considered consequences of higher-order thinking (ibid.). When a person encounters a set of circumstances that requires a decision regarding what to do or believe, higher-order thinking skills are necessary (ibid.). If a student can achieve his or her purpose "through the recall of information and without a need to interrelate or rearrange this information" then higher-order thinking is unlikely to take place. Students would need to be presented with a situation or problem that cannot be resolved through "simple recall of information" for higher-order thinking to be encouraged (ibid.). Anderson and Garrison (1995, p. 196) support this when they suggest that higher-order thinking is implied when there is an association with the "integration of new concepts and ideas with previous knowledge and experience". McLoughlin and Luca (2000, p. 2) indicate that theorists generally agree that higher-order thinking suggests the ability to "go beyond the information given, to adopt a critical stance, to evaluate, to have a metacognitive awareness", and to be able to solve problems.

Ping and Kee (2009, p. 20) state that rote learning is not suited to the promotion of higher-order thinking as it is not capable of "transforming thinking" and converting information into knowledge. Students would need to be encouraged to take an active, more commanding role in the attainment of knowledge (ibid.). Educators must allow students to assume a greater level of control over their learning and the emphasis should be on designing experiences that initiate curiosity about the world and the way it works (ibid.). The learning tasks embedded in this experience must be of such a nature and complexity to provide students with the opportunity to develop higher-order thinking skills and capabilities (ibid.). Hauer and Daniels (2008, p. 2) suggest that one of the goals of education providers is to endeavour to develop "higher-order critical thinking skills" in their students. Higher learning institutions should ideally provide students with opportunities to transform their thinking in such a way that their general attitudes toward life and people are more meaningful (Ping & Kee 2009, p. 13). A learning environment that aims to encourage the development of higher-order thinking will need to provide students with the opportunity for discussion and negotiation, shared control, critical evaluation, individual relevance and uncertainty (ibid., p. 12).

2.5.1 Critical thinking

Willingham (2007, p. 8) indicates that critical thinking comprises seeing all aspects of an issue, being receptive to new evidence that disproves one's ideas, insisting that claims be supported by evidence, "deducing and inferring conclusions from available facts" and solving problems. Critical thinking is novel because the thinker does not merely recall a "solution or a situation" that is comparable enough to act as a guide (ibid., p. 11). Lewis and Smith (1993, p. 134) point out that critical thinking has been allocated "three distinct meanings". Firstly, critical thinking is synonymous with problem-solving, secondly it is associated with "evaluation or judgment" (ibid.) and lastly critical thinking is considered "a combination of evaluation and problem solving". They do, however, indicate that the "most common usage" is to associate critical thinking with "evaluation and judgment" as well as problem solving. Ennis (1993, p. 180) indicates that critical thinking is "reasonable reflective" thinking that focuses on a decision concerning what to believe or do. This may involve the following:

- Judging a source of information's credibility.
- Identifying "conclusions, reasons, and assumptions".
- Assessing the "quality of an argument". This may include the "acceptability of its reasons, assumptions, and evidence".
- "Develop and defend" a point of view.
- Pose appropriate questions for clarification.
- Devise experiments and "judge experimental designs".
- Define terms so that they are contextually appropriate.
- "Be open minded".
- Attempt to be properly informed.
- Draw conclusions when appropriate (ibid.).

Willingham (2007, p. 12) indicates that to think critically one must have "adequate content knowledge" regarding the issue that one is considering, as one cannot think critically "about a topic that [one] knows little about or solve problems" that one "[does not know well enough to recognize and execute the type of solution they call for" (own insertion).

Wang (2009, p. 52) expands on this when she suggests that students develop their potential to articulate their ability to "organize, synthesize, and express their originality and their reflection upon the topic" when they apply critical thinking. Students adept at critical thinking are better able to pose appropriate questions, "address arguments", and search for evidence that supports their thinking and beliefs (ibid.). They are skilled at rejecting information that is "incorrect, illogical, or irrelevant" (ibid.). Critical thinking enables students to "comprehend and express meaning or significance" and to identify "implicit and explicit" relationships, as well as to provide logical assessments (ibid.). Wang (ibid.)

proposes that students who engage in critical thinking “should know how to monitor their cognitive process, draw reasonable and logical conclusions, and illustrate the results”.

2.5.2 Social interaction and higher-order thinking

Learning is achieved when an individual makes sense of his or her experience within a social context and in order to take advantage of the “social construction of knowledge” it is necessary to provide students with opportunities for sustained interaction “between and amongst learner and teacher” (Anderson & Garrison 1995, p. 184). This sustained interaction amongst learner and instructor is a “significant precursor to the development of meaningful learning" (ibid.). Anderson and Garrison (ibid. p. 186) suggest that when action is not linked to thought, students are just being fed information in a meaningless way. When students reflect critically, an attempt is made to “detach from the external world” in order to construct meaning (ibid.). This meaning is, however, always valid because it is “grounded in experience” (ibid.). A critical dialogue results in a deeper exploration of a subject area and the development of higher-order cognitive skills (ibid. 1995, p. 185). “Discourse and reflection” are vital components of “the critical thinking process” (ibid.). Exposing students to “communities of enquiry” is an indispensable part of a meaningful educational experience.

Critical thinking should involve articulating the “underlying premises” on which factual statements, “deductions, opinions or hypothesis are grounded” (ibid.).

Learning is most effectively achieved when there is integration of both social and cognitive approaches to learning (McLoughlin & Luca, 2000 p. 4). Ongoing interaction between learners initiates “argumentation, negotiation, discussion” as well as the “joint construction of understanding” (ibid.). The cognitive advantages and level of social support are likely to be greater when the learning tasks require "greater problem solving and creativity" (ibid.). A critical approach to learning is promoted through the participation and contribution of a community of students (Anderson & Garrison 1995, p. 196).

Higher-order thinking is developed when thinking processes are externalised through the making of statements and the defense and challenge to fellow learners' assumptions (ibid.). Learners are able to compare and contrast their own understanding to that of others when they observe their fellow learners and instructors "modeling the process of interpretation and application" (ibid.).
Ping and Kee (2009, p. 14) point out that language use is an important means of determining the way in which students acquire thinking skills because "advanced modes of thought are transmitted by means of words". Proficient thinkers are better at "describing mechanisms and cause-effect relationships" associating phenomena with actual experience and posing questions that "focus on explanations and causes" (ibid.). Educators are advised to use language to mediate thinking in order to foster the development of higher-order thinking (ibid. 2009, p. 19).

McLoughlin and Luca (2000, p. 4) have identified the following types of activity between peers that are likely to lead to conceptual development:

- offer and receive assistance;
- exchange resources and information ;
- explain and elaborate on concepts;
- share existing knowledge;
- give and receive feedback;
- challenge others' contributions;
- monitor one another's contributions;
- engage in collaborative tasks;
- negotiate solutions to problems.

Instructors can support interactions between students that result in higher-order thinking by providing well-timed feedback, encouraging autonomous thinking and by offering alternative points of view (ibid., p. 8). This support could also include "timely questions, recommendations, comments and articulation of key concepts" (ibid.). McLoughlin and Luca (ibid.) emphasise the importance of peers reviewing ideas, group work, team building and the development of a social atmosphere that promotes discussion in order to develop the social skills necessary for successful interaction.

2.5.3 Problem-solving

Hauer and Daniels (2008, p. 2) define problem-solving as the "search for answers to difficult or perplexing questions or situations". They point out that there are generally two problem classifications or types; these are well structured and ill structured. Ill structured problems can be termed open-ended and constitute problems that have unspecified boundaries and goals; these problems are generally "unclear or insufficient in various ways" and can often be considered more complex and representative of real world dilemmas (Hauer & Daniels 2008, p. 2). Weiss (2003, p. 27) suggests that problems that promote higher-order thinking are generally ill structured, similar to actual problems encountered in real-life situations. These ill structured problems can be solved in a variety of ways and not all the elements of the problem are always known (ibid.). Solving ill structured problems often requires students to explore different disciplines (ibid.). Because students are likely to encounter ill structured problems in their professional lives, it can be seen as the responsibility of educators to provide "learning experiences" that incorporate these types of problem "in the educational setting" (Hauer & Daniels 2008, p. 2). These educational settings that focus on open-ended, ill structured problem-solving activities are suited to the "educational goal of higher-order thinking" (ibid.).

Hauer and Daniels (ibid. p. 4) believe that because ill structured problem-solving activities are intrinsically more difficult to engage with, a type of "balanced scaffolding" would need to be incorporated into the learning environment. Learners should be kept challenged by the learning tasks but should not be overwhelmed by the challenges presented to them. An appropriate level of scaffolding together with the strategic incorporation of well-structured problems can help students to manage the "inherent complexity" of ill structured problem-solving activities, which they would need to do as they move toward the attainment of higher-order thinking skills (ibid.).

The balanced scaffolding suggested by Hauer and Daniels (ibid.) requires the instructor to act as a "facilitator or consultant" that prepares students to engage successfully with ill structured problems. This scaffolding should ideally be supplied when the students reach a point when they realise that they need information or assistance. The instructor or the community should then "help the student to obtain information to assist them in their reasoning and decisions" (ibid.). If the student does not reach such a realisation, the instructor should notice when the student is approaching an "irresolvable impasse" (ibid.) and provide the necessary support. The instructor must understand the state of the students" engagement with the learning activity in "order to know when support is called for and what level of support is needed" (ibid.).

An effective way to provide scaffolding to students who are engaged in ill structured problem-solving is to group students with a diversity of skills and levels of understanding and then to allow them to provide scaffolding to one another (ibid.). This can be useful because students are often an effective "source of knowledge for each other". Hauer and Daniels (ibid., p. 5) advise that an important aspect of a learning environment that includes ill structured problem-solving activities is to allow students to work together to uncover "resolutions for the current situation". Interaction that takes place among learners during an engagement with a problem can be seen as an effective form of scaffolding that provides “opportunities and support for cognitive development” (McLoughlin & Luca 2000, p. 5). The articulation and exploration of ideas that this interaction encourages and facilitates, enable a more organised and “explicit” understanding on the part of the learner (ibid.). McLoughlin and Luca (ibid.)maintain that this construction of understanding that leads to cognitive change is “critical to the development of higher-order thinking processes”.

Weiss (2003, p. 25) proposes that there should be two stages for designing problems to promote higher-order thinking. Firstly the educational purpose of the problem must be considered and secondly the problem must be designed to meet that purpose. An effective problem must be appropriate for the student and should be based on “an analysis of the students’ current content knowledge” (ibid. p. 26). It is also important that the student find the problem to be solved challenging so educators should design the problem to be “slightly beyond what the students currently know” (ibid.). These challenging problems will compel the students to think further than what they already know; they will, therefore, not be able merely to regurgitate information but will be encouraged to acquire a richer understanding of subject matter to solve an existing problem (ibid.).

Collaboration among students is an important feature of problems designed to foster higher-order thinking (ibid.). Weiss (ibid. p. 27) suggests that students could each be required to complete a portion of an assignment, which is then collectively assembled before submission. It is, however, important that the group “synthesize their ideas and make decisions throughout the course of the” problem-based learning activity, if higher-order thinking skills are to be cultivated (ibid.).

