Chapter 1
Introduction to the research

1.1 Introduction

Jaffer, Ng'ambi and Czerniewicz (2007, p. 131) propose that educational technology should principally be used to contribute supplementary strategies that can be used to address various educational challenges that educators face in higher education. Among these challenges is the "general lack of academic preparedness" of students who typically enter South African higher education institutions (ibid.). These students often expect to be provided with answers and are not able to engage with material at a higher cognitive level. Jaffer *et al.* (ibid.) indicate that the challenges that higher educational institutions need to address centre on issues related to student diversity and include differences in "student academic preparedness, language and schooling background". They point out that even though educational technology cannot address all the educational challenges faced by learning institutions, it has the potential to leverage and widen conventional teaching and learning activities under certain circumstances (ibid., p. 136). It consequently has the capability to have a bearing on learning outcomes (ibid.). Educational technology enables teachers to attempt various "teaching and learning activities" that they are unlikely to have otherwise thought of (ibid.). It is, however, important to recognise the situations in which educational technology are suitable and to identify the best way to use technology in these particular contexts.

Traditionally making use of educational computer technology involved instructional delivery, using the computer as a tutor or a surrogate teacher and behaviourist-based drill-and-practice exercises (Fouts 2000, p. i). Using computer technology as a cognitive tool "represents a significant departure from traditional conceptions of technology" (Yildiram 2006, p. 27). Cognitive tools allow students to perform the role of designer and encourage them to solve problems by "analyzing, accessing, interpreting and organizing their

personal knowledge" (ibid.). Using computer technology as a cognitive tool is expected to encourage "critical thinking and higher-order learning in students" (ibid.).

This chapter introduces this study by providing a background that outlines some of the reasons why many South African students enter higher learning institutions under-prepared and the role educational computer technology can play in addressing challenges related to this under-preparedness.

1.2 Definition of terms

A brief definition and explanation of the core concepts are explored in this section to assist in the reading of this thesis. A more detailed discussion of these is offered in the literature review chapter (Chapter 2) and in the discussion and literature reflection chapter (Chapter 6).

The concepts explored in this section are as follows:

- Conceptual change
- Models
- Cognitive load theory
- Cognitive tool
- Expert system shell
- Educational design research
- Embodied conjecture
- Design principle
- Higher order thinking

1.2.1 Conceptual change

Conceptual change may be viewed as a learning process “that requires the significant reorganization of existing knowledge structures” (Vosniadou, Ioannides, Dimitrakopoulou & Papademetriou 2001, p. 383). Jonassen (2006,

p. 3) 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 has become one of the most common conceptions of meaningful learning, because it treats learning as an intentional, dynamic, and constructive process that encompasses developmental differences among learners" (ibid.).

1.2.2 Models

Jonassen (2004, p. 4) explains that models are “conceptual systems" that are made up of "elements, relations, operations, and rules governing interactions using external notation systems". These models are in the mind of the learner and are used to "construct, describe or explain" the activities of "other systems". Though these models are in the mind, they are also articulated using "representational media" that represent a learners understanding. Jonassen (ibid.) indicates that the relationship between mental models and externally represented models is not clearly understood but maintains that there is "a dynamic and reciprocal relationship between internal mental models and the external models that students construct".

1.2.3 Cognitive load theory

Cognitive load theory is primarily concerned with the learning of complex or difficult cognitive undertakings during which learners are commonly " overwhelmed by the number of information elements and their interactions that need to be processed simultaneously before meaningful learning can commence" (Paas, Renkl & Sweller 2004, p. 1). Central to cognitive load theory is the assumption that human cognitive structures consist of a working memory that has limited capacity when handling new information and a long-term memory that has unlimited capacity for storing schemas of information (ibid., p. 2).

1.2.4 Cognitive tool

When computers are used as instruments that support cognitive processes that extend people's cognitive capacity, they can be described as cognitive tools (Van Joolingen 1999, p. 389). Cognitive tools are synonymous with mind tools and "are computer applications that, when used by learners to represent what they know, necessarily engage them in critical thinking about the content they are studying" (Jonassen, Carr & Yueh 1998, p. 1). Cognitive tools scaffold or support various types "of reasoning about content" (ibid.). As a consequence, students are required "to think about what they know in different, meaningful ways".