2.6 Design-based research

Mantei (2008, p. 131) indicates that the design-based research approach is frequently associated with research into computer-based technologies and the learning environment that they facilitate. Plomp (2007, p. 13) defines educational design research as:

> *the systematic study of designing, developing and evaluating educational interventions (such as programs, teaching-learning strategies and materials, products and systems) as solutions for complex problems in educational practice, which also aims at advancing our knowledge about the characteristics of these interventions and the processes of designing and developing them.*

From a design research perspective, the researcher aims to gain insight into a particular aspect of learning by designing and developing an intervention that gets progressively better at enhancing and supporting that aspect of learning. Bowler and Large (2008, p. 40) suggest that design research is “iterative, interventionist, and theory orientated”. They go on to indicate that it tests and generates hypotheses. The researcher aims to improve the effectiveness of the design by using “research on the use of the designed intervention, as well as prior research knowledge” (Joseph 2004, p. 235). Plomp (2007, p. 13) supports this when he says that, in collaboration with practitioners and based on prior research and with reference to relevant literature, researchers design and develop practical and effective interventions through the careful study of successive versions or prototypes of the intervention. He points out that while doing this, the researchers would need to “reflect on their research process with the purpose to produce design principles”. The process of being involved in design and research enables participants to achieve a thorough understanding of both the “theoretical and design ideas involved in the intervention" and should, therefore, enable the researcher to “get better at the process of education” (Joseph 2004, p. 236).

The Design-Based Research Collective (2003, p. 5) suggests that design-based research should exhibit the following characteristics:

- The goals of designing learning environments and developing preliminary theories are intertwined.
- Development and research involve continuous cycles of “design, enactment, analysis, and redesign”.
- Theories arrived at through research on designs need to be sharable and need to “communicate relevant implications to practitioners” and others involved in the design of educational interventions.
- The research has to present an insight into how “designs function in authentic settings”.
- These insights must be arrived at through “methods that can document and connect processes of enactment to outcomes of interest”.

2.6.1 Real world context

Design research invariably takes place in a particular real world context, consequently “the day-to-day needs of the real world practice place constraints and demands on both design and the research activities” (Joseph 2004, p. 236). Bowler and Large (2008, p. 40) point out that design research is “contextual, authentic, and immersive”. It allows researchers to gain a thorough understanding of practical problems as experienced in a real world context, while at the same time it allows practitioners to gain a thorough understanding of the purpose and implications of research (Joseph 2004, p. 241). Bowler and Large (2008, p. 41) seem to support this when they suggest that the strength of design-based research is that it takes place in context, “within the framework of the real worlds of students”. They go on to suggest that the advantage of design-based research is its ability to describe the problem from a user’s perspective and would therefore give researchers access to authentic definitions of the problem under investigation.

Cobb, Confrey, Disessa, Lehrer and Schauble (2003, p. 12) point out that a design research intervention calls for the cultivation of an ongoing relationship with practitioners due to its extended nature. The relationship between practitioner and researcher influences the design choices and allows the research to be extremely relevant to a particular real world context (ibid.). Collins, Joseph and Bielaczyc (2004, p. 17) expand on this when they suggest that design research has been developed to address the following issues:

- Theoretical questions concerning the nature of learning in authentic settings ;
- the need for an approach to "the study of learning phenomena in the real world rather than the laboratory";
- the requirement to expand on limited measures of learning; and
- the "need to devise research findings from formative evaluation".

2.6.2 The cyclic nature of design research

Owen (1997, p. 37) points out that in design-based research knowledge is generally created and accumulated through implementing an intervention and then judging the results. He indicates that the cycle of design-based research involves using knowledge to create works and then judging these works in order to generate knowledge (ibid.). Collins, Joseph and Bielaczyc (2004, p. 22) support this when they say by "studying a design in practice with an eye towards progressive refinement, it is possible to develop more robust designs over time". Owen (1997, p. 37) points out that existing knowledge, which is informed by theory, is used to generate proposals and these "proposals are tested with measures that verify or refute conclusions to build knowledge" (ibid.). The works that are produced through the application of principles that are informed by knowledge are "judged for their worth as additions to the knowledge base using the criteria of the discipline" (ibid., p. 38). Each of the design-research cycles focuses on specific research questions and requires an appropriate research design (Nieveen 2007, p. 93).

Plomp (2007, p. 13) mentions that design research is similar to all "systematic educational and instructional design processes", which would involve the cyclic process of "analysis, design, evaluation and revision activities" that are "iterated until a satisfying balance between ideas ('the intended') and realization has been achieved".

2.6.2.1 Stages in design-based research

Plomp (ibid.) points out that there is general agreement that design-based research comprises the following stages or phases:

- Preliminary research: this would involve a "needs and content analysis, review of literature, development of a conceptual or theoretical framework for the study" (ibid. p. 15).
- Prototyping phase: this is the iterative design phase and is characterised by cycles, "each being a micro-cycle of research with formative evaluation as the most important research activity aimed at improving and refining the intervention".
- Assessment phase: a summative or semi-summative evaluation is conducted to determine the extent to which the intervention meets the "pre-determined specifications". The evaluation conducted is not completely summative as it often results in suggestion for the improvement of the intervention.

Plomp (ibid.) stresses the fact that the researcher will undertake "systematic reflection and documentation" throughout all the phases, to produce theories or design principles. He states that it is this systematic documentation and reflection that make the “systematic design and development of an intervention” become design research.

2.6.3 Developing prototypes of an intervention

By initially developing a small part of a proposed intervention, a research designer can "learn from failures" (Nieveen 2007, p. 91) and implement successes when designing successive parts of an intervention (ibid.). The process of progressive refinement, as characterised by the iterative nature of design-based research, entails putting a first version or prototype of the design into an authentic context to see how it works (ibid.). The design will then be “constantly revised based on experience, until all the bugs are worked out” (Collins, Joseph & Bielaczyc 2004, p. 22).

A prototype in design research can be defined as a “preliminary version of the whole or part of an intervention before full commitment is made to construct and implement the final product” (Nieveen 2007, p. 90). There are two ways in which prototypes are used. Evolutionary prototypes evolve from a process of continual refinement that is informed by formative evaluation results and the reflection of developers (ibid.). Then there are throw-away prototypes that are discarded once they have been evaluated and their evaluation results have been taken into account (ibid.). A narrative description of a representative and critical situation “that prospective users participate in” and paper-based mock-ups are examples of throw-away prototypes (ibid.). Often a design research intervention will involve both these types of prototype. Cobb *et al.* (2003, p. 9) propose that from a prototyping perspective, design research should involve both engineering “particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them”. He indicates that the designed context is then subject to revision, “and the successive iterations that result play a role similar to that of systematic variation in experiment”.

2.6.3.1 Formative evaluation of the intervention

Prototyping requires the researcher to collect empirical data in order to "gain insight into the quality of the tentative intervention and design principles" (Nieveen 2007, p. 91). Nieveen (ibid.) states that this is the reason why "formative evaluation is a crucial feature of each prototyping approach and thus of each design research project". She supports this by indicating that the results of formative evaluation facilitate the improvement of the prototype (ibid.). This allows the prototype to evolve into a high quality deliverable while at the same time it enables the underlying tentative design principles to develop into "an elaborate set of design principles". In the context of design research, formative evaluation can be defined as:

> *a systematically performed activity (including research design, data collection, data analysis, reporting) aiming at quality improvement of a prototypical intervention and its accompanying design principles*
> (ibid., p. 93).

Cobb *et al.* (2003, p. 12) allude to formative evaluation when they point out that a distinctive characteristic of design-based research is that the researchers gain a deeper understanding of the "phenomenon under investigation" while the research project or "experiment is still in progress". They suggest that it is for this reason that it is important that the research "generates a comprehensive record of the ongoing design process". The practical process of achieving these aims would commonly involve the "collection and coordination of a complex array of data sources". These multiple sources of "data ensure that retrospective analysis conducted when the experiment has been completed will result in rigorous, empirically grounded claims and assertions" (ibid.).

2.6.4 Emergent theory

The Design-Based Research Collective (2003, p. 5) argues that good design-based research can assist in the creation and expansion of knowledge of "developing, enacting, and sustaining innovative learning environments". Design research is undertaken in order to develop theories and not simply to refine successful implementations of learning events (Cobb *et al*. 2003, p. 9). The theory and findings that emerge during the research would typically inform both the evolving design as well as the evolving research apparatus (Joseph 2004, p. 236). Collins, Joseph and Bielaczyc (2004, p. 22) reinforce this when they say that design research "should always have the dual goal of refining both theory and practice". The value of the knowledge that results from design research is greater when it is supported by "theoretical arguments, well-articulated in providing directions, and convincingly backed-up with empirical evidence about the impact of those principles" (Plomp 2007, p. 21). Cobb *et al.* (2003, p. 9) emphasize that the prominence placed "on theories reflects the view that the explanations and understandings inherent in them are essential if educational improvement is to be a long-term generative process".

Joseph (2004, p. 241) points out that in design-based research both the design and the research methods are shaped by emergent theory. The interdependent goals of "developing effective designs and contributing to basic understandings create, through their interaction, a powerful engine for driving innovative work in education" (ibid.). Owen (1997, pp. 41-42) expands on this when he points out that the processes "of knowledge using and building are fundamentally the same for inquiry and application" and that in both instances "what is known is used to generate something new and that will provide answers to questions inspired by a felt need" (ibid.). He explains that in regard to enquiry, "the need is for deeper understanding of the subject of the discipline" and with regards to application "the need is for artifacts and institutions that employ the knowledge of the discipline more successfully". Cobb *et al.* (2003, p. 9) maintain that a design theory provides an explanation why a particular design works and suggests how this may be adapted to other circumstances. Plomp (2007, p. 20) indicates that design research endeavours to produce knowledge concerning “whether and why an intervention works in a certain context”. Bowler and Large (2008, p. 40) expand on this by suggesting that the design research process should ultimately lead to a working design “for a series of classroom interventions, a plausible explanation for why they work, a set of guiding principles for teaching and learning” and then ideally a positive result for the learner. Plomp (2007, p. 20) indicates that the knowledge produced by design research “has been called design principles or intervention theory”.

2.6.5 Specifying research questions in design-based research

Joseph (2004, p. 236) states that, as in many other types of research, design research specifies research questions by identifying gaps in the research literature. She points out that in addition to this, a design researcher views the research through “the lens of design” and targets “questions central to the design of the intervention itself” (ibid.). Owen (1997, p. 42) emphasises the importance of questions related to the design of the intervention when he says that “the process of framing questions and constructing answers or decisions lies at the heart of good research, and ultimately, the basis for its quality”. These questions are of critical importance to design-based research and may include “How are the designed artifacts used? How are they implicated in learning? How do they fail?” (Joseph 2004, p. 236). Bowler and Large (2008, p. 43) expand on this when they suggest that potential design-based research could include the following:

> *What criteria do users identify as important in the design of an information product or service? How can these criteria be implemented in a real product or service? How will the users react to this product or service, once a prototype has been designed and built?*

2.6.6 Designing artifacts

The design researcher creates artifacts that embody assumptions and hypotheses concerning a particular learning phenomenon and places them within an authentic context for testing (Joseph 2004, p. 236). Joseph (ibid.) suggests that by focusing on particular assumptions and hypotheses, the set of potentially relevant research questions is effectively restricted. In design-based research investigations revolve around "the evaluation of the designed artifact" (ibid.). The refinement of research questions is primarily concentrated on the design of the artifact, irrespective of whether these emerge from the design process itself or from existing literature. The researcher then focuses on questions that affect the design, in particular those that "address the key hypotheses embedded in those designs" (ibid., p. 237). In this way the myriad of questions that a design researcher is initially exposed to, after an early version of a design is placed in the real world, are reduced to those that provide insight into the key hypotheses that have, by design, been incorporated into the artifact (ibid.).

Design-based research can, therefore, provide an effective means of enabling important research questions to emerge and for developing penetrating research methods that are informed by these questions (ibid., p. 241). Plomp (2007, p. 19) points out that because the researcher endeavours to determine design principles that are valid and applicable within a certain context, the research question can be expressed as follows: "What are the characteristics of an <intervention X> for the purpose/outcome Y(Y1,Y2,…,Yn) in context Z" (ibid.). He points out that this exact phrasing may not always be appropriate but the phrasing "of the main research question in design research always implies a search for characteristics".

2.6.7 Design principles

Plomp (ibid., p. 17) indicates that one of the goals of design research is to design and develop an intervention to serve as an innovative solution to a complex problem; he starting point for the design research project could then be "educational problems for which no or only a few validated principles ('how to do' guidelines) are available to structure and support the design and development activities".

Van den Akker (quoted in Plomp 2007, p. 20) has developed the following format for the heuristic statements that are characteristic of design principles:

> *If you want to design intervention X for the purpose/function Y in the context Z, then you are best advised to give that intervention the characteristics A, B and C [substantive emphasis], and to do that via procedures K, L and M [procedural emphasis}, because of arguments P, Q, and R.*

Nieveen (2007, p. 89) stresses that a "set of well-articulated design principles" can "provide insight into the purpose and function of the intervention", the "key characteristics of the intervention", the guidelines for designing the intervention, the implementation conditions and the "theoretical and empirical arguments (proof) for the characteristics and procedural guidelines". Plomp (2007, p. 21) expands on this by pointing out that although design principles are aimed at supporting designers in their endeavours, they cannot assure success. Their purpose is to assist designers of other projects to select and apply the most suitable "substantive and procedural knowledge" (ibid.) to a particular design and development project. Plomp (ibid.) explains that substantive knowledge is knowledge concerning the "essential characteristics of an intervention" and is partly obtained "from the intervention itself". Procedural knowledge is knowledge concerning the “set of design activities that are considered most promising in developing an effective and workable intervention” (ibid.).

2.6.8 Transferability of designs to other settings

Collins, Joseph and Bielaczyc (2004, p. 20) point out that when evaluating any design in an educational setting, it is important to be aware of the limitations of the evaluation as the “effectiveness of a design in one setting is no guarantee of its effectiveness in other settings”. This is often because the intentions and principles that informed the design are “undermined by the way the design is enacted” (ibid.). Many of the decisions made during the implementation of the design are impossible to include in the design itself as no design can anticipate or include all the details. The actions of participants during the implementation of the design would almost certainly require “constant decisions about how to proceed at every level” (ibid.). Consequently, even though design in education can be reasonably specific, the evaluation of a design can only be made relative to a particular implementation and this is greatly influenced by the specific characteristics of the participants (ibid.).

Design researchers attempt to optimise the design as much as possible and then carefully observe the extent to which the different elements of the design work out (ibid., p. 23). Collins, Joseph and Bielaczyc (ibid.) suggest that these observations would need to involve both qualitative and quantitative observation in the same way that consumer reports evaluate “products in terms of both qualitative and quantitative measures”. They point out that different options to improve the design in practice should be considered when certain aspects of the design do not work. This is due to the fact that these aspects need to be considered in relation to “how well they fit with other aspects of the design”.

Though design experiments are situated within a particular educational setting, the focus is on generalising from those settings in order to guide the design process (ibid., p. 27). Collins, Joseph and Bielacsyc (ibid) suggest that these experiments "fill a niche in the array of experimental methods that is needed to improve educational practices”.

2.7 Grounded theory

Welman and Kruger (2005, p. 29) maintain that grounded theory involves the researcher observing and systematically describing “the phenomenon being studied” while gradually attempting to “unravel relationships and patterns in order to eventually formulate a theory”. Brown, Stevens, Troiano and Schneider (2002, p. 2) state that grounded theory “provides techniques and procedures to create an inductively – deductively integrative theory”. The purpose of grounded theory is to “explore and understand how complex phenomena occur” (ibid.). Using a grounded theory approach, a researcher focuses on an “area of study” and gathers “data from a variety of sources, including interviews and field observations” (Haig 1995, p. 1). These data are then “analyzed using coding and theoretical sampling procedures”, after which theories are generated with the assistance of “interpretative procedures” (ibid.). Douglas (2003, p. 48) uses the term *theoretical sensitivity* to refer to the “researcher’s capacity to think about the data in theoretical terms”. He suggests that theoretical sensitivity requires the researcher constantly to interact “with the data collection and analysis”, without pre-empting or judging possible outcomes.

2.7.1 Data collection in a grounded theory approach

Douglas (ibid., p. 49) points out that there “are three main categories of data in grounded theory research”. These are “field data (notes), interview data (notes, recordings, transcripts) and any existing literature and artifacts that may be useful to the research”. Corbin and Strauss (1990, p. 5) indicate that “data for grounded theory can come from various sources” and that often observations and interviews are used. Focus group interviews are considered to be an effective way of collecting data in qualitative research that “might otherwise be fairly difficult to obtain” (Berg 2004, p. 142).

2.7.1.1 Focus group interviews

Focus group interviews “are a means of better understanding how people feel or think about an issue, product or service” (De Vos et al., Strydom, Fouché and Delport, 2009 p. 299). A collective activity focuses the group and those that take part are “selected because they have certain characteristics in common that relate to the topic” under investigation (ibid.). Its purpose “is to promote self-disclosure among participants” (ibid., p. 300) as well as to create “a process of sharing and comparing among participants” (ibid., p. 301). Focus groups are a proficient way of uncovering reality and of exploring “complex behavior and motivation”.

De Vos *et al.* (ibid., p. 303) identify the following “basic decisions” that need to be undertaken during the planning process:

- "define the purpose and outcome of the project";
- obtain permission from the focus group members to use their input;
- develop the timeline for the project;
- determine who the participants will be;
- write questions that are going to be used during the focus group interview in a question guide;
- develop a recruitment plan for obtaining focus group participants.
- "set the location, dates and time for the session";
- "design the analysis plan".

De Vos *et al.* (ibid., p. 304) maintain that nearly all aspects of a focus group are dependent on “who the participants are” and when deciding on whom to invite to the group, the researcher has to consider the purpose of the study. Purposive sampling is usually relied on when assembling a focus group (De Vos *et al*. p.

304, Welman & Kruger 2005, p. 189) and they normally consist of between six to ten participants (De Vos *et al* 2009, p. 305). The purpose and aims of the study will determine the number of focus groups used in the investigation but too few could result in "something being missed" while too many may be superfluous (ibid., p. 306). Welman and Kruger (2005, p. 189) identify the following phases in conducting focus group interviews:

- The topic for discussion is introduced to the group.
- Certain rules are then set out and communicated to the group.
- Each member of the group makes an opening statement "regarding their experience of the topic" under discussion.
- Questions are asked by the researcher (or interviewer) in order to guide the "opening group discussion".
- Each member gives a final unchallenged statement to end the focus group session.

The analysis of the information gained from focus group interviews is based on the researcher's records and often consists of "systematic coding through content analysis" (ibid.). During the data analysis "trends and patterns that reappear within a single focus group or among various focus groups" are sought (De Vos *et al.* 2009, p. 311). "Transcripts, tapes, notes and memory" form the basis of data analysis.

2.7.2 Coding in grounded theory

The most basic and fundamental process in grounded theory is the coding process. This can be done "line-by-line, sentence-by-sentence, paragraph-by-paragraph, page-by-page, section-by-section, and so on" (Willig 2009, p. 39). Willig (ibid.) recommends that where practical, line-by-line coding should "always be carried out". Coding is the "central way in which theories are built from data" (De Vos *et al.* 2009, p. 340). Coding and theory building describe the process of breaking down data and putting it back together in new ways after they have been "conceptualized" (ibid.). Douglas (2003, p. 49) states that coding "is the result of raising questions and giving provisional answers about categories and their relations". He points out that from a grounded theory perspective, three "types of coding are preferred". These are open coding, axial coding and selective coding.

2.7.2.1 Open coding

Open coding involves the "naming and categorizing of phenomena through close examination of data" (De Vos *et al.* 2009, p. 641). Without this first "basic analytical step" (ibid.), subsequent analysis cannot take place. Berg (2004, p. 278) states that the main purpose of open coding is to initiate a broad enquiry. He suggests that even though "interpretations, questions, and even possible answers may seem to emerge" during the open coding phase, these need to be considered as "tentative at best" (ibid.). These early conclusions are likely to be contradicted during the coding of subsequent documents (ibid.). Berg (ibid) points out that the most comprehensive "analysis of the various concepts and categories will best be accomplished after all the material has been coded". Henning (2008, p. 131) indicates that during the open coding phase data "are broken down into discrete parts, which are compared and questioned with 'what, where, who, when and how'". This results in data being fractured into "concepts and categories".

2.7.2.1.1 Identifying categories

Emerging categories and subcategories are identified through a process of constant comparison. This involves "moving back and forth" during the coding process, identifying differences and similarities between "emerging categories" (Willig 2009, p. 36). After instances of a phenomenon have been united to form categories, differences within these categories are focused on (ibid.). Categories represent the combining of events, processes and occurrences that contain similar "central features or characteristics" with one another (ibid., p. 35). These categories can function as a "descriptive label" if they are at a low level of abstraction". Initially it is common for tentative categories to emerge. These "low-level" (ibid.) categories are integrated into meaningful units as the coding process progresses and "higher-level" categories are identified (ibid.). These categories should not be sourced from established "theoretical formulations", but should rather be grounded in the data. The "words and phrases used by participants in the study" should ideally be used as category labels; this is referred to as in-vivo coding (ibid., p. 36). This will assist the researcher in grounding the category creation in the data and to avoid "importing existing theory into the analysis" (ibid.). The categories become more analytic, as opposed to descriptive, as the grounded theory analysis progresses and are therefore formulated at a higher-level of abstraction (ibid.). Grouping together instances of a higher-level of abstraction involves an interpretation of events, processes or occurrences of phenomena rather than the simple labelling of these (ibid.). Distinct from content analysis, categories in grounded theory emerge from the data "and the same data can be allocated to different categories" (ibid.).

Pandit (1996, p. 1) makes the distinction between a category and a concept by pointing out that categories "are higher in level and more abstract than the concepts they represent" (ibid.). He suggests that categories are the basis of theory development and "provide the means by which the theory can be integrated".

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2.7.2.2 Axial coding

Axial coding takes place after the open coding phase (Douglas 2003, p. 50) and involves reassembling data that were separated during the open coding process in "new ways to make connections between categories and codes" (Henning 2008, p. 132). De Vos *et al.* (2009, p. 343) point out that even though open coding and axial coding are two separate processes "when the researcher is actually engaged in analysis he alternates between the two modes". The emphasis during axial coding is on the "relationship between categories or codes" (Henning 2008, p. 132). In a coding context, a category signifies a "phenomenon, such as a problem, an issue or an event that has been defined by respondents as being significant" (ibid.). Identified categories are "related to their subcategories to form more precise and complete explanations of the phenomena" (ibid.). De Vos *et al.* (2009, p. 343) expand on this when they indicate that in grounded theory subcategories and categories are linked together "in a set of relationships denoting causal conditions, phenomena, context, intervening conditions, actions/interactional strategies and consequences" (ibid.). This set of relationships would allow the researcher to "think systematically about data and to link the data in more complex ways" (ibid.).