1.2.5 Expert system shell

An expert system is a computer application that simulates or mimics "the way human experts solve problems; it is an artificial decision maker" (Jonassen 2006, p. 134). A computer application that allows students to build their own expert system would than be an expert system shell. The application, CourseLab, was used as an expert system shell in the study reported on in this thesis.

1.2.6 Educational Design research

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”.

1.2.7 Embodied conjecture

Sandoval (2004, p. 215) explains that an “embodied conjecture is a conjecture about how theoretical propositions might be reified within designed

environments to support learning". He expands on this by pointing out that these conjectures need to be developed from "extant knowledge of learning in particular domains" and, therefore, should ideally be a "theoretically principles activity". Embodied conjectures should also lead "not simply to the improvement of a particular learning environment design, but can potentially lead to refinement in learning theory itself" (ibid.). Sandoval (2004, p. 215) distinguishes an embodied conjecture from a design principle by pointing out that design principles are "articulated at a very general level" and as a consequence "are unassailable and empirically untestable". In contrast, embodied conjectures involve conjectures that are embodied in a specific learning environment or design activity.

1.2.8 Design principles

The aim of design research is to produce "knowledge about whether and why an intervention works in a certain context". (Plomp 2007, p. 20). Plomp (2007, p. 20) indicates that the knowledge produced by design research "has been called design principles or intervention theory".

1.2.9 Higher order thinking

Lewis and Smith (ibid., p. 136) propose that higher order thinking occurs when information stored in an individual's memory is interrelated or rearranged and the individual "extends this information to achieve a purpose to find possible answers in perplexing situations". They go on to indicate that 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 [sic] thinking is unlikely to take place.

1.3 Background

Many school leavers have not been provided with the necessary resources that are important to the development of cognitive skills (Fiske & Ladd 2005, p. 9). They often come from educational and social environments that present

them with very little that would stimulate thought that is beyond their direct experience (ibid.). The school setting is frequently not conducive to meaningful learning and students are often taught by under-qualified teachers who lack the necessary skills to develop the learners' cognitive abilities (Stephen, Welman & Jordaan 2004, p. 45; Fiske & Ladd 2006, pp. 9-11). Rote learning, without very much effort at comprehension, often seems to be characteristic of their school experience (Stephen *et al*. 2004, p. 45). Students are often more interested in passing examinations than gaining knowledge and feel as though they are being deprived of something when they are not simply provided with ready-made answers (ibid., p. 43).

1.3.1 Students are under-prepared for the demands of higher education

Thanasoulas (2001, p. 4) maintains that students who do not come from appropriate educational backgrounds are unable to understand and interpret information that is presented to them accurately. Greater demands are made on students who enter higher education institutions. As a consequence it is no longer adequate simply to reproduce information; these students are required to "participate in knowledge creation", rather than to be "mere receptacles of inert knowledge" in order to achieve "higher-order learning outcomes" (McLoughlin 1999, p. 226). Table 1.1 summarises some of the reasons why students are under-prepared for the academic demands of higher education. This table separates these reasons into the following clusters:

- Learners' school results as an indicator of student preparedness for higher education
- Legacy of Apartheid
- Teacher quality and lack of resources

Table 1.1 Factors contributing to the under-preparedness of students for higher education

Clustering	Supporting quotations found in the literature
Learners' school results as an indicator of student preparedness for higher education	**Unrealistic expectations brought about by learners' school results** Bothma, Botha and Le Roux (2004, p. 73) indicate that there is an "alarming degree of under-preparedness among many prospective students regarding what is expected of them at university". They suggest that the situation is aggravated by the "unrealistic expectations of performance in the first year of university" created by school marks (ibid.). **Inadequate measure of students' potential for success** School-leaving certificates are often "viewed as an inadequate measure of a student's potential for success in higher education" (Jaffer *et al*. 2007, p. 134). Often students find it "extremely difficult" to maintain their "school performance at a university level" and it is a "matter of great concern" as to whether "school results are still a reliable indicator" of a student's "preparedness for higher education" (Bothma *et al*. 2004, p. 86). **Drop in standards** Although pass rates may have improved, these are possibly the result of a drop in standards, "resulting in many academically poor and under-prepared students gaining access to higher education" (Stephen *et al*. 2004, p. 45). Jansen (2012, p. 7) maintains that the improvements in the matriculation pass rate are suspect because "students have to put in a special effort to fail".