Henning (2008, p. 132) advises that even though the text would point to how categories may or may not relate to one another, the "actual linking of categories does not take place" at a textual level, but rather at a conceptual level. This "implies that text is converted into concepts" (ibid.). Pandit (1996, p. 1) points out that theories cannot "be built from actual incidents or activities as observed or reported; that is, from 'raw data'" (ibid.). These occurrences would need to be given "conceptual labels" as only "by comparing incidents and naming like phenomena with the same term can the theorist accumulate the basic units of theory" (ibid.).

Rodon and Pastor (2007, p. 71) point out that this systematic linking of concepts is based on the paradigm model that "is a tool to help contextualize the phenomenon by modeling the action and interaction strategies of the actors". Using a coding paradigm, the researcher is sensitised to the various "ways in which categories are linked with each other" (Willig 2009, p. 40). It helps to determine which categories may be considered core categories and which periphery ones (ibid.).

2.7.2.2.1 Coding paradigm

Strauss and Corbin's version of grounded theory proposes that the researcher pose questions related to the data (Willig 2009, p. 40). These questions are concerned with the context "within which the category is embedded, the interactional strategies used by participants to manage the category, and the consequences of such interactional strategies" (ibid.). These questions are asked of the data during the axial coding part of the grounded theory process (ibid.).

The coding paradigm is invoked during the axial coding part of the grounded theory process when intense analysis is performed around a single category at a time with reference to the paradigm items (Bryant & Charmaz 2010, p. 201). The purpose is to generate or uncover concepts that match the data (ibid.). The axis in axial coding is comprised of the category and it is around this category that additional "coding and category building" is carried out (ibid.). Strauss's coding paradigm "represents a group of abstract terms which are used to develop categories from the data and to find relations between them" (ibid.). The coding paradigm recognises that categories are developed using either a predefined theoretical framework or the leeway to make use of various such frameworks in order to avoid being overwhelmed by the data (ibid., p. 202). The paradigm model places particular emphasis on the "intentions and goals of the actors" (ibid.).

The categories that were established earlier in the grounded theory process are explored and investigated to determine how they relate to the following:

- The phenomena toward which "the action and interaction in the domain under study are directed";
- the causal conditions that give rise to the occurrence of the phenomena under investigation;
- "attributes of the context of the investigated phenomena";

- other intervening conditions by which the phenomena under investigation are influenced;
- "action and interaction strategies the actors use to handle the phenomena and
- the consequences of these actions and interactions" (ibid.).

2.7.2.3 Selective coding

Selective coding involves the selection of the core category, "the central phenomenon that has emerged from the axial coding process", and relating all other categories to this central phenomenon (Douglas 2003, p. 50). Pandit (1996, p. 7) describes the core category as being the story line of a "descriptive narrative about the central phenomenon of study". The story line would be the "conceptualization of this story" (ibid.). Henning (2008, p. 132) indicates that selective coding "implies the process of integrating and refining categories". De Vos *et al.* (2009, p. 344) suggest that selective coding does not differ significantly from axial coding "but takes place at a higher, more abstract level of analysis". Douglas (2003, p. 50) points out that these "codes can be classified as representing context, conditions, actions, interactions and outcomes". He states that "in this way a theoretical framework of interrelated concepts can be developed" showing relationships between the categories and the central concept.

2.7.3 Memoing

Memoing refers to the recording of "reflective notes about what you are learning from the data" (Henning 2008, p. 132). Memo writing involves keeping a "written record of theory development" (Willig 2009, p. 37). This is done throughout the data collection and analysis process and involves recording definitions of categories and explaining the labels chosen for them, "tracing their emergent relationship with one another", and recording the "progressive integration of higher- and lower-level categories” (ibid.). These memos are used to “reflect upon and explain meanings ascribed to codes”, “identify relationships between codes; to clarify, sort and extend ideas; and to record crucial quotations or phrases” (Douglas 2003, p. 51). Pandit (1996, p. 10) suggests that writing “theoretical memos is an important part” of conducting research using a grounded theory approach and that memos are not merely a record of the researcher's ideas, but involves the “formulation and revision of theory during the research process”.

2.8 Research paradigm

A paradigm can be regarded as a set of fundamental or basic beliefs that "represents a worldview that defines, for its holder, the nature of the 'world', the individual's place in it, and the range of possible relationships to the world and its parts" (Guba & Lincoln 1994, p. 107). The underlying beliefs that "define enquiry paradigms" are encapsulated in three fundamental questions. These are the "ontological question", the "epistemological question" and the "methodological question" (ibid., p. 108). The ontological question explores the "form and nature of reality" (ibid.) and what can be known about it. The epistemological question is concerned with the relationship between the "knower and what can be known" (ibid.). The methodological question concerns the way in which the researcher goes about investigating whatever "he or she believes can be known" (ibid.).

What follows is a discussion of the ontological assumptions relating to positivism and interpretivism and the epistemological assumptions related to empiricism and rationalism. The social constructivist worldview will then be discussed due to its particular relevance to this study. This section concludes with an exploration of qualitative and quantitative research approaches.

2.8.1 Positivism and interpretivism

Positivism is concerned with the discovery of truth “through empirical means” and proposes that it is impossible to gain knowledge without observation and measurement (Henning, 2008, p. 17). Trochim (2001, p. 18) proposes that from a positivist perspective the aim of “knowledge is simply to describe the phenomena that are experienced”. The empirical position that positivists adhere to stresses that “observation and measurement are at the core of scientific endeavor” (ibid.). Personal insights and experience that is not derived from sensual input are therefore excluded in an empirical “theory of knowledge” (ibid.). In a positivist paradigm existence “operates by laws of cause and effect” that can be detected “by means of scientific methods” (ibid.). It would, therefore, only require “deductive reasoning to postulate theories that can be tested in order to confirm or reject them” (ibid.).

Interpretivism is concerned not only with “observable phenomena” but also involves constructing knowledge by taking note of “descriptions of people’s intentions, beliefs, values and reasons, meaning making and self-understanding” (Henning 2008, p. 20). Henning (ibid) states that “interpretivist research is a communal process, informed by participating practitioners and scrutinized and/or endorsed by others”. The interpretive researcher uses the same “discourses” that “drive society” during the analysis process (ibid.). These are closely examined in an attempt to determine the “way in which people make meaning in their lives, not just that they make meaning, and what meaning they make”. An awareness of the “role of context” is, therefore, important to an interpretative researcher as the “frames that shape the meaning” are embodied in the meaning itself (ibid.). This makes in necessary to “collect substantial situational information” by conducting inquiry in “natural settings” (ibid.). Henning (2008, p. 20) points out that “unstructured observation, open interviewing, idiographic descriptions and qualitative data analysis” are some of the ways in which interpretive information can be handled.

2.8.2 Empiricism and rationalism

Within epistemology, "the branch of philosophy devoted to studying the nature sources and limits of knowledge" (Markie 2008, p. 1), there is a "dispute between rationalism and empiricism". Empiricism is the view that "observation and measurement" are central to "scientific endeavor" (Trochim 2001, p. 19). Empiricists propose that all "concepts and knowledge" are gained through "sense experience" (Markie 2008, p. 5). Rationalists, on the other hand, propose "that there are significant ways in which our concepts and knowledge are gained independently of sense experience" (ibid., p. 1). Rationalists will argue that there are instances "where the content of our concepts or knowledge outstrips the information that sense experience can provide" (ibid.). A form of reason "provides the additional information about the world" (ibid.).

2.8.3 Qualitative and quantitative research

De Vos *et al.* (2009, p. 73) point out that there are essentially two "recognized approaches to research, namely the qualitative and the quantitative paradigms" and that these two paradigms "differ incisively from each other". Henning (2008, p. 3) maintains that the "distinction between the qualitative paradigm and the quantitative paradigm" lies in the "quest for understanding and for in-depth inquiry". She explains that "qualitative studies usually aim for depth rather than 'quantity of understanding'". A quantitative study focuses on controlling all "the components in the actions and representations of the participants" (ibid.). All "components of the phenomenon that is studied" are controlled and the study "is guided with an acute focus on how" these components are related to each other (ibid.). The central aims of quantitative research "are to objectively measure the social world, to test hypotheses and to predict and control human behavior" (De Vos *et al.* 2009, p. 74). A qualitative study aims at capturing the "freedom and natural development of action and representations" (ibid.) that are characteristic of a phenomenon under investigation and will, therefore, not usually control the various components of the phenomenon. A qualitative method "denotes the type of inquiry in which the qualities, the characteristics or the properties of a phenomenon are examined for better understanding and explanation" (Henning 2008, p. 5). Data collected in a qualitative study will be carefully documented and analysed to determine "primary themes" (ibid.). Henning identifies observation, artifact and document studies, and interviewing as the "three main categories of data collection or gathering methods in qualitative research" (ibid., p*. 6*) indicates that during qualitative research, when the researcher analyses collected data, the number of "times something happened" is not of primary interest. Rather the researcher attempts to "find a pattern in and a reason for the way in which something happened" (ibid.). Qualitative researchers do not only want to determine what happens, "but also how it happens and, importantly, why it happens the way it does" (ibid., p. 3).

2.8.4 Social constructivist worldview

In a social constructivist worldview individuals attempt to gain an understanding of the world around them and develop "subjective meanings and experiences" (Creswell 2009, p. 8). This results in numerous meanings or versions of 'reality' and the researcher attempts to understand a "complexity or views" rather than a single definitive explanation or interpretation (ibid.). Participants in a study are relied on to communicate their "view of a situation" and predominantly open-ended questions are presented to them (ibid.). This allows them to "construct the meaning of a situation" rather than have one imposed or imprinted on them (ibid.). Meanings are often "negotiated socially and historically" and typically involve "interaction among individuals"(ibid.). This interaction often leads the researcher to focus on "the specific context in order to understand historical and social settings of individuals "as meanings are formed through the social, cultural and historical norms that operate on the individuals' lives (ibid.).

In a social constructivist worldview researchers acknowledge that their own background influences the interpretations that are made (ibid.). This acknowledgement encourages the researcher to indicate "how their interpretation flows from their personal, cultural, and historical experiences" (ibid.). When adopting a social constructivist worldview, a researcher does not typically begin with a theory that is to be proven or refuted, but rather aims to "generate or inductively develop a theory or pattern of meaning" (ibid.).

2.9 Synthesis

What follows is a synthesis of the various learning theories explored during a review of the literature together with a discussion concerning computer technology as a cognitive tool, higher-order thinking, design research and grounded theory.

2.9.1 Behaviourism

From a review of the literature (Schunk 1996; Boyle 1997; Alessi & Trollip 2001; Uden & Beaumont 2006; Neo 2003; Tan, Aris & Abu 2006; Ally 2008; Dalgarno 2001; Young 2003; Jonassen 2006), it seems reasonable to assume that a behaviourist approach to learning is not suited to the development of higher-order thinking skills. Figure 2.2 represents a synthesis of the behaviourist principles outlined in 2.2.1 of this chapter. This approach seems better suited to assist learners in the acquisition of procedural knowledge and learning that involves simple recall. The behaviourist emphasis on demonstrable behavioural change and the division of a learning event into predetermined steps, as illustrated in the shaping concept and the ISD approach (Alessi & Trollip 2001; Boyle 1997), suggests that very little emphasis is placed on individual understanding and individual representation of knowledge. This is underscored by the behaviourists' assertion that the cognitive processes that have led to the behavioural change are inconsequential and the focus should rather be on observable behaviour and the extent to which it matches the predetermined aims of the learning event (Alessi & Trollip 2001; Boyle 1997; Schunk 1996; Uden & Beaumont 2006; Dalgarno 2001).

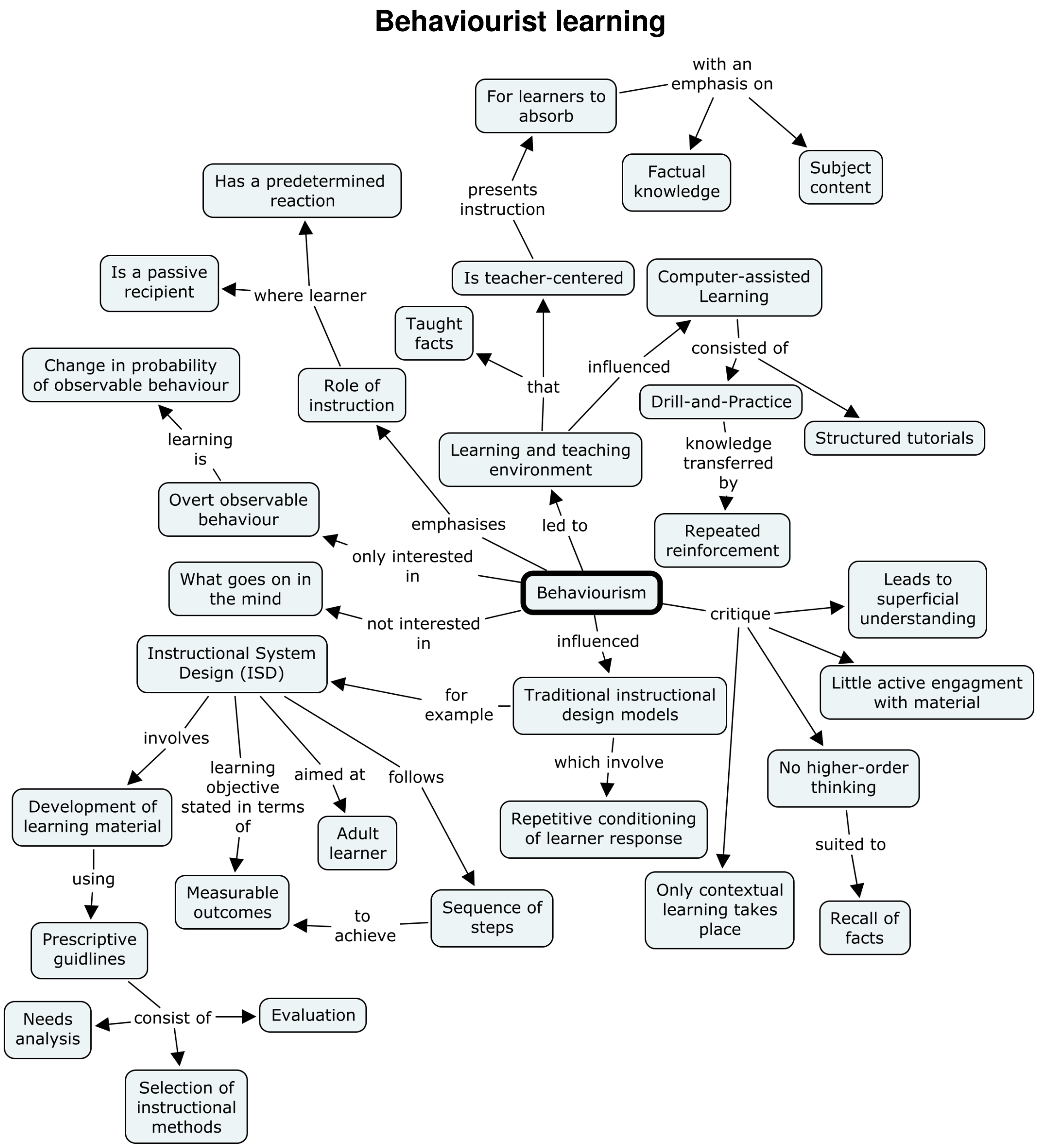

Figure 2.2 A synthesis of behaviourist-based learning

In addition it seems reasonable to assume that a computer's ability to tirelessly present learning material in a consistent manner has rendered it well suited to accommodate behaviourist principles, especially those based on conditioned learner responses that are the result of the repetitive presentation of learning material. Once again, an individual representation of understanding is irrelevant and would seem to contradict the notion of a predetermined learning objective.

2.9.2 Cognitivism

The literature (Alessi & Trollip 2001; Uden & Beaumont 2006; Debbagh 2005; Schunk 1996; Al-Issa 2006; Louw & Edwards 1997; Alexander 2006; McCown, Driscoll & Roop 1996) suggests that the cognitivist approach rejects the behaviourist proposition that the internal workings of the mind are inconsequential to the study of learning. Rather, cognitivists appear to place a great deal of emphasis on the processes that occur within the mind and the structures, which are constructed as a consequence of learning. The assertion, however, that learning based on behaviourist principles is a passive process, while cognitivism encourages active learning, seems to be problematic as the very nature of learning implies the active involvement of the learner. The distinction seems to be that the cognitive approach focuses on the role of the learner in the learning process, while the behaviourist approach appears to be concerned merely with behavioural change that results from a learning event. This emphasis on the processes that result in understanding and the structure of knowledge in the mind of the learner, appear to allow for individual and context-specific representations of knowledge. Due to the cognitivist emphasis on the changes in the configuration of knowledge, it seems conceivable that these representations can be expressed in a manner that will allow for comparison and contrast. Even though the cognitive approach places a great deal of emphasis on individual representations of understanding, it does not appear to contradict the notion of an objective reality and a predetermined learning outcome. Figure 2.3 represents a synthesis of the cognitivist principles outlined in 2.2.2 of this chapter.

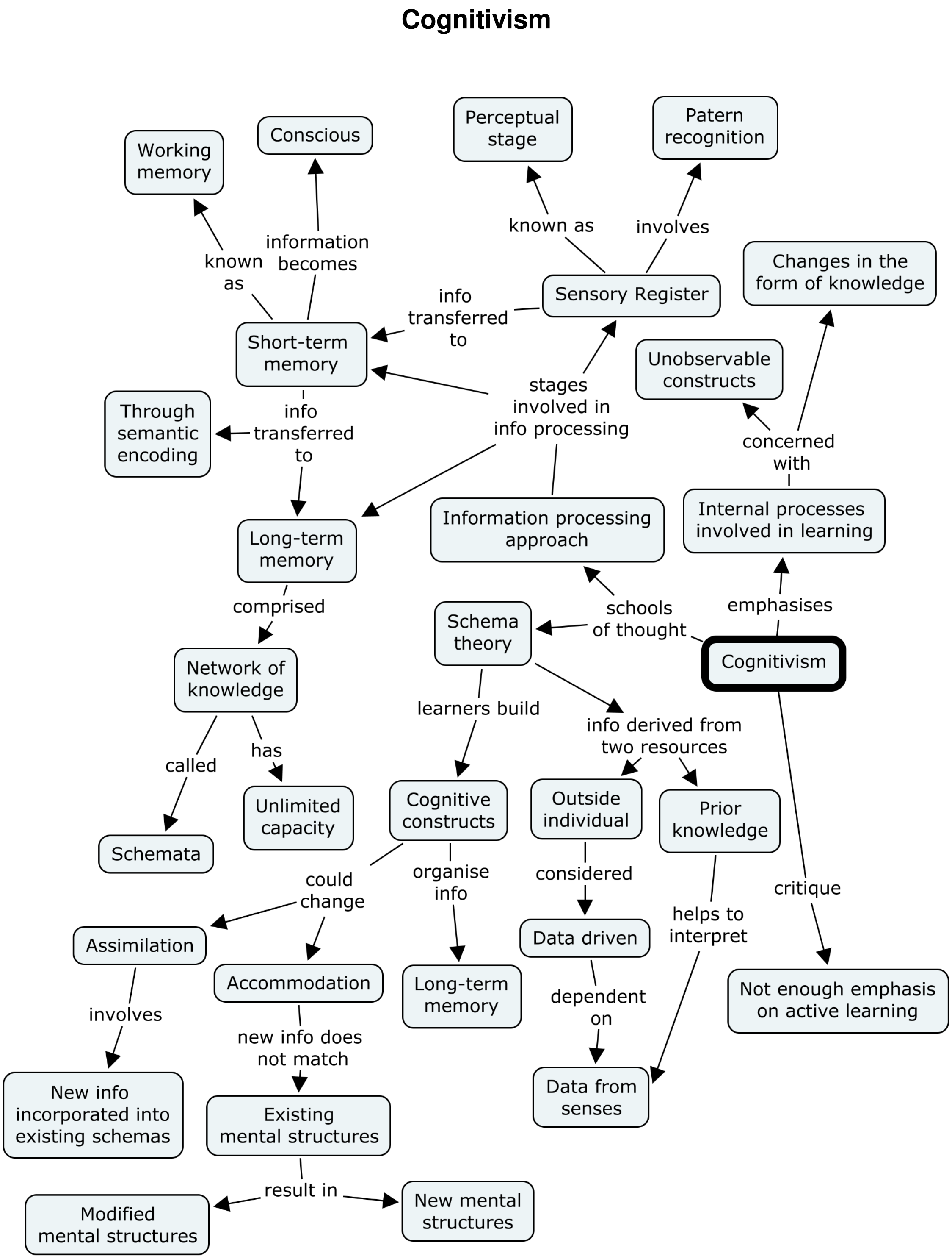

Figure 2.3 A synthesis of cognitivist-based learning

In a learning event based on cognitivist principles, the focus seems to be on the processes involved in achieving an understanding of an objective body of knowledge that exists outside of the individual learner.

2.9.3 Constructivism

A review of the literature (Dalgarno 2001; Schunk 1996; Alessi & Trollip 2001; Yilmaz 2008; Uden & Beaumont 2006; Kanuka & Anderson 1999; Alexander 2006; Boyle 1997; Anderson, Reder & Simon 1996; McCown, Driscoll & Roop 1996; Reeves, Herrington & Olver 2002; Karagiorgi & Symeou 2005; Applefield, Huber & Moallem 2001; Phillips 1995; Doolittle 1999; Neo 2003; Yilmaz 2008; Von Glasersfeld 2008; Derry 1996; Marsh & Ketterer 2005) indicates that constructivism seems to have been developed in reaction to the prescriptive and objectivist characteristics of both the behaviourist and cognitivist approaches to learning. A prominent characteristic of constructivism is the subjective nature of knowledge (Phillips 1995; Dalgarno 2001; Kanuka & Anderson 1999; Doolittle 1999). Figure 2.4 represents a synthesis of the constructivist principles outlined in 2.2.3 of this chapter. Though a review of the relevant literature indicates that cognitive constructivists purport that knowledge is a reflection of an external reality (Doolittle 1999; Alexander 2006; Neo 2003; Kanuka & Anderson 1999), constructivists generally seem to consider knowledge to be individual in nature. There is an emphasis on encouraging numerous representations of knowledge and discouraging the formulation of learning environments that promote replication of material and rote memorisation. Radical constructivists, in particular, maintain that knowledge cannot be an accurate reflection of an objective reality, but is essentially adaptive in nature. Knowledge is particular to an individual and is embedded in that individual's experience. This knowledge needs to be adapted in such a way that it will allow the individual to function appropriately and to make sense of experience.