Table 1.1 Factors contributing to the under-preparedness of students for higher education (continued)

Clustering	Supporting quotations found in the literature
Learners' school results as an indicator of student preparedness for higher education (continued)	Gammon (quoted in Solomons 2012, p. 7) points out that widespread research "found that first-year students lack key knowledge due to it being excluded from the current high school curriculum". As a result of this these students are "forced to compensate by taking bridging courses" (ibid.). Ramphele (quoted in Mtshali (2012, p. 1)) states, "even matriculants who had a 'so-called Bachelor's pass' did not fare well at university because the standard of their pass was low".
Legacy of Apartheid	Scott and Yeld (2008, p. 28) maintain that the "legacy of Apartheid" together with factors such as "teacher content knowledge" and "learning through a poorly mastered language", have "powerful negative effects on the preparedness of school leavers for the demands of higher education".
Teacher quality and lack of resources	**Under-qualified and badly trained educators** Legotlo, Maaga, Van Der Westhuizen, Mosoge, Nieuwoudt and Steyn (2002, p. 115) indicate that teachers are often "badly trained or under-qualified". These teachers are themselves products of a bad education system (ibid.). **Poor teacher quality exacerbated in rural areas** Van der Berg and Louw (2006, p. 5) suggest that the problem of poor teacher quality may be exacerbated in rural areas as rural schools "often experience difficulty in filling posts due to the reluctance of teachers to relocate to remote areas".

Table 1.1 Factors contributing to the under-preparedness of students for higher education (continued)

Clustering	Supporting quotations found in the literature
Teacher quality and lack of resources (continued)	**Teacher management** Van der Berg and Louw (2006, p. 6) point out that the "potential learning benefit associated with drawing on relatively good teacher resources is likely to be limited by how well teachers are managed by the schools in which they are employed". The students' socio-economic background together with "teacher absenteeism, principal monitoring of student progress, and teacher quality" (ibid.) interact with one another to determine the quality of education that students are exposed to (ibid. p. 14). **African pupils being taught by African teachers** Howie (2003, p. 14) points out that school conditions are particularly inadequate "where there are African pupils taught by African teachers…[as the conditions]…in these schools are" typically worse than in other schools. She indicates that these schools are often characterised by "limited resources and facilities, large percentages of under-qualified teachers, pupils from poor socio-economic backgrounds and instruction occurs in a secondary language" (ibid.). Scott and Yeld (2008, p. 35) point out that under-preparedness "associated with poor schooling" primarily affects black students. **Lack of subject knowledge, language proficiency and poor classroom management** Howie (2003, p. 2) indicates that there are various factors that contribute to the inadequate school education of many South African pupils.

Table 1.1 Factors contributing to the under-preparedness of students for higher education (continued)

Clustering	Supporting quotations found in the literature
Teacher quality and lack of resources (continued)	These include the teachers' lack of "subject knowledge", lack of proficiency in the "language of instruction", the inability of teachers to manage classroom interaction and "pressure to complete examination driven syllabi adequately" (ibid.). Howie (2003, p. 14) stresses the fact that the "difficulty of not being able to communicate fluently in a common language…[results in teacher frustration and student disorientation as well as]…a slow rate of learning, disciplinary problems and teacher centred instruction". **Lack of teacher commitment and the decline of a culture of teaching and learning** Legotlo *et al.* (2002, p. 116) point out that a further contributing factor to the under-preparedness of students appears to be teachers' inadequate commitment and morale which often translate into "high rates of absenteeism and truancy" which impact on the amount of teaching. Legotlo *et al.* (ibid.) found that learners are sometimes left without a teacher for days. Howie (2003, p. 14) suggests that teacher "commitment appears to play a key role in pupils' performance". Ngidi and Qwabe (2006, p. 529) state that "inadequate staffing"; lack of subject knowledge and the lack of commitment demonstrated by teachers are suggested as some of the factors that have contributed to the "decline of a culture of teaching and learning in schools".