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Constructivism

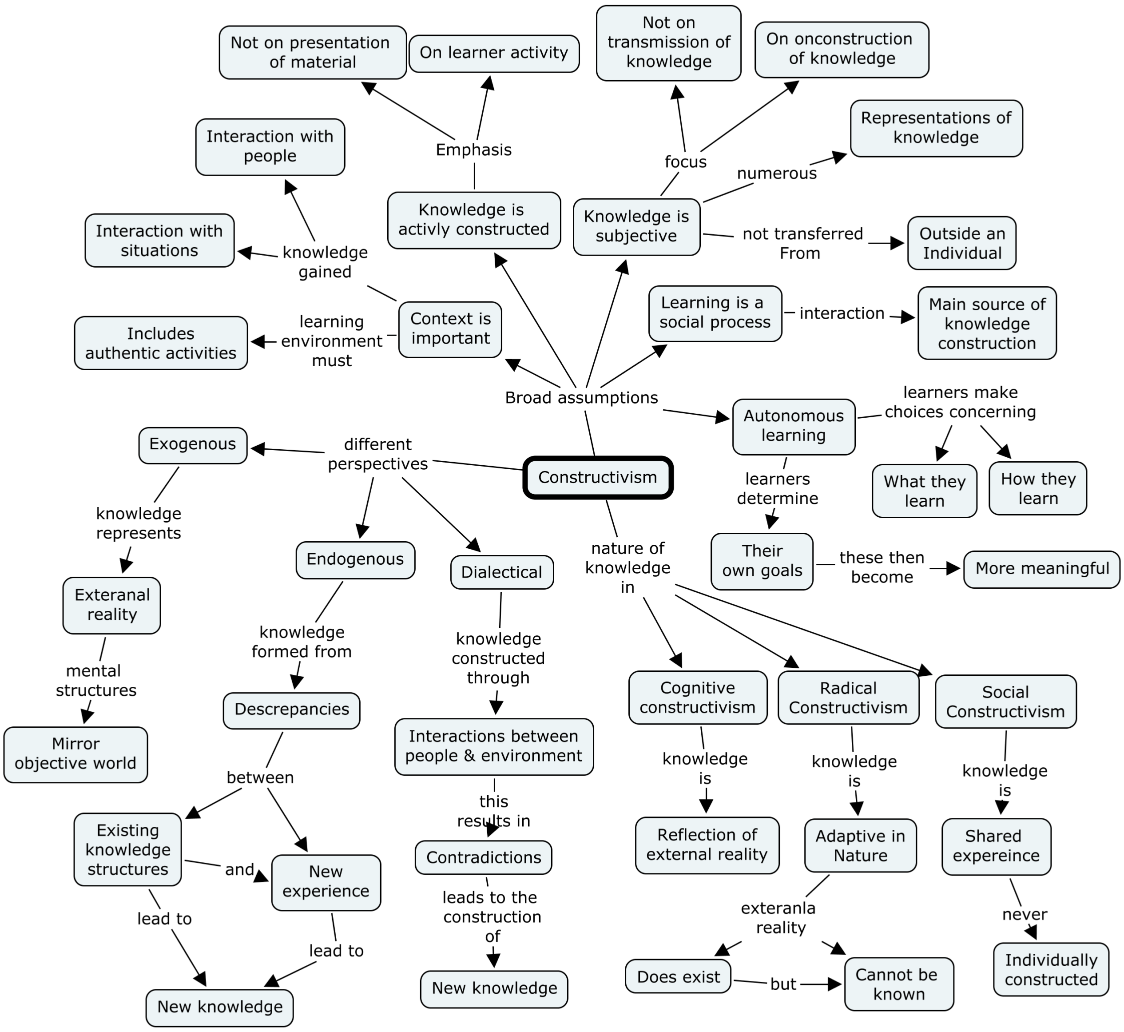

Figure 2.4 Synthesis of constructivism

Due to the fact that no two individuals can ever have the same experiences, no two versions of understanding or awareness can be exactly the same. The subjective and unique nature of knowledge leads to the encouragement and acceptance of multiple perspectives and adaptations of understanding. As a consequence, learners should be allowed to explore the environment that they are learning about with limited support and guidance. In a constructivist environment students are encouraged to participate actively in problem-solving activities, thereby uncovering concepts, related to the specific area of learning under investigation, for themselves.

Unlike behaviourists but similar to the cognitive approach, constructivists seem to place a certain emphasis on how people learn and construct knowledge. This emphasis seems to be less prominent in social constructivism, which stresses the social context and the role of experience in learning. Cognitive constructivists, in particular, seem to focus on learning processes. A review of the literature (Doolittle 1999; Alexander 2006; Neo 2003; Kanuka & Anderson 1999) has revealed that, from a cognitive constructivist perspective, changes in the internal structure of the mind occur when learners encounter inconsistencies between their experience and their current understanding. This suggests that ideas and approaches are tested with reference to prior knowledge and experience. This process allows understanding to be modified as a result of this new tested information. It is in this way that ideas develop in complexity. Constructivists consistently seem to discourage the notion that learners are merely passive receptacles of knowledge.

The context in which learning takes place is also emphasised in a constructivist approach. A review of the literature (Alexander 2006; Boyle 1997; Alessi & Trollip 2001; Schunk 1996; Anderson, Reder & Simon 1996; Herrington & Oliver 1995; McCown, Driscoll & Roop 1996) suggests that from a constructivist perspective, learning should be rooted in authentic tasks and meaningful contexts. The real world setting should reflect the complexity of the phenomenon under investigation and not be a simplified representation based on a series of instructions. The collaborative nature of learning also seems to form an important part of a constructivist approach to learning. This seems to be specifically germane to the social constructivist approach in which learning is seen to be a social process in which knowledge is constructed through social interaction and the use of language. Understanding is both tested and refined by means of social discourse. Collaborative leaning appears to facilitate the process of accepting or rejecting the opinions of others and expressing one's own, which can in turn be accepted or rejected. A literature review (Neo 2003; Doolittle 1999; Kanuka & Anderson 1999) indicates that knowledge cannot be considered to be an entirely individual construct, but rather a shared experience. The distribution and negotiation of knowledge seem to take place over a social network where people interact with one another in a meaningful way.

While there seems to be considerable emphasis on the social nature of knowledge construction, there is also significant emphasis on autonomous learning. A literature review (Schunk 1996; Alessi & Trollip 2001; Karagiorgi & Symeou 2005) reveals that when adopting a constructivist approach to learning, students should be given a choice of what and how to learn. The learning goals and activities should be collaboratively determined to allow for an exploration of particular interests. This in turn will make the learning more meaningful and allow the learner to become aware of how learning takes place. Strategic thinking will then be cultivated, which may facilitate the effective discovery of solutions to problems.

2.9.4 Computer technology as a cognitive tool

A review of the literature (Hokanson & Hooper 2000; Jonassen 2006; Jonassen & Reeves 1996; Karagiorgi & Symeou 2005; Jonassen, Carr & Yueh 1998; Van Joolingen 1999; Kirscher & Wopereis 2003; Vosniadou *et al.* 2001; Vosniadou 2007; Van Joolingen 1999) reveals that computer technology has traditionally been used in education to communicate ideas to learners in a way that does not require them to construct their own knowledge actively. Placing the focus, not on the learner but on the instruction and how it has been put together to transmit information, seems to have been a characteristic of this more established use of technology in education. The use of computers in education seems to have been based substantially on behaviourist learning theories that promote the formulation of distinct learning objectives and a clear path to achieve these objectives.

Adopting a more constructivist approach to using technology in education could involve using computers as cognitive tools that initiate and encourage reflective thinking, exploration of multiple perspectives, modelling of understanding and problem-solving. Using computer technology in this way means that the focus is no longer on how technology is used to teach, but rather on how it enables learning to occur. The notion that technology is a tool that learners should be encouraged to learn with and not from is clearly a departure from tradition. When learners learn with the aid of computers, they act as designers and the computer is simply a tool that extends the capabilities of the mind by interpreting and organising information (Jonassen 2006; Jonassen, Carr & Yueh 1998; Van Joolingen 1999). This allows the computer to support different forms of reasoning and allows the learner to think critically about what is being studied. The fact that various tasks can be off-loaded to the computer does not necessarily make learning easier, as these tasks are normally the more unproductive tasks that the computer is better suited to undertake. The allocation of appropriate activities to the computer will allow the learner to dedicate more cognitive energy to the exploration of ideas and the articulation of information. The learning process will appear to be more efficient and meaningful if more cognitive effort is delivered by the learner than is supplied by the technology.

Using technology as a cognitive tool clearly constitutes a more constructivist approach to using technology in education, as learners are discouraged from duplicating existing formulisations of information. When using technology as a cognitive tool, learners are encouraged to represent, manipulate and reflect on their understanding and in this way develop and refine their individual conceptualisations of a particular subject. The development of an individual view of a subject requires an active process of reflection and interpretation which is in keeping with a constructivist approach to learning.

From a review of the literature (Jonassen 2006; Vosniadou *et al*. 2001, Vosniadou 2007) it can be concluded that meaningful learning involves conceptual change. This constitutes a substantial reorganisation of existing knowledge structures which form the personal theories that individuals have constructed to make sense of reality. It is unlikely that conceptual change can be achieved if learners engage with information at a superficial or trivial level. A literature review (Jonassen 2006; Vosniadou *et al*. 2001, Vosniadou 2007) has revealed that conceptual change often takes place when learners come across information that is inconsistent with their current conceptualisations. This cognitive conflict can be successfully used to encourage conceptual change, particularly if supported by knowledge building activities such as model building.

It has emerged from a review of the literature (Jonassen 2006; Van Joolingen 1999; Kirscher & Wopereis 2003; Vosniadou 2007; Hokanson & Hooper 2000, Jonassen 1995; Jonassen, Carr & Yueh 1998) that in a constructivist learning environment, computer technology is often seen as a cognitive tool when it is used to develop models of understanding. These models demonstrate and articulate learning and can facilitate meaningful cognitive activity that often initiates conceptual change. It is through the modelling process that information is transformed into knowledge. The development of models using computer technology allows learners to compare, contrast and revise their conceptualisations in an effort to achieve a deeper more meaningful understanding. This seems to be in keeping with the social constructivist's approach that meaning and knowledge are socially negotiated and constructed through language mediated-interaction. A review of the literature (Jonassen 2006; Jonassen, Carr & Yueh 1998) related to using technology as a cognitive tool strongly indicates that it is not sufficient simply to use existing conceptual models. Learners would need to be the designers and developers of their own models if meaningful learning is to be accomplished. This forces the learners to reflect on their conceptualisation of a particular subject domain, which in turn may lead to conceptual change.

2.9.5 Higher-order thinking

There seems to be a clear distinction between higher- and lower-order thinking skills. Higher-order thinking involves the integration of new information with existing knowledge to create a new understanding of a situation or to solve a perplexing problem (Lewis & Smith 1993, Ping & Kee 2009). When a student engages with a problem merely by using simple recall to achieve a solution, it is unlikely that higher-order thinking skills will be applied or developed. Rote learning is not likely to result in the enhancement of higher-order thinking as during this sort of learning, students are merely required or encouraged to regurgitate the understanding of others. Higher-order thinking is encouraged when students are required to adopt an active role in the learning process. Problem-solving, critical thinking and creative thinking together with a metacognitive awareness all seem to be an integral part of higher-order thinking. Figure 2.5 represents a synthesis of the higher-order thinking as outlined in 2.5 of this chapter.

Higher-order thinking

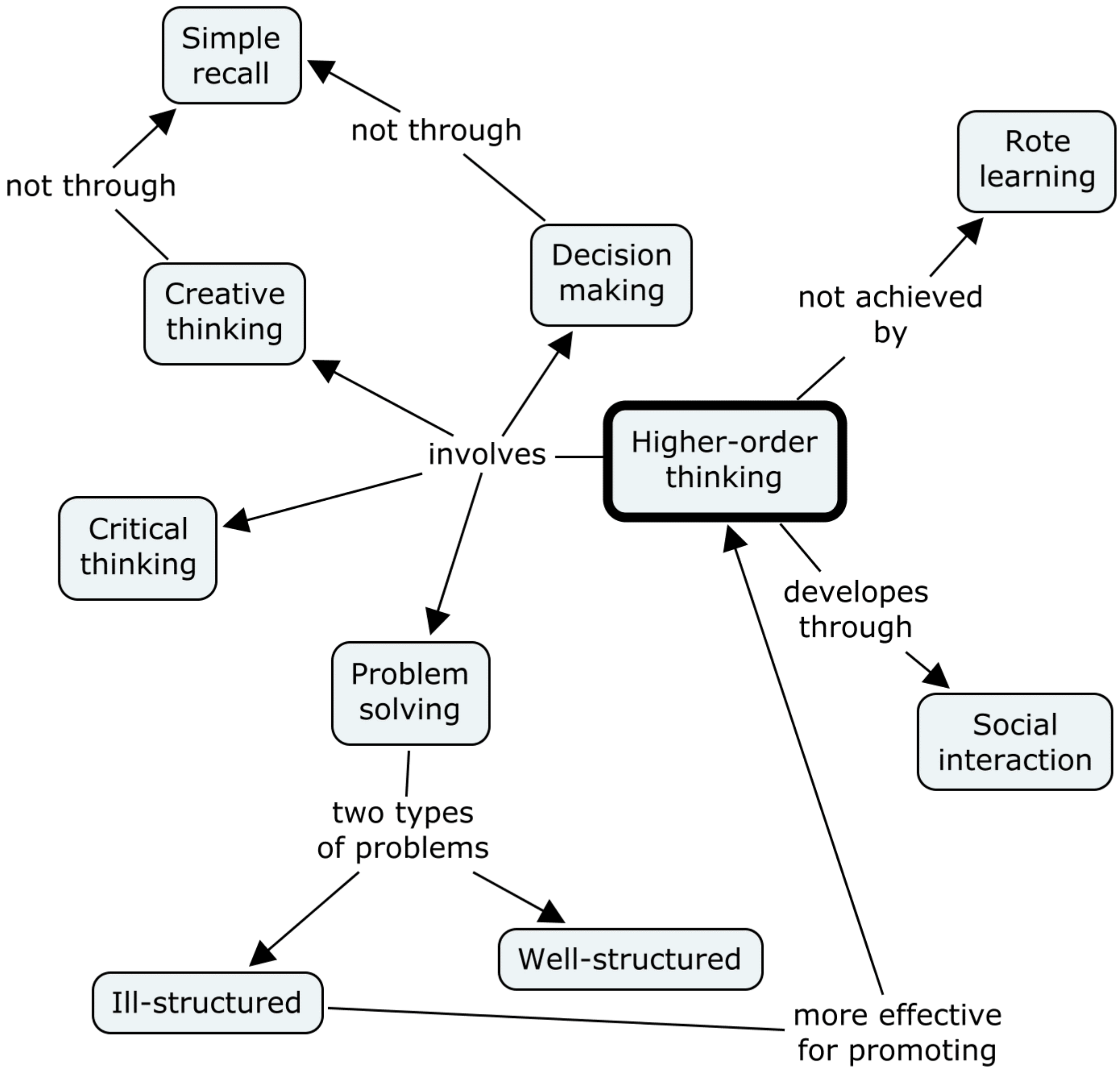

Figure 2.5 A synthesis of higher-order thinking

Critical thinking involves having insight into all aspects of a situation and being sensitive to evidence that refutes existing ideas. A critical thinker draws conclusions from available facts and is adamant that assertions be supported by evidence (Willingham 2007; Lewis & Smith 1993; Ennis 1993; Wang 2009). The quality of an argument is assessed before it is accepted or rejected and the critical thinker does not simply rely on the recollection of information. Figure 2.6 represents a synthesis of critical thinking as outlined in 2.5.1 of this chapter.

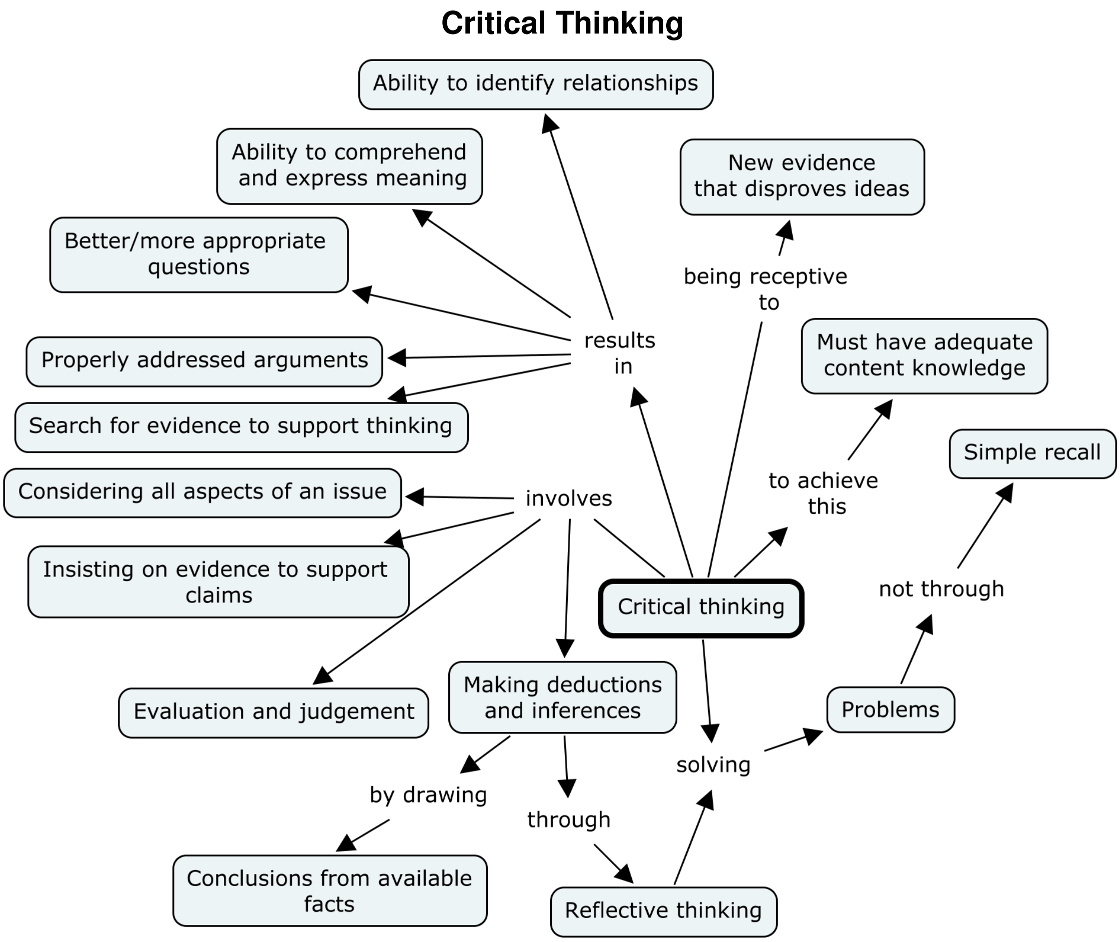

Figure 2.6 A synthesis of critical thinking

Critical thinking encourages the development of a point of view and provides the impetus to defend a standpoint. Critical thinking seems to encourage a person to appreciate the significance of meaningful information. Adequate content knowledge does, however, seem to be a precondition for critical thinking to take place as one can only evaluate the veracity of a claim or point of view if one has sufficient insight into the domain within which the argument is situated.

The ability to engage effectively in problem-solving activities seems to be an important aspect of higher-order thinking (Hauer & Daniels 2008; Weiss 2003; McLoughlin & Luca 2000). Problems that are ill defined and for which there are a variety of possible solutions seem to provide the most valuable opportunities for the development of higher-order thinking. Figure 2.7 represents a synthesis of problem-solving as outlined in 2.5.3 of this chapter. These problems more accurately reflect the dilemmas encountered in the real word.

Problem-solving

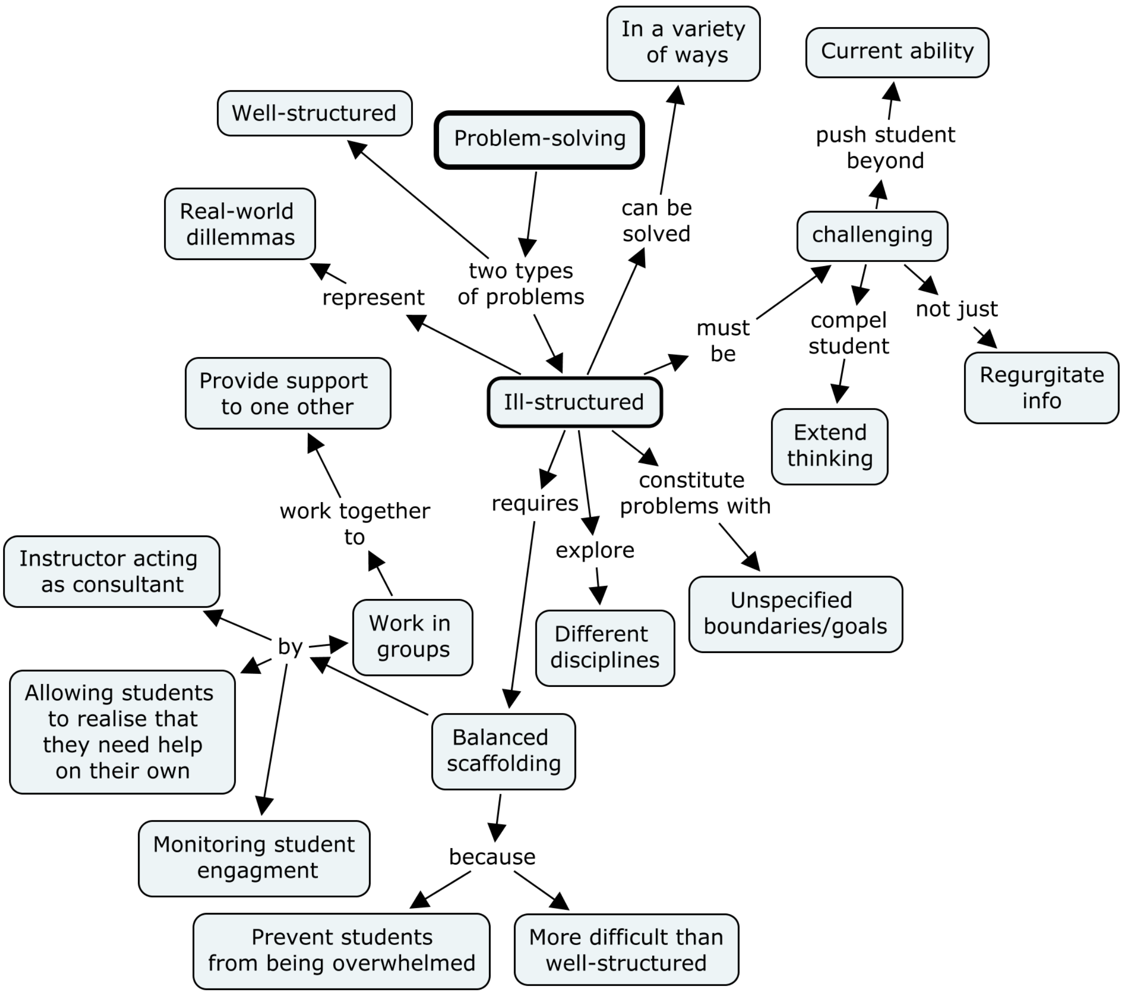

Figure 2.7 A synthesis of problem-solving

Educators need to create learning environments that present students with ill structured problems in order to promote the acquisition of higher-order thinking skills. To prevent the student from becoming overwhelmed these environments must include a kind of balanced scaffolding. This support includes, grouping students of differing abilities and skills, monitoring student progress and understanding, timely questions, provision for collaboration and the inclusion of well-structured problems.