1.3.2 Poor schooling's impact on learning and cognitive development

Thanasoulas (2001, p. 4) suggests that learning is successful when students acquire a conceptual understanding of information being learnt and can successfully apply this learning. The result of an exclusively instructionist approach to learning is that students enter universities academically under-prepared. Learners expect to be provided with prescriptive answers to questions relating to the learning material and become despondent in an environment that requires them to explore different points of view (Stephen *et al*. 2004, p. 43). They feel disadvantaged when these answers are not supplied, as they feel entitled to be passive receivers of information. Schlebusch and Thobedi (2004, p. 36) suggest that established teaching approaches in languages "such as the telling method" prevent the adequate development of cognitive abilities and often lead to underachievement.

1.3.3 Synthesis of the reasons for South African students' under-preparedness for the demands of higher learning institutions

The academic under-preparedness of students who enter South African higher learning institutions seems to be related mainly to issues pertaining to inadequate schooling. A literature review indicates that, not only do school marks bring about an unrealistic expectation of performance at higher learning institutions, but that a drop in standards is possibly allowing a larger number of under-prepared students access to higher education. As a result predictions of academic success based on school-leaving certificates are becoming increasingly unreliable.

Issues related to inadequate schooling's contribution to the under-preparedness of South African students for higher education seems to affect mainly black students. It is reasonable to assume that the reasons for this state of affairs can be traced to the legacy of Apartheid, which continues to have an influence on the poor management of schools and teacher quality. Teachers often seem to have poor content knowledge and interact with learners in a poorly mastered language. This often seems to result in teachers

prescribing answers to questions related to the learning material rather than encouraging critical reasoning and a constructive engagement with the subject matter.

Teacher absenteeism and poor teacher management also appear to be a significant contributing factor to the under-preparedness of students. Many schools are characterised by a lack of discipline among teaching staff as well as by inadequate commitment to the cognitive development of learners. It seems reasonable to assume that these factors related to inadequate schooling have resulted in the stunted conceptual development of many students who enter South African higher learning institutions. These academically under-prepared students are characterised by a lack of academic language proficiency, inadequate subject knowledge and a general lack of cognitive development. Their background of rote learning and being taught answers lead them to expect to be provided with solutions to problems without applying any cognitive effort.

1.3.4 The role of educational technology in addressing educational challenges

To assist in the learning process, educators must focus on student learning rather than on the teacher and the technology used in instruction (Jonassen 2006, p. xiii). Jonassen (2004, p. 3) suggests that the “cognitive-constructivist and situated learning movements…[of the nineties focussed educators’ attention]…on…[the]…sense-making and other conceptions of meaningful learning”. Meaningful learning requires “conceptual engagement” and “conceptual development, also known as conceptual change” (Jonassen 2006, p. xiv). Conceptual change has become recognised as one of the most common concepts underlining meaningful learning (Jonassen 2004, p. 3). This is because it views "learning as an intentional, dynamic, and constructive process that encompasses developmental differences among students” (ibid.). A powerful means of facilitating and supporting conceptual change and conceptual engagement is through a process of model building (Jonassen 2006, p. xiv). Model building also provides proof of conceptual change.

Jonassen (ibid., p. 4) indicates that one of the most effective ways of facilitating conceptual change is to use technology to build these models.

A constructivist approach to using educational technology in teaching and learning has the potential to assist “students to grasp the substantive and syntactical components” of learning material (Yilmaz 2008, p. 170).

1.3.5 Metacognition and conceptual change

By building simulations of cognitive processes through modelling, learning becomes more meaningful as learners are not only exploring their own cognitive processes but are also evaluating the results of those processes (Jonassen 2003, p. 14). McCown, Driscoll and Roop (1996, p. 222) suggest that metacognitive awareness encourages students to question their understanding of concepts and make decisions concerning how to study, based not only on the material to be learned, but also on their own cognitive strengths and weaknesses. Schunk (1996, p. 204) points out that metacognition consists of “two related sets of skills”. Firstly, the students must have an understanding of the “skills, strategies, and resources as the task requires” . Secondly, the student would need to "know how and when to use these skills and strategies to ensure the task is completed successfully”. Metacognitive activities “allow students to become aware of their conceptual advancement, as well as of changes in their practices of inquiry” (Ma 2009, p. 146). Vosniadou (2007, p. 15) suggests that conceptual change involves "an opening up of the conceptual space through increased metaconceptual awareness, creating the possibility of entertaining different perspectives and different points of view”.

1.4 Aims of the research

The primary aim of this study is to formulate design principles in the form of conjectures and principles related to a learning environment that uses technology as a cognitive tool in the form of an expert system shell to promote higher-order thinking skills.

The second aim of this study is to explore the experiences of students who are exposed to a learning environment based on the conjectures and principles formulated during the design phase of the research. It was considered important to explore the students' experiences of the learning environment in order to gain more comprehensive insight into the value and significance of the conjectures and principles on which it is based.

1.5 Rationale and statement of the problem

A literature review (see Table 1.1) clearly indicates that many South African students enter higher learning institutions academically under-prepared and are not able to meet the cognitive demands expected of them. Scott, Yeld and Hendry (2007, p. 43) indicate that the high drop-out rate among students who enter higher education institutions for the first time "points to a mismatch between the outcomes of schooling and the demands of the entry level of higher education programmes". Significant new demands are placed on students when they progress to a "higher educational phase" (Scott *et al.* 2007, p. 23). Higher education institutions need to contribute to the production of a workforce that "consists of curious, critical, analytical and reflective thinkers" so that this workforce can contribute constructively to an economic system (Lombard & Grosser 2008, p. 561). A great number of the changes implemented by the South African educational system have been based on the realisation that the country requires "independent, critical thinkers who are able to question, weigh evidence, make informed judgments and accept the incomplete nature of knowledge" (Lombard & Grosser 2008, p. 561). Hopson, Simms and Knezek (2002, p. 109) point out that the requirement to prepare students for the demands of adult life is a "theme throughout educational reform".

A review of the literature (see 1.4) suggests that technology may have the potential to support initiatives aimed at addressing issues related to students' academic preparedness. Educational computer technology is capable of contributing to the advancement of "cognitive skills such as comprehension,

reasoning, problem-solving and creative thinking" and offers students "opportunities for higher-order thinking and creativity in processing, constructing and conveying knowledge" (SA 2004, p. 15). Educational technology, however, has traditionally been used to communicate information and has often attempted to perform the role of a teacher (Fouts 2006, p. i). A review of the literature indicates that technology is typically deficient at performing the role of a teacher and a more effective strategy should involve using technology as a cognitive tool. This would allow students to use technology to construct their own understanding and develop a metacognitive awareness of their conceptual advancement. From the literature it has been determined that when using technology as an expert system shell, students are required to demonstrate the reasoning of an expert and to exhibit an understanding of causal relationships and procedural knowledge. This requires the student to engage in higher-order thinking and is likely to create a metacognitive awareness of the reasoning that needs to be applied to solve a problem. Computer technology can contribute to improvements in education by making it possible for both educators and learners to explore alternatives to "traditional approaches to teaching and learning" (SA 2004, p. 16).

Chen (2005, p. 15) indicates that "there is little research about the applications of expert systems as cognitive tools in education". There therefore appears to be a need to explore what a learning environment that uses technology as an expert system shell in order to develop higher-order thinking skills in foundation students at the Tshwane University of Technology (TUT) would look like and how it would function.

The White Paper on e-Education (SA 2004, p. 33) proposes that research for e-learning "be linked to practice…[and that the education profession]…play an important role in generating ideas, testing prototypes and implementing strategies". The Design-Based Research Collective (2003, p. 5) states that design-based research is a useful method "for understanding how, when and why educational innovations work in practice". Design is fundamental to endeavours aimed at creating practical knowledge and advancing "theories of learning and teaching in complex settings".

Accordingly the rationale for this study is to present the design principles formulated during this study as a guide that may inform similar endeavours undertaken by lecturers or instructional designers. These design principles should also contribute to the body of knowledge related to the application of an expert system shell as a cognitive tool in an educational environment.

1.6 Theoretical framework

This research project is situated within a framework that consists of various well-established theories and propositions. Among these are ideas concerning constructivist learning theories, higher-order thinking, problem-solving, computers as cognitive tools and social interaction.