Figure 2.8 represents a synthesis of the higher-order thinking and social interaction as outlined in 2.5.2 of this chapter.

Higher-order thinking and social interaction

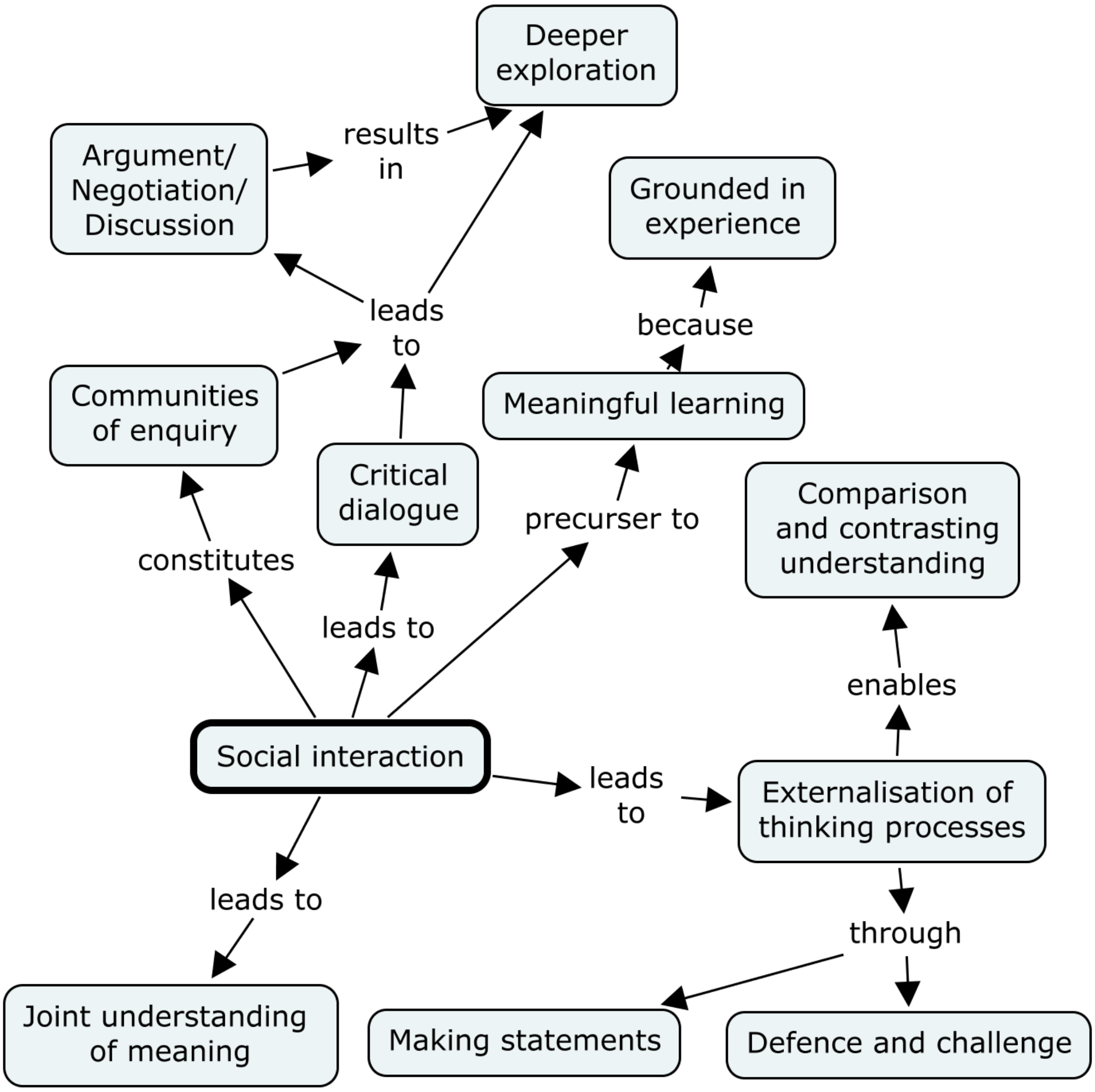

Figure 2.8 A synthesis of higher-order thinking and social interaction

Sustained interaction appears to be a requirement for meaningful learning to take place. This sustained interaction within a social context allows for critical reflection, a deeper exploration of concepts through dialogue, an articulation of understanding and a more meaningful educational experience. Conceptual development is encouraged when learners assist one another, share information, rationalise their understanding, question the contributions of others and collaborate with one another to solve problems (Anderson & Garrison 1995; McLoughlin & Luca 2000; Ping & Kee 2009).

2.9.6 Design-based Research

The literature suggests that design-based research is suited to the development and evaluation of educational interventions that address complex real world problems (Mantei 2008; Plomp 2007; Bowler & Large 2008; Joseph 2004; The Design-Based Research Collective 2003; Cobb *et al*. 2003; Collins, Joseph & Bielaczyc 2004). It seems reasonable to assume that the aim of this type of research is to improve knowledge of the characteristics and processes involved in the design and development of these interventions and to produce design principles that can support similar design and development activities. This will contribute to an understanding of the purpose and value of the intervention and establish guidelines that can assist other designers in their efforts. The literature strongly suggests that these guidelines need to be supported by theoretical and empirical arguments that serve as proof of their dependability.

2.9.6.1 Phases in the research into using technology as a cognitive tool

A literature review concerning design-based research brings to light three phases that can be used when undertaking design-based research (Plomp 2007). These are a preliminary investigation phase, a prototyping phase that involves using a provisional version of an intervention in an authentic setting, and an assessment phase. These phases will be discussed with particular reference to the way in which they will be used in the research into using computer technology as a cognitive tool.

2.9.6.1.1 Phase 1: Preliminary investigation

The literature (Plomp 2007) indicates that knowledge gained from previous research is used to develop an innovation and this innovation is then evaluated to produce further knowledge. The design research processes, therefore, seem to involve a preliminary investigation that includes a literature review, a needs analysis and the development of a conceptual framework.

A review of the literature (Plomp 2007) relating to using technology to facilitate the development of higher-order thinking skills indicates that a constructivist intervention would be appropriate. This constructivist intervention is likely to be effective if computer technology is used as a cognitive tool rather than as a medium that simply communicates information. The literature further indicates that by modelling understanding by constructing an expert system, students will be able to gain a deep understanding of both the structural and procedural aspects of a particular subject domain. It is within this conceptual framework that the design research will take place.

2.9.6.1.2 Phase 2: Prototyping

A literature review (Plomp 2007) indicates that once a preliminary investigation has been undertaken, the design research process moves on to a prototyping phase. This phase appears to involve the placing of a provisional version of the innovation in a real-world context and then formatively evaluating it through cycles of improvement and refinement. It is during this phase that a prototype or trial version of the intervention that uses technology as a cognitive tool was presented to a group of experienced English Communications Skills lecturers and instructional designers. This intervention was then formatively evaluated through a process of observation and by analysing the feedback obtained from focus group interviews held after each design session.

2.9.6.1.3 Phase 3: Assessment

The final phase in the design research process is an assessment phase, which aims to determine the extent to which the intervention is able to achieve the predetermined objectives of the learning intervention. From a review of the literature it seems reasonable to assume that the prototyping phase involves the creation or development of artifacts that give substance to the assumptions and speculations concerning a particular learning phenomenon. The subsequent investigation revolves around the evaluation of these artifacts with particular attention focused on those questions that have a bearing on their design. A review of the literature (Plomp 2007) indicates that during the design research process constant reflection should be undertaken in order to promote the informed production of design principles.

2.9.7 Grounded theory

From a review of the literature (Welman & Kruger 2005; Brown *et al*. 2002; Douglas 2003; Corbin & Strauss 1990; Berg 2004; De Vos et al. 2009; Henning 2008; Willig 2009) it seems sensible to assume that the purpose of a grounded theory approach to research is to generate a theory based on propositions derived from an identification of a series of credible relationships between and among concepts. The literature (Henning 2008; Willig 2009) suggests that the researcher approach data with theoretical sensitivity. This involves the development of an ability to recognise concepts allied to specific data. This would allow the researcher not only to discern significant data but also to develop conceptually rich theory. The literature further suggests that grounded theory provides an organised and efficient means of acquiring, analysing and judging data in order to generate substantive theory.

2.9.7.1 Determining the research question

After a review of the literature (Welman & Kruger 2005; Brown *et al*. 2002; Douglas 2003; Corbin & Strauss 1990; Berg 2004; De Vos et al. 2009; Henning 2008; Willig 2009) it has become apparent that the technical literature relevant to the field of study related to the investigation should be referred to when determining research questions. This literature can include articles related to research studies as well as published theoretical and philosophical discussions. A review of the literature related to the use of technology in education should clearly outline the various learning theories that have informed traditional and current practices in this regard. The literature further indicates that it is reasonable to assume that a more constructivist approach that employs technology as a cognitive tool, rather than as simply as a medium that communicates information, is likely to be useful in the development of higher-order thinking skills in students. These assumptions have helped to focus attention on problems related to the identification of the characteristics of an intervention that uses technology as a cognitive tool, and the variety of design implications of such an intervention.

2.9.7.2 Data collection

From a review of the literature it has been determined that qualitative data collection methods, such as focus group interviews, can provide a rich insight into human behaviour and understanding (Henning 2008; De Vos *et al*. 2009). These methods are considered to be appropriate to a grounded theory approach as they provide a rich source of material that can be coded in order to generate concepts and categories that can form the basis of a theory.

2.9.7.3 Data analysis

When analysing the data questions will be asked in relation to the data in order to break it down and compare various incidents to one another. This would allow the raw data to be converted into concepts and then grouped together into categories. The relationship between categories and subcategories will than be explored and defined when the data is reassembled in new ways. It is expected that at this point a central phenomenon or core category will be identified and this will allow for the integration of all categories with this core category.

2.10 Chapter summary

This chapter investigates the various learning theories that have informed digital educational technology with a particular emphasis on those that advance using computer technology as a cognitive tool that students learn with and not from. The chapter also examines the constructivist use of educational technology as a cognitive tool. The focus in this section is primarily on using computer software as an expert system shell that would allow students to model their understanding in order to achieve or promote conceptual change. Higher-order thinking was then investigated by exploring a definition of higher-order thinking, critical thinking, problem-solving and the influence social interaction has on higher-level thinking. A design-based research approach was explored by explaining the characteristics of design research as well as the stages typically included in this approach. The grounded theory approach to data collection and analysis was then investigated. Various epistemological, ontological and methodological issues were investigated under the heading *Research paradigm* with particular emphasis on a social constructivist worldview.