Higher-order thinking is not facilitated through a process of rote learning and simple recall but involves critical thinking, creative thinking, problem-solving and decision-making. Critical thinking is an important component of higher-order thinking and requires a careful and reflective thought process. When undertaking critical thinking, all aspects of an issue are open for consideration and the learner is receptive to arguments that refute or contradict existing ideas and understanding. Arguments that support understanding are properly considered and evaluated. There is an insistence on evidence that supports claims and conclusions are drawn from available facts. A process of inference and deduction is consistently undertaken. The result is an enhanced ability to identify relationships, pose appropriate questions and express and unravel meaning properly. It is, however, important that adequate content knowledge is applied to the critical thinking process, as it is often fruitless to attempt to think at a higher level when there is a deficiency in domain knowledge.

Constructivist learning theories are central to this study as they place the student at the centre of learning and involve an individual construction of knowledge based on individual experience and multiple representations of understanding. Using computer technology as a cognitive tool rather than a medium that simply delivers information, is firmly based on a constructivist

learning philosophy. When the learner acts as the designer rather than simply the user, reproduction of knowledge is discouraged and the student is encouraged to represent, reflect and manipulate understanding through active engagement. This process prompts the learner to think more deeply about the subject that is being explored, as the learner is responsible for providing the ideas, motivation and information. Computer technology then serves as an extension of the learner's mind or becomes an intellectual partner that the learner can learn with rather than from.

Constructivist learning ideas place a great deal of emphasis on the importance of social interaction in the learning process. Social interaction leads to discourse and reflection, which in turn encourage a deeper exploration of a subject domain. The externalisation of the thinking process enables understanding to be compared and contrasted and contributes to the higher-order thinking process. The arguments, negotiations and discussions that result from social interaction constitute a community of enquiry and can lead to a shared understanding of meaning. During social interaction ideas are challenged and defended, resulting in a critical dialogue and a more meaningful learning experience. Social interaction is also considered a precursor to meaningful learning as it is grounded in experience.

An important component of a learning environment that is designed to promote higher-order thinking involves problem-solving. There are essentially two types of problem that can be presented to a learner: well structured and ill structured. Ill structured problems are better suited to developing higher-order thinking skills and fit more comfortably in a constructivist learning environment. Ill structured problems do not have an obvious solution, have unspecified boundaries and goals, and can be solved in a variety of ways. This makes them more representative of real-world dilemmas and often requires the student to explore different disciplines in order to come up with a solution. In order for ill structured problems to be effective, they must challenge the students to go beyond their current ability and to think in ways that they are not accustomed to. A solution to an ill structured problem must require more than just a regurgitation of information. Ill structured problems

can be difficult to solve; to prevent students from becoming overwhelmed it is appropriate to include a calculated amount of balanced scaffolding in the learning environment. This involves allowing students to work in groups in order to provide one another with support. The facilitator is also responsible for acting as a type of consultant that guides the students when they encounter difficulties. To achieve this, the facilitator should monitor the students' engagement with the ill structured problem and find a balance between allowing the students to realise on their own that they need to seek guidance and offering guidance when they encounter an irreconcilable impasse.

1.7 Research questions

The following research questions have been used to guide this study:

- What conjectures and principles are associated with an intervention that uses computer technology as an expert system shell to develop higher-order thinking skills in Foundation students at TUT?
- How will students experience a learning intervention based on conjectures and principles formulated to use computer technology in the form of an expert system shell in order to achieve higher-order thinking skills?

1.8 Research design

This study adopts a design-based research approach in order to formulate design principles in the form of conjectures and principles. Focus group interviews were used as a data collection method and a grounded theory approach to data analysis and the development of conjectures and principles that included coding, memoing, sorting, categorising and writing was employed. This study is qualitative in nature and assumes a social constructivist worldview.

The Design-Based Research Collective (2003, p. 5) argues that design-based research is ideally suited to "create and extend knowledge…[concerning the development and implementation of]…innovative learning environments". Qualitative data is able to offer "rich insight into human behavior" (Guba & Lincoln 1994, p. 106). Grounded theory is considered to be a qualitative research strategy and involves grounding theory of "process, action, or interaction in the views of participants" (Creswell 2009, p. 13). Social constructivism is also associated with a qualitative approach and encourages the researcher to depend on the varied views of participants concerning a particular situation being explored (Creswell 2009, p. 8).

1.9 Delimiters of the study

The delimiters of the study are set out under two broad headings. Under the first a description of the perspective adopted concerning design principles and conjectures is presented. The second presents the delimiters related to addressing the question of how students experienced the learning environment based on conjectures and principles formulated in this study.

1.9.1 View concerning design principles and conjectures

The focus of this study is not on formulating design principles concerning the process that needs to be followed in order to develop a learning environment but rather on the conjectures embodied in the environment and designed to support learning. This is in line with Van den Akker's (1999, p. 5) assertion that design "principles can be of a 'substantive' nature, referring to the characteristics of the intervention (what it should look like), or of a 'procedural' nature (how it should be developed)". "Design principles are not…[inflexible]…and are offered as advice on how others might benefit from the findings of a particular development and research endeavour" (Herrington, Herrington and Mantei 2009, p. 131).

For the purpose of this study the term *design principle* will be used to include conjectures embodied in the learning environment that can be actualised as

well as heuristic statements concerning the "production of knowledge of a generalizable nature" (Van der Akker 1999, p. 5).

The challenge implied in design-based research is to devise a design that embodies verifiable conjectures concerning "both significant shifts in student reasoning" as well as the particular "means of supporting those shifts" (Cobb 2003, p. 11). Sandoval (2004, p. 213) argues that design-based research "embodies conjectures about learning within educational designs". Design in this context means "the design of interventions…[such as]…designed technologies, curricular materials and participation structures" as well as academic task structures. Sandoval (2004, p. 215) mentions "that design-based research…[is the]…systematic study of designed interventions" and this type of research can develop theories concerning learning

> *because designed learning environments embody design conjectures about how to support learning in a specific context that are themselves based on theoretical conjectures of how learning occurs in particular domains..*

He proposes the term "embodied conjecture [to mean] a conjecture about how theoretical propositions might be reified within designed environments to support learning". Embodied conjectures are developed from existing theories of learning in "particular domains". These are said to differ from design principles in that design principles are more abstract and cannot be easily tested whereas embodied conjectures are expressed "at a level of specificity that allows them to be empirically refined or rejected" (ibid.).

1.9.2 Exploring the experiences of students through a single case

This study explores the experiences of students who worked within a learning environment that is based on the conjectures and principles formulated during this study. Even though a sample was selected from across two different classes, it is reasonable to consider this a single case as both classes were enrolled for the same course at the same campus during the same semester.

At times the two classes were grouped in the same venue when timetables and venue size permitted.

1.10 Ethical considerations

This study received ethical clearance from the ethics committee of both the University of Pretoria and the Tshwane University of Technology. Informed consent was obtained from both the sample drawn from the student population as well as from the design team that was used in the design of the learning environment. All participants were informed that their participation in the research was completely voluntary and that they were free to withdraw at any stage of the research (see Addenda B and C). The study did not place anyone involved in any harm.

1.11 Outline of chapters

What follows is an outline of the subsequent chapters of the research report.

Chapter 2

This chapter provides a literature review that consists of the following:

- A discussion of the learning theories that have informed technology-based instructional design.
- Educational computer technology as a cognitive tool.
- An exploration of what an expert system is and how it can be used as a cognitive tool.
- A discussion of higher-order thinking.
- A discussion of Design-Based Research.
- A discussion of grounded theory.

Chapter 3

Chapter 3 presents the research design. The philosophical worldview applicable to this study together with the strategy of enquiry is discussed. An overview of the way in which the study employs a design-based research approach is presented. The sampling methods, data collection methods and data analysis techniques employed are provided. The chapter concludes with a discussion of issues related to the trustworthiness of findings and ethical considerations.

Chapter 4

The design principles in the form of conjectures and principles that emerged from a grounded theory-based analysis of transcripts of focus group interviews held with the design team are presented in this chapter. This chapter also provides a description of the learning environment developed during the design phase of the study in order to place these conjectures and principles in context.

Chapter 5

Chapter 5 includes findings related to an exploration of how students experienced the learning environment based on these design principles.

Chapter 6

This chapter presents a discussion of the findings together with a literature reflection that attempts to link findings presented in Chapters 4 and 5 to the established literature.

Chapter 7

This chapter provides a summary of the research design, the research problem, the conjectures and principles formulated and the students'

experience of the learning environment. The relevance of the research is then presented together with the significance of the research and suggestions for further research